Connecticut Department of Transportation

# NEW BRITAIN-HARTFORD BUSWAY SERVICE PLAN



DRAFT

AUGUST 13, 2009

IBI GROUP

**New Britain Hartford Busway Service Plan**

The New Britain – Hartford Busway Service Plan describes the characteristics of the bus route network that will use the busway to provide fast, frequent and reliable service to the traveling public in the heavily-traveled New Britain to Hartford corridor. All routes in the corridor are covered – the plan includes both routes that operate on the busway and routes that connect with the busway. Bus routes, conceptual schedules, stopping patterns, span of service, and vehicles used for each route are included. User benefit, boarding rides, annual service hours, service miles, and operating costs are estimated. The service plan builds on previous planning and demand modeling work that has been completed for the project over the past 10 years.

The goal of the service plan is to create an efficient route structure that attracts the maximum number of riders and provides the highest user benefit for the minimum operating cost. This maximizes the public benefit of the project and ensures a worthwhile long-term investment, critical to securing Federal and State funding for the project.

Process

The development of the service plan involved the following steps:

Analysis of Previous Plans – IBI Group reviewed seven (7) public transportation plans relevant to the study corridor. Three of these plans, the 2000 *Statewide Bus System Study*, the 2001 *New Britain-Hartford Busway Service Plan*, and the 2004 *Busway West* plan were particularly relevant to developing the new service plan. The Statewide Bus System Study included recommendation to expand service in the Farmington area north of New Britain, suggestions for improving the productivity of the “P” route (41), “O” Oak route, and “W” (69) routes, and suggested reducing service on express route 2- Corbins. The 2000 *New Britain-Hartford Busway Service Plan* recommended increases to the service span, frequency, and weekend service of many routes in the busway and proposed a network concept that routes four express, eight local, and one shuttle route via the busway. The Busway West plan recommended better headways for many New Britain area local routes, the creation of “mini-hubs” to make connections between routes and modes more convenient, and new route extensions and park-and-ride locations.



Demographic Analysis – A graphic analysis of the demographic characteristics of the study corridor was completed. Specific characteristics that indicate the need for and likelihood of using public transit services were mapped using GIS with data provided by the United States Census. Maps were produced showing a busway base map with the route and station locations, existing transit routes, land use, population density, population over 65, population under 15, employment density, households without vehicles, and public transit mode share for the journey to work. This analysis helped to identify areas where new transit services could be expected to perform well or areas where existing services were not performing as well as could be expected.

Network Concept Development and Peer Review – This memo explored the conceptual network alternatives available for the bus system that will serve the New Britain - Hartford Busway. This task is required of all busways and each of the North American systems has approach it in a different way. A review of the route network approaches of several other busway and BRT systems around the world was completed to gain the benefits of the experience of these operations. The study looked at five different alternative network concepts: all shuttle service on the Orange Line in L.A., all through service on the O-Bahn in Adelaide, Australia, a mix of through service and shuttle in Pittsburgh, a mix of through and shuttle service by time of day in Ottawa, and a combination of shuttle and arterial BRT service in Eugene, Oregon.

A ranking matrix was developed using the following criteria: Minimize Transfers, Minimize Operating Cost, Serve Modeled Ridership Patterns, Attractiveness to New Users, Operational Simplicity, and Operational Flexibility. Through this matrix and the service planning committee discussion that followed, a network concept was chosen that combines the Shuttle and Through Service network types. This network combines the benefits of through service on major corridors and the easy-to-use aspects of a rail-like operation. The peer review noted a tendency over the past 5 to 10 years of busways to move toward this model.

Public Meetings – Two sets of public meetings were held to provide the public with opportunities to discuss the service planning process, make suggestions, express concerns, and review preliminary plans. The first set of four meetings were held on December 3 in West Hartford, December 4 in Hartford, December 8 in Newington and December 9 in New Britain. These meetings were focused specifically on the service plan and presented attendees with a range of ideas for how the bus routes serving the busway could be designed. Attendees could provide their input through a variety of methods including speaking directly to a project representative, filling out a response form, or writing or drawing on the poster boards arranged around the room. Phone calls and emails were welcome after the meeting. The second set of two meetings were held on May 19 in New Britain and May 20 in West Hartford. These meetings included draft route maps for the service plan as part of a larger presentation of progress on the design of the busway. The public was again invited to provide their thoughts and suggestions in whatever means they were most comfortable with.



Travel Demand Modeling – After the preliminary network was developed based on analysis of previous planning efforts, the demographic analysis, network concept development, and the first public meeting, a process of iterative demand model runs was begun. CRCOG carried out this work using their regional transportation demand forecasting model. Two alternatives were initially modeled, Alternative A based on a single shuttle route with an expanded feeder network and Alternative B using multiple through routed services and a smaller feeder network. The results of these runs were integrated into Alternative C which was then further refined through a series of additional model runs and tests and service planning analysis.

The resulting service plan performed better when modeled than the previous 2008 plan by approximately 400 daily hours of user benefit, over 1100 daily boarding rides, and over 600 new riders to transit, all significant positive changes. See CRCOG's *Summary of forecast and explanation of changes since forecast of June 2008* for more details.

Service Planning Committee – A project steering committee, called the Service Planning Committee, met approximately monthly to review progress on the development of the plan and provide information, ask questions, and make suggestions. The SPC was made up of members from ConnDOT, CT Transit, DATTCO, NBT, CRCOG, and CCRPA.

## Route Structure

All transit projects form part of a greater regional transit system. The first task in developing a service plan is deciding how the new project will contribute to that larger network and what it means for the design of routes and schedules. The network concept selected for the New Britain-Hartford Busway was a modified shuttle-only system where a simple easy-to-understand main trunk line was supplemented by a small number of through routes, three in this case, with other routes feeding riders to this trunkline structure. Most other busway systems in the United States, such as Pittsburgh, Los Angeles, and Miami, are moving toward similar network designs due to the simple and attractive service pattern, operational simplicity and flexibility in adjusting individual elements to varying levels of demand. A simple, easy-to-understand service plan is especially important when attracting new riders who may not currently be using transit to a new transit service like the busway.

The proposed service plan has four types of routes: busway local service, busway express services, connectors and circulators, and existing local transit services. Each one fills a role in the complete network.



- Busway local services – These routes operate between downtown Hartford and various destinations along the corridor via the busway making stops at all busway stations on their route. Two of these routes operate as far as New Britain, with BW1 terminating there and BW2 continuing to Bristol. Routes BW3 and BW4 travel as far as Oakwood Avenue where they leave the busway, travel along New Park Avenue as far as New Britain Avenue, then west on New Britain to Westfarms Mall where Route BW3 continues south along Stanley Street to New Britain busway station and BW4 continues west to UConn Health Center via South Street.
- Busway Express Services – These routes operate between park-and-ride stations located along I-84 and downtown Hartford, Asylum Hill and Capitol Hill, primarily serving long distance commuters to downtown Hartford, bus also providing reverse commute service. Busway expresses stop only at park and ride lots, New Britain Station and Sigourney and Union Station, running non-stop between these points. There are three busway express routes, BX1, a completely new route from Waterbury to Hartford, BX2, currently route 24 from Cheshire and Southington to Hartford, and BX3 which provides off-peak service to all stops on both routes when demand is lower.
- Connectors and Circulators – These new local transit routes are created specifically to link important employers, neighborhoods, or other activity centers to the busway. C1 connects the CCSU campus to Cedar Street Station and East Street Station. C2 connects St. Francis Hospital, Hartford Hospital, Asylum Hill, and Capitol Hill to Sigourney Street Station. C3 is a new crosstown route that links Flatbush Station West Hartford and Bishop's Corner. C4 circulates

throughout Newington connecting it to the busway at Newington Junction, Cedar Street, and New Britain.

- Existing Local Transit Routes – Many existing routes in the CT Transit system will be modified to serve busway stations. A few routes will be discontinued, shortened, or reduced in frequency where they duplicate new services provided along the busway.

The route numbering system used here is for clarity in the busway service plan and will not necessarily be the route number used by CT Transit when the route is put into operation.

**Individual Route Plans**

The following pages describe each of the busway system routes in detail including routing, schedules, running time, service hours, vehicle types and purpose. Routes included are:

**Existing New Britain Area Local Routes**

Arch Street
Burritt Street
Corbin Avenue
Farmington Avenue
Oak Street
Plainville/Bristol
Berlin Turnpike
Berlin Turnpike (Cromwell)
Combined South and East Street

**Existing Hartford Area Local Routes**
West Hartford Place via Park
West Hartford Place via Park and Kane St.
Park Rd and S Quaker via Park
Westfarms via Park
Hartford Newington Local
Charter Oak Marketplace West Hartford Place via NB Ave
Elmwood via New Britain Ave
Capital - Berlin Tpk via Willard

**Existing and New Express Routes**
BX1 Waterbury Express
BX2 Cheshire Express
BX3 Waterbury Cheshire Off-peak Express

**Busway Local Routes**
BW1 New Britain to Hartford Shuttle
BW2 Bristol to Hartford Shuttle
BW3 New Britain-Westfarms-Hartford
BW4 UConn Health Center-Westfarms-Hartford
BW5 Newington Junction to Hartford Shuttle

**New Connector and Circulator Routes**
C1 CCSU Connector
C2 Hospitals - Capitol Connector
C3 Newington Circulator
C4 West Hartford - Bishops Corner Connector

**Existing New Britain Area Local Routes**

Arch Street

This route provides a feeder service to and from the busway and Meriden and the southwest neighborhoods of New Britain.

Route: This route runs between New Britain station and Meriden. From New Britain station it travels along Arch Street, Kensington Avenue and Chamberlain Highway into Meriden, turning west onto Johnson Avenue before terminating.

Service Pattern: All trips operate in local transit service between Meriden and New Britain station making all local stops.

One Way Travel Time: 30 minutes

One Way Mileage: 10.1 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>60</td><td rowspan="3">60</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>60</td></tr>
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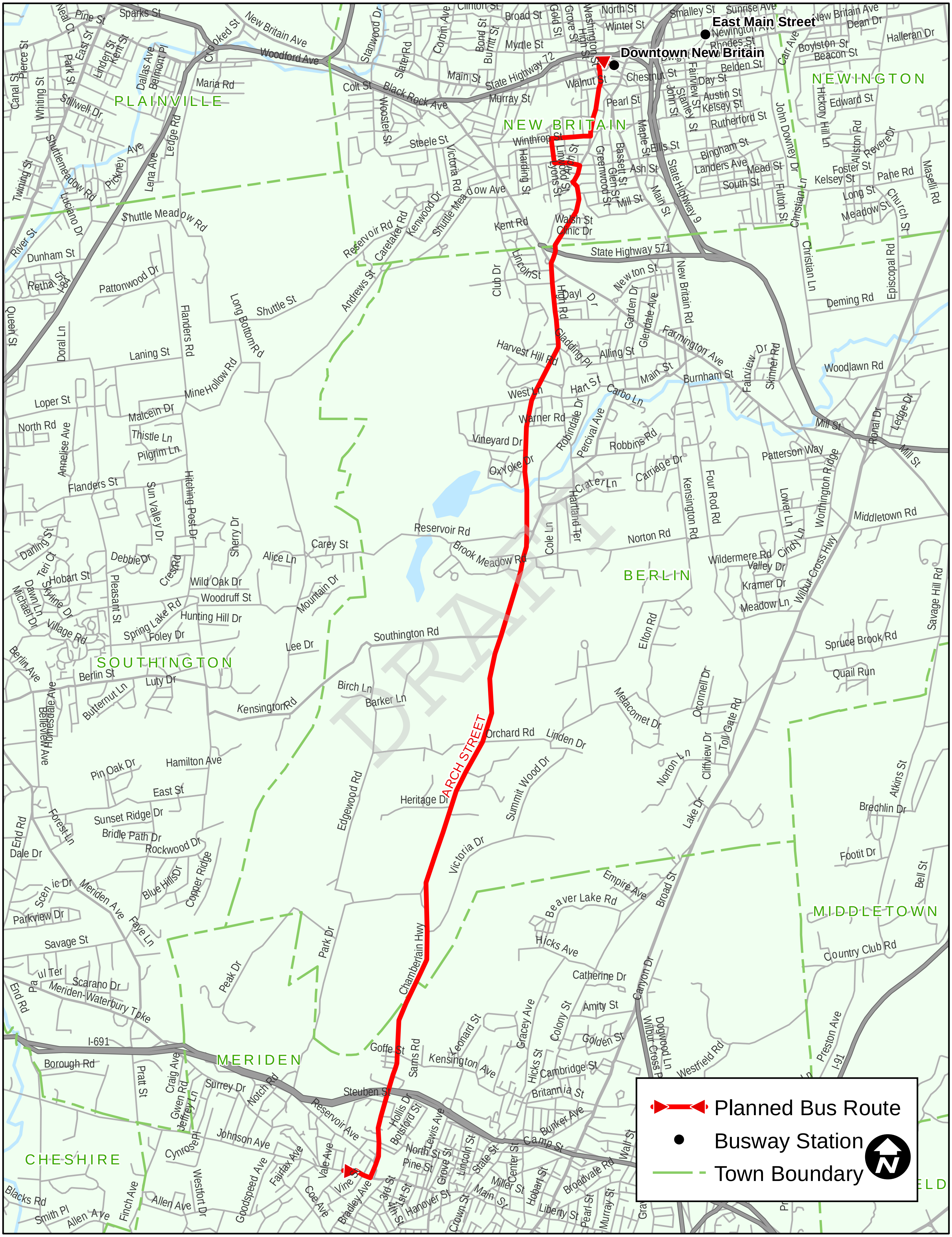
Service Plan Annual Service Hours: 6,204

Vehicle: This route will be served by one 30ft low floor transit bus, the same number of vehicles as existing service.

Modeled Weekday Boardings: 343

Notes: This route will be changed to operate more directly between its outer terminal and New Britain station. Fixed bus stop locations will be established.


East Main Street
Downtown New Britain
NEW BRITAIN
NEWINGTON
PLAINVILLE
BERLIN
SOUTHINGTON
MIDDLETOWN
MERIDEN
CHESHIRE
ARCH STREET
DRAFT
Planned Bus Route
Busway Station
Town Boundary

**Existing New Britain Area Local Routes**

Burritt Street

This route provides a feeder service to and from the busway and the northwest neighborhoods of New Britain.

Route: This route operates between New Britain station and Slater Road and Long Swamp Road. From New Britain station the route travels north on Arch Street to Myrtle, then west. At the intersection of Myrtle and Burritt the route travels north on Burritt to Osgood Avenue, where it turns west. From Osgood Avenue the route proceeds to Corbin Avenue, where it turns north toward Horseplain Road, then turning west. From Horseplain the route proceeds to Slater Avenue, where it turns south, traveling along Slater to Maplehurst and returning via Corbin.

Service Pattern: All trips operate in local transit service between Slater Road and New Britain station making all local stops.

One Way Travel Time: 20 minutes

One Way Mileage: 5.6 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



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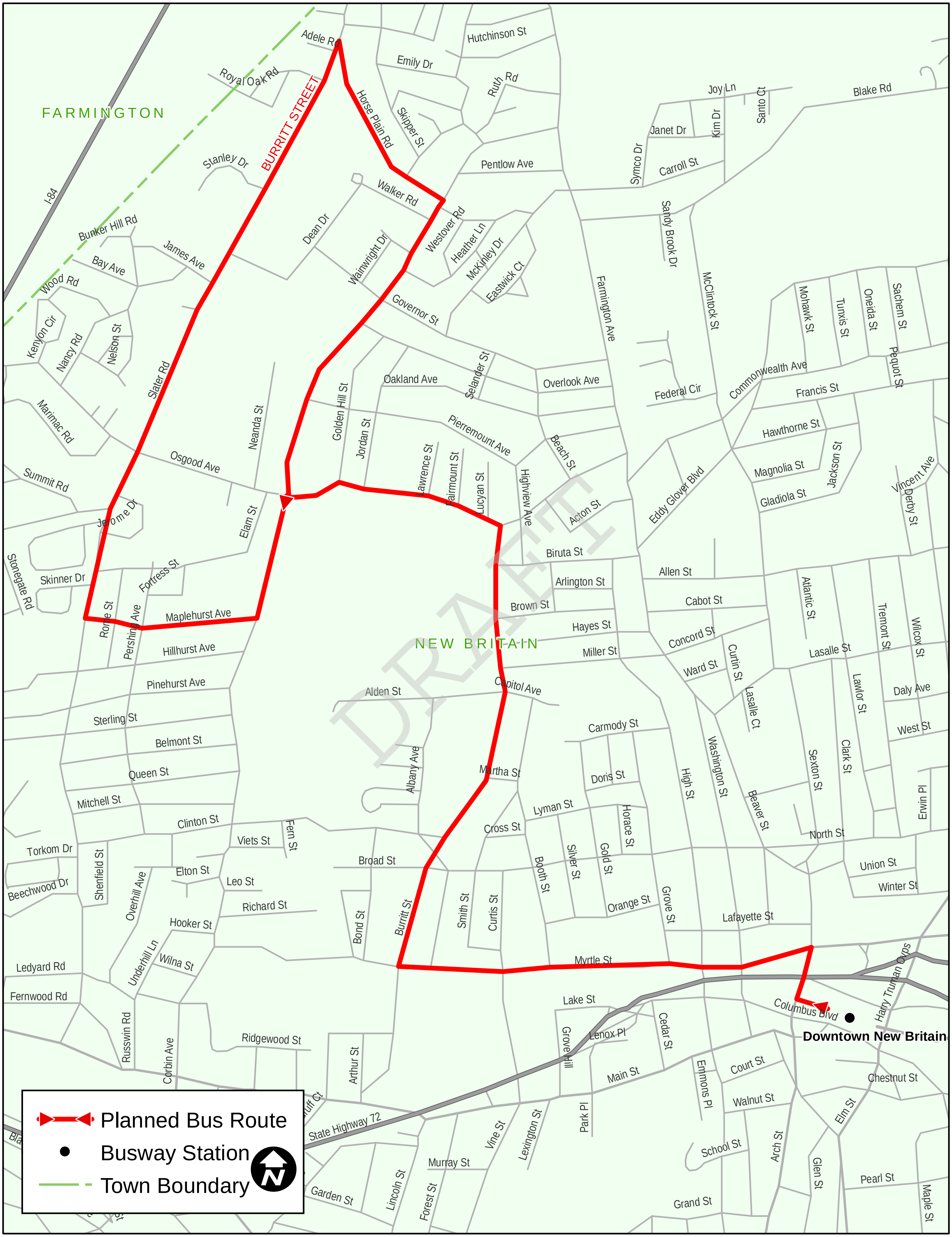
<tr><td>PM Peak</td><td>30</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 5,726

Vehicle: Peak hour service on this route will require two 30ft low floor transit buses, one more vehicle than currently serves this route.

Modeled Weekday Boardings: 969

Notes: Formal bus stop locations will be established along this route.


FARMINGTON
NEW BRITAIN
DRAFT
BURRITT STREET
Downtown New Britain
Planned Bus Route
Busway Station
Town Boundary
I-84
State Highway 72
Adele Rd
Royal Oak Rd
Hutchinson St
Emily Dr
Horse Plain Rd
Skipper St
Ruth Rd
Joy Ln
Blake Rd
Santo Ct
Kim Dr
Janet Dr
Carroll St
Symco Dr
Pentlow Ave
Stanley Dr
Walker Rd
Westover Rd
Heather Ln
Mckinley Dr
Eastwick Ct
Dean Dr
Wainwright Dr
Governor St
Sandy Brook Dr
McClintock St
Farmington Ave
Bunker Hill Rd
James Ave
Bay Ave
Wood Rd
Kenyon Cir
Nancy Rd
Nelson St
Slater Rd
Marimac Rd
Neanda St
Golden Hill St
Jordan St
Oakland Ave
Selander St
Overlook Ave
Federal Cir
Commonwealth Ave
Mohawk St
Tunxis St
Oneida St
Sachem St
Pequot St
Francis St
Hawthorne St
Magnolia St
Jackson St
Gladiola St
Vincent Ave
Derby St
Pierremont Ave
Beach St
Lawrence St
Fairmount St
Lucyan St
Highview Ave
Acton St
Eddy Glover Blvd
Summit Rd
Osgood Ave
Elam St
Jerome Dr
Stonegate Rd
Skinner Dr
Fortress St
Biruta St
Allen St
Arlington St
Atlantic St
Tremont St
Wilcox St
Brown St
Cabot St
Rome St
Pershing Ave
Maplehurst Ave
Hayes St
Concord St
Miller St
Lasalle St
Hillhurst Ave
Ward St
Curtin St
Lawlor St
Pinehurst Ave
Alden St
Capitol Ave
Lasalle Ct
Daly Ave
Sterling St
Carmody St
West St
Belmont St
Washington St
High St
Sexton St
Clark St
Albany Ave
Queen St
Martha St
Doris St
Beaver St
Mitchell St
Lyman St
Horace St
Erwin Pl
Clinton St
Cross St
North St
Torkom Dr
Fern St
Viets St
Silver St
Gold St
Union St
Beechwood Dr
Shenfield St
Overhill Ave
Elton St
Leo St
Broad St
Booth St
Winter St
Richard St
Bond St
Burritt St
Smith St
Curtis St
Orange St
Grove St
Lafayette St
Hooker St
Ledyard Rd
Underhill Ln
Wilna St
Myrtle St
Fernwood Rd
Lake St
Columbus Blvd
Harry Truman Ops
Russwin Rd
Corbin Ave
Ridgewood St
Arthur St
Grove Hill
Lenox Pl
Cedar St
Emmons Pl
Court St
Chestnut St
Main St
Walnut St
Elm St
Park Pl
Vine St
Lexington St
School St
Arch St
Glen St
Murray St
Garden St
Lincoln St
Forest St
Grand St
Pearl St
Maple St

**Existing New Britain Area Local Routes**

Corbin Avenue

This route provides a feeder service to and from the busway and Tunxis Community College, Plainville, and the western neighborhoods of New Britain.

Route: This route travels between New Britain station and Tunxis Community College in Farmington. From New Britain station it travels west along Main Street to Corbin Avenue, where it proceeds north to Clinton Street, then southwest along Clinton, Beechwood Drive, and Starwood Drive before turning west onto New Britain Avenue. At the intersection of New Britain Avenue and Farmington Avenue the route turns north on Farmington, where it proceeds to Northwest Drive and Spring Lane heading northwest. At the intersection of Spring Lane and Scott Swamp Road the route turns west, then south on Plainville Avenue, where it terminates.

Service Pattern: All trips operate in local transit service between Tunxis Community College and New Britain station making all local stops.

One Way Travel Time: 30 minutes

One Way Mileage: 9.4 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



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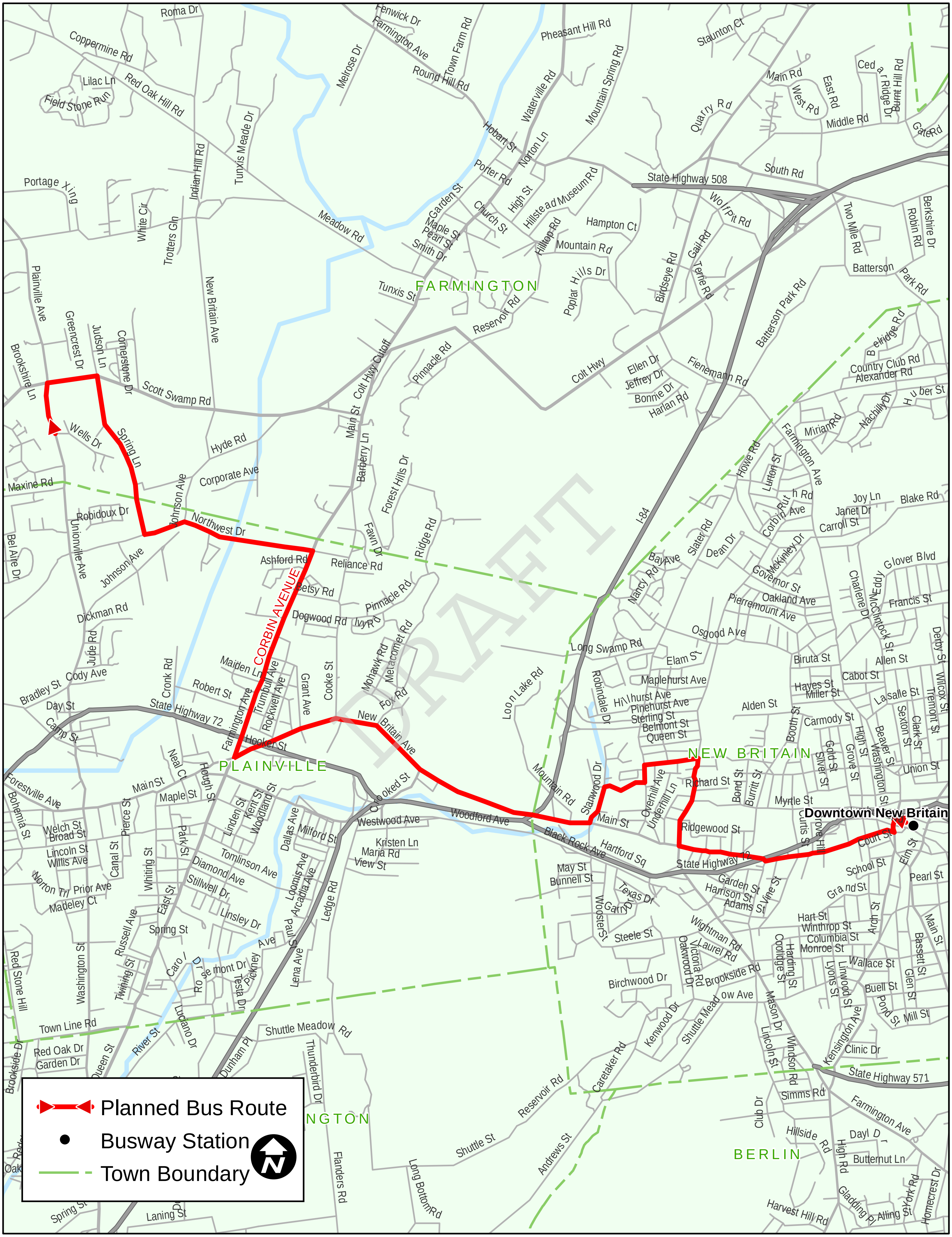
<tr><td>PM Peak</td><td>30</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 7,716

Vehicle: Peak hour service on this route will require two 30ft low floor transit buses, one more vehicle than currently serves this route.

Modeled Weekday Boardings: 1,157

Notes: The routing for this bus route would be simplified in the Plainville area. Formal bus stop locations would be established along this route.



DRAFT
FARMINGTON
PLAINVILLE
NEW BRITAIN
BERLIN
CORBIN AVENUE
Downtown New Britain
Planned Bus Route
Busway Station
Town Boundary
N
Roma Dr
Fenwick Dr
Farmington Ave
Town Farm Rd
Round Hill Rd
Coppermine Rd
Melrose Dr
Pheasant Hill Rd
Staunton Ct
Red Oak Hill Rd
Lilac Ln
Field Stone Run
Waterville Rd
Mountain Spring Rd
Main Rd
East Rd
Burnt Hill Rd
Quarry Rd
West Rd
Middle Rd
Gate Rd
Tunxis Meade Dr
Indian Hill Rd
Hobart St
Norton Ln
Porter Rd
State Highway 508
South Rd
Portage Xing
White Cir
Trotters Gln
Meadow Rd
Garden St
Maple St
Pearl St
Smith Dr
Church St
High St
Hillstead Museum Rd
Hilltop Rd
Hampton Ct
Mountain Rd
Wolf Pit Rd
Gail Rd
Two Mile Rd
Robin Rd
Berkshire Dr
Batterson
Park Rd
New Britain Ave
Plainville Ave
Greencrest Dr
Judson Ln
Cornerstone Dr
Brookshire Ln
Tunxis St
Reservoir Rd
Poplar Hills Dr
Birdseye Rd
Terrie Rd
Batterson Park Rd
Colt Hwy Cutoff
Pinnacle Rd
Colt Hwy
Ellen Dr
Jeffrey Dr
Bonnie Dr
Harlan Rd
Fienemann Rd
Country Club Rd
Alexander Rd
Scott Swamp Rd
Main St
Wells Dr
Spring Ln
Hyde Rd
Barberry Ln
Forest Hills Dr
Corporate Ave
Maxine Rd
Johnson Ave
Northwest Dr
Robidoux Dr
Unionville Ave
Bel Aire Dr
Fawn Dr
Ridge Rd
I-84
Howe Rd
Lurton St
Farmington Ave
Miriam Rd
Nachilly Dr
Huber St
Corbin Ave
Joy Ln
Janet Dr
Carroll St
Blake Rd
Slater Rd
Dean Dr
Bay Ave
Nancy Rd
McKinley Dr
Governor St
Oakland Ave
Pierremount Ave
Charlene Dr
Eddy
McClintock St
Glover Blvd
Francis St
Ashford Rd
Reliance Rd
Betsy Rd
Pinnacle Rd
Dogwood Rd
Ivy Rd
Dickman Rd
Metacomet Rd
Mohawk Rd
Osgood Ave
Long Swamp Rd
Elam St
Biruta St
Allen St
Derby St
Maiden Ln
Jude Rd
Cody Ave
Bradley St
Cronk Rd
Robert St
Trumbull Ave
Rockwell Ave
Grant Ave
Cooke St
Fox Rd
Loon Lake Rd
Robindale Dr
Maplehurst Ave
Hillhurst Ave
Pinehurst Ave
Sterling St
Belmont St
Queen St
Alden St
Cabot St
Hayes St
Miller St
Lasalle St
Wilcox St
Tremont St
Day St
Camp St
State Highway 72
Farmington Ave
Hooker St
New Britain Ave
Carmody St
Booth St
High St
Beaver St
Sexton St
Clark St
Gold St
Grove St
Silver St
Washington St
Union St
Forestville Ave
Bohemia St
Neal Ct
Hough St
Main St
Maple St
Pierce St
Welch St
Broad St
Lincoln St
Willis Ave
Linden St
Kent St
Woodland St
Crooked St
Mountain Rd
Stanwood Dr
Overhill Ave
Underhill Ln
Richard St
Bond St
Burritt St
Myrtle St
Curtis St
Dove Hill
Dallas Ave
Milford St
Westwood Ave
Woodford Ave
Main St
Ridgewood St
Court St
Elm St
Canal St
Park St
Whiting St
Tomlinson Ave
Diamond Ave
Kristen Ln
Maria Rd
View St
Black Rock Ave
Hartford Sq
State Highway 72
Norton Trl
Prior Ave
Madeley Ct
East St
Stillwell Dr
Loomis Ave
Arcadia Ave
Ledge Rd
May St
Bunnell St
Texas Dr
Garden St
Harrison St
Adams St
Vine St
School St
Pearl St
Grand St
Linsley Dr
Spring St
Russell Ave
Garry Dr
Wooster St
Hart St
Winthrop St
Columbia St
Monroe St
Arch St
Main St
Steele St
Wightman Rd
Laurel Rd
Oakwood Dr
Victoria Rd
Coolidge St
Harding St
Bassett St
Wallace St
Red Stone Hill
Washington St
Twining St
Carol Dr
Rosemont Dr
Testa Dr
Pickney Ave
Paul St
Lena Ave
Birchwood Dr
Brookside Rd
Lyons St
Linwood St
Buell St
Glen St
Pond St
Mill St
Town Line Rd
Luciano Dr
Shuttle Meadow Rd
Kenwood Dr
Shuttle Meadow Ave
Mason Dr
Kensington Ave
Clinic Dr
Red Oak Dr
Garden Dr
Queen St
River St
Dunham Pl
Thunderbird Dr
Caretaker Rd
Lincoln St
Windsor Rd
State Highway 571
Brookside Dr
Reservoir Rd
Simms Rd
Farmington Ave
Club Dr
Hillside Rd
Dayl Dr
High Rd
Butternut Ln
Shuttle St
Andrews St
Flanders Rd
Long Bottom Rd
Spring St
Laning St
Harvest Hill Rd
Gladding Pl
Alling St
York Rd
Homecrest Dr

**Existing New Britain Area Local Routes**

Farmington Avenue

This route provides feeder service to and from the busway and the UConn Health Center and the northern neighborhoods of New Britain.

Route: This route travels between New Britain station and Farmington via Farmington Avenue. In Farmington it completes a loop on Birdseye Road, Batterson Park Road, Fienemann Road, Two Mile Road, West Road, and Munson Road.

Service Pattern: All trips operate in local transit service between the UConn Health Center and New Britain station making all local stops.

One Way Travel Time: 30 minutes

One Way Mileage: 7.0 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.

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Service Plan Annual Service Hours: 6,204

Vehicle: Peak hour service on this route will require one 30ft low floor transit bus, the same number of vehicles as currently serves this route.

Modeled Weekday Boardings: 562

Notes: Formal bus stop locations would be established along this route.


FARMINGTON
NEW BRITAIN
PLAINVILLE
FARMINGTON AVENUE
DRAFT
East Street
East Main Street
Downtown New Britain
Planned Bus Route
Busway Station
Town Boundary
N
Farmington Ave
Fienemann Rd
Batterson Park Rd
Two Mile Rd
Munson Rd
Middle Rd
West Rd
Main Rd
Washington St
Columbus Blvd
State Highway 508
State Highway 72
State Highway 71
State Highway 9
I-84
Colt Hwy

**Existing New Britain Area Local Routes**

Oak Street

This route provides feeder service to and from the busway, Central Connecticut State College, and the densely populated residential neighborhood along Oak Street in the northern section of New Britain.

Route: This route travels between New Britain station and Cedar Street station. From New Britain it travels north on Main Street, then proceeds east on Broad Street before turning north again on Oak Street. From Oak it turns east on Allen Street, then north on Carlton Street, before proceeding east on Francis Street to Stanley Street. The route travels north on Stanley to Ella Grasso Boulevard, where it proceeds east to Cedar Street station.

Service Pattern: All trips operate in local transit service between Cedar Street station and New Britain station making all local stops.

One Way Travel Time: 15 minutes

One Way Mileage: 3.8 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



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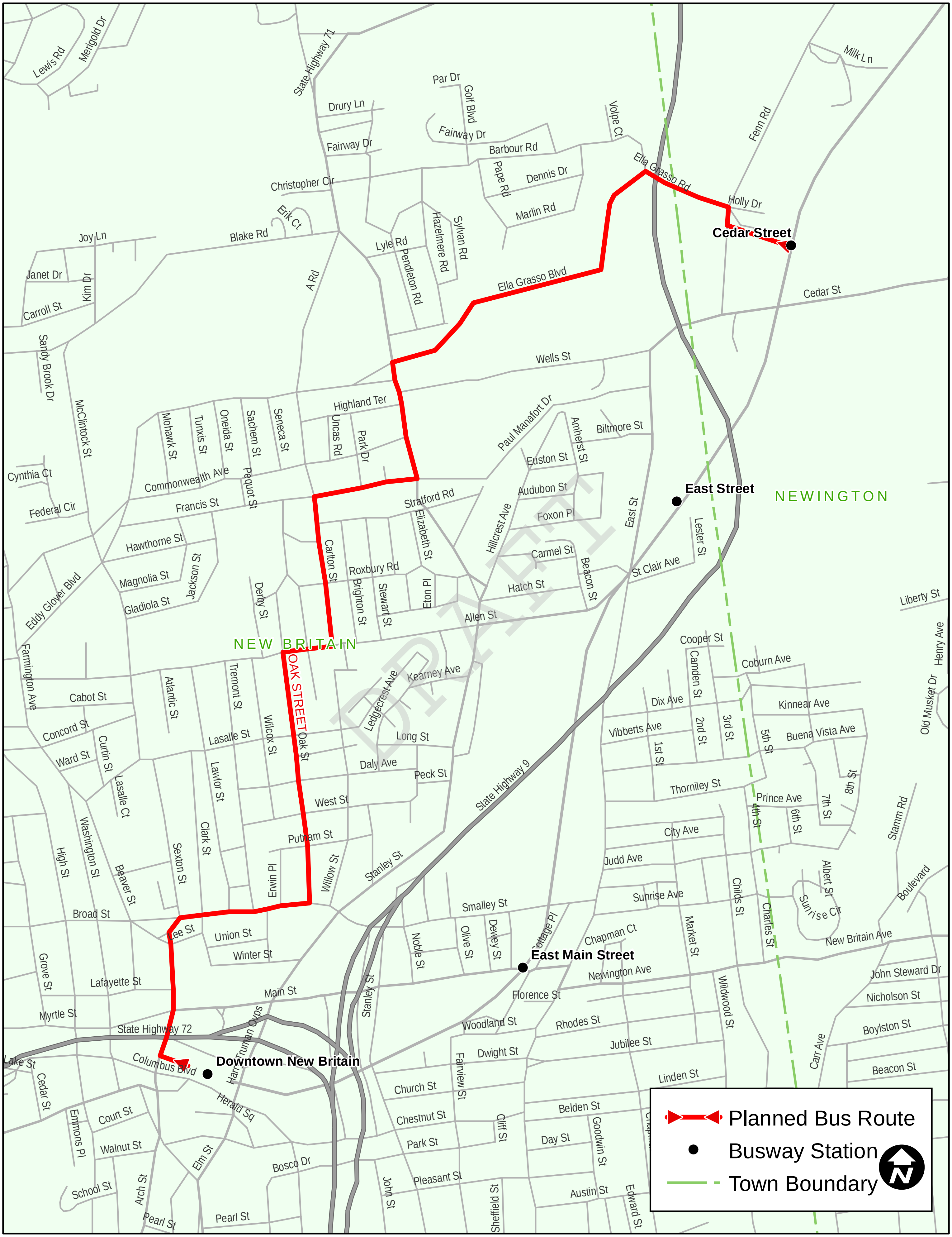
Service Plan Annual Service Hours: 5,448

Vehicle: Peak hour service on this route will require one 30ft low floor transit bus, the same number of vehicles as currently serves this route.

Modeled Weekday Boardings: 401

Notes: This route is modified to serve Cedar Street station as its northern terminal, rather than Westfarms Mall. Riders can transfer at CCSU to the Stanley Westfarms Hartford route to reach the Mall. Several time-consuming route deviations would be removed to make the route more direct. Formal bus stop locations would be established along the route.


Planned Bus Route
Busway Station
Town Boundary
DRAFT
NEW BRITAIN
NEWINGTON
Cedar Street
East Street
East Main Street
Downtown New Britain
OAK STREET
Ella Grasso Blvd
Ella Grasso Rd
Holly Dr
Cedar St
Wells St
Highland Ter
Stratford Rd
Carlton St
Allen St
Oak St
Putnam St
Lee St
Columbus Blvd
State Highway 71
State Highway 72
State Highway 9
Main St
Broad St
Paul Manafort Dr
Commonwealth Ave
Francis St
Hawthorne St
Magnolia St
Gladiola St
Eddy Glover Blvd
Farmington Ave
McClintock St
Sandy Brook Dr
Blake Rd
Christopher Cir
Fairway Dr
Drury Ln
Par Dr
Golf Blvd
Barbour Rd
Dennis Dr
Marlin Rd
Pape Rd
Volpe Ct
Fenn Rd
Milk Ln
Lyle Rd
Pendleton Rd
Hazelmere Rd
Sylvan Rd
A Rd
Erik Ct
Joy Ln
Janet Dr
Kim Dr
Carroll St
Cynthia Ct
Federal Cir
Mohawk St
Tunxis St
Oneida St
Sachem St
Seneca St
Uncas Rd
Park Dr
Pequot St
Jackson St
Derby St
Roxbury Rd
Brighton St
Stewart St
Eton Pl
Elizabeth St
Hillcrest Ave
Hatch St
Carmel St
Foxon Pl
Audubon St
Euston St
Amherst St
Biltmore St
Beacon St
East St
St Clair Ave
Lester St
Liberty St
Henry Ave
Old Musket Dr
Cooper St
Camden St
Coburn Ave
Dix Ave
Kinnear Ave
Vibberts Ave
2nd St
3rd St
1st St
5th St
Buena Vista Ave
Thorniley St
Prince Ave
4th St
6th St
7th St
8th St
Stamm Rd
City Ave
Judd Ave
Sunrise Ave
Albert St
Sunrise Cir
Childs St
Charles St
Boulevard
New Britain Ave
Market St
Chapman Ct
Newington Ave
John Steward Dr
Nicholson St
Boylston St
Beacon St
Carr Ave
Wildwood St
Linden St
Jubilee St
Rhodes St
Florence St
Cottage Pl
Woodland St
Dwight St
Smalley St
Noble St
Olive St
Dewey St
Stanley St
Kearney Ave
Ledgecrest Ave
Long St
Daly Ave
Peck St
West St
Stanley St
Willow St
Erwin Pl
Cabot St
Atlantic St
Tremont St
Lasalle St
Wilcox St
Concord St
Ward St
Curtin St
Lasalle Ct
Lawlor St
Clark St
Sexton St
High St
Washington St
Beaver St
Union St
Winter St
Grove St
Lafayette St
Myrtle St
Lake St
Cedar St
Harry Truman Ovps
Herald Sq
Church St
Fairview St
Chestnut St
Park St
Cliff St
Belden St
Day St
Goodwin St
Austin St
Edward St
Sheffield St
Pleasant St
John St
Bosco Dr
Elm St
Pearl St
Arch St
School St
Walnut St
Court St
Emmons Pl
Lewis Rd
Merigold Dr

**Existing New Britain Area Local Routes**

Plainville/Bristol

This route provides feeder service to and from the busway and Forestville, Plainville and the western neighborhoods of New Britain.

Route: This route travels between New Britain station and Bristol. From New Britain it proceeds east on Route 372 (Main Street, New Britain Avenue, and Forestville Avenue) through New Britain and Plainville. At the junction of Route 72 in Plainville it continues west on Main Street to Forestville.

Service Pattern: All trips operate in local transit service between Forestville and New Britain station making all local stops.

One Way Travel Time: 30 minutes

One Way Mileage: 6.6 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



**Service Plan Headways**

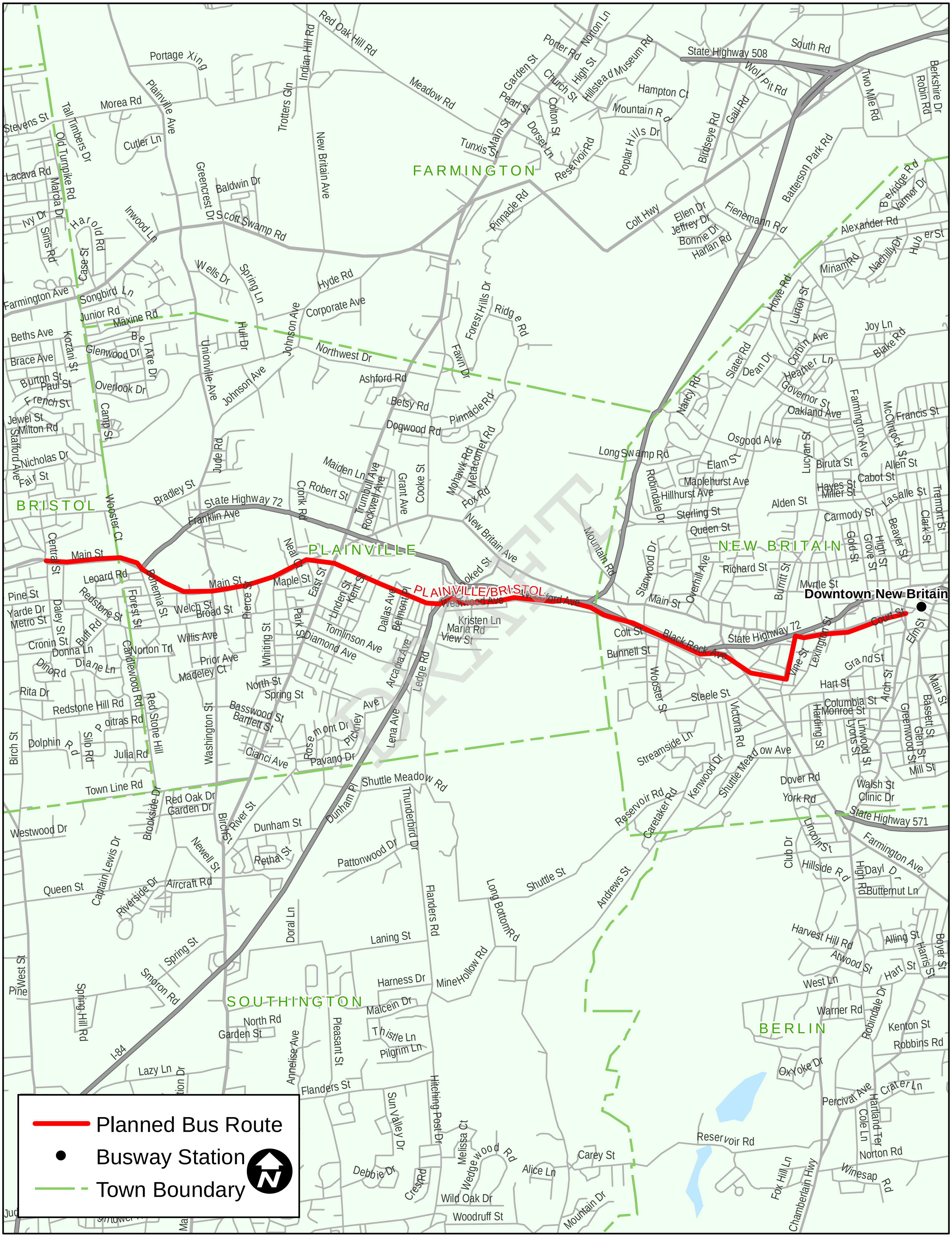
| | *Weekday* | *Saturday* | *Sunday* |
|---|---|---|---|
| AM Peak | 60 | 60 | 60 |
| Midday | 60 | | |
| PM Peak | 60 | | |
| Evening | 60 | 60 | |

Service Plan Annual Service Hours: 6,204

Vehicle: Peak hour service on this route will require one 30ft low floor transit bus, the same number of vehicles as currently serves this route.

Modeled Weekday Boardings: 3,331

Notes: This route is truncated at Forestville where riders can transfer to the Bristol Shuttle to reach Bristol. Formal bus stop locations would be established along this route.



FARMINGTON
BRISTOL
PLAINVILLE
NEW BRITAIN
SOUTHINGTON
BERLIN
PLAINVILLE/BRISTOL
Downtown New Britain
State Highway 72
State Highway 508
State Highway 571
I-84
DRAFT
Planned Bus Route
Busway Station
Town Boundary
N

**Existing New Britain Area Local Routes**

Berlin Turnpike

This route provides supplemental peak hour feeder service to and from the busway and the Berlin Turnpike, Berlin, and the southern neighborhoods of New Britain.

Route: This route travels a U-shaped path between New Britain station and the Berlin Turnpike in Newington. From New Britain the route proceeds south along Route 71 to Route 372 (Farmington Avenue), where it turns southeast toward the Berlin Turnpike. At the Berlin Turnpike this route travels north to its end at Main Street in Newington.

Service Pattern: All trips operate in local transit service between the Berlin Turnpike and New Britain station making all local stops.

One Way Travel Time: 30 minutes

One Way Mileage: 7.4 miles

Service Span: Weekday peak periods only, from 6am to 9am and from 3pm to 6pm.

| **Service Plan Headways** | | | |
|---|---|---|---|
| | *Weekday* | *Saturday* | *Sunday* |
| AM Peak | 60 | | |
| Midday | — | — | — |
| PM Peak | 60 | | |
| Evening | — | — | |

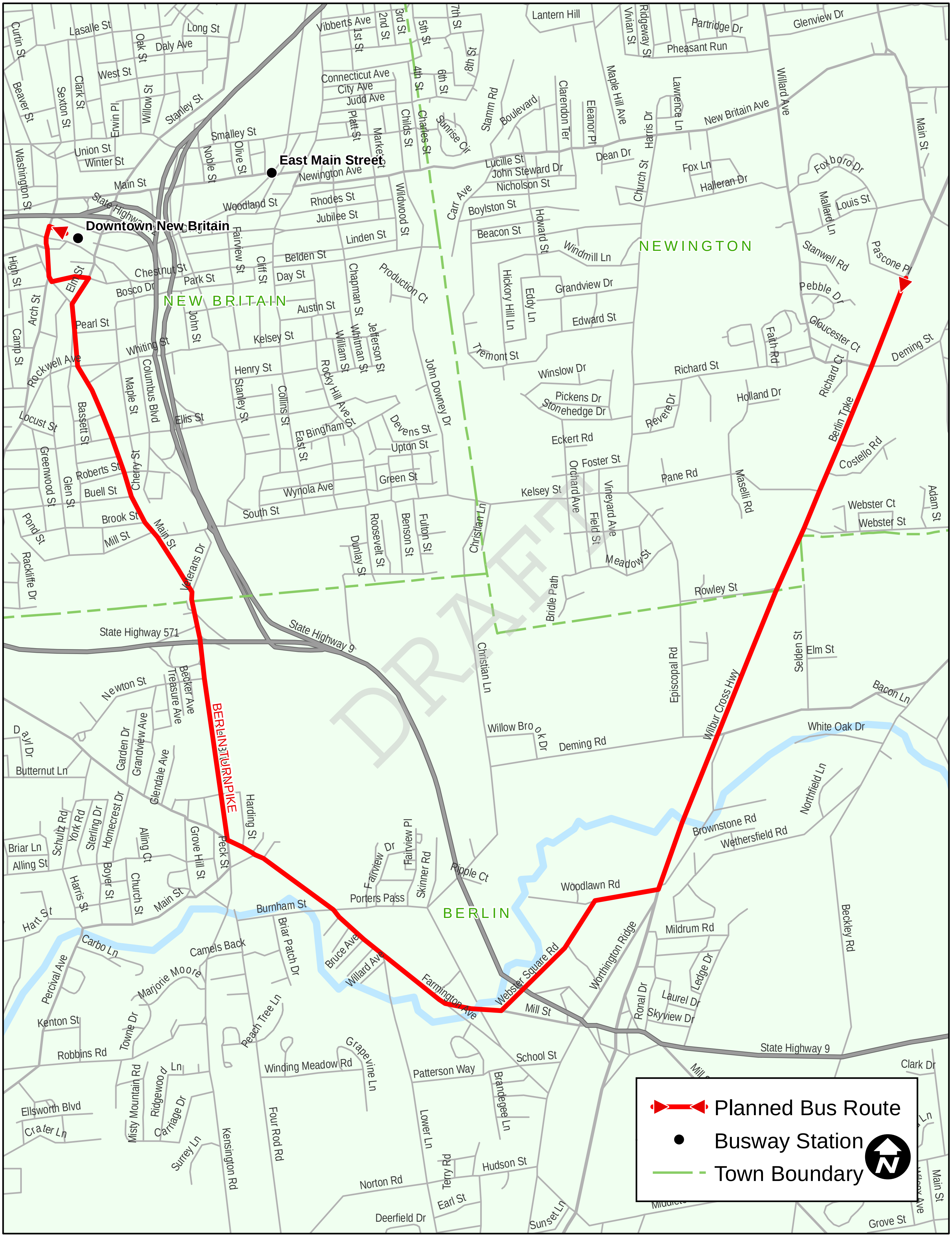


Service Plan Annual Service Hours: 1,512

Vehicle: Peak hour service on this route will require one 30ft low floor transit bus, the same number of vehicles as currently serves this route.

Modeled Weekday Boardings: —

Notes: Formal bus stop locations would be established along this route.



East Main Street
Downtown New Britain
NEW BRITAIN
NEWINGTON
BERLIN
BERLIN TURNPIKE
DRAFT
State Highway 571
State Highway 9
Planned Bus Route
Busway Station
Town Boundary
Newington Ave
New Britain Ave
Main St
Woodland St
Chestnut St
Park St
Elm St
Pearl St
Rockwell Ave
Whiting St
Ellis St
Veterans Dr
Kelsey St
Richard St
Deming St
Berlin Tpke
Wilbur Cross Hwy
Willard Ave
Christian Ln
Deming Rd
Webster Square Rd
Farmington Ave
Mill St
Woodlawn Rd
Burnham St
Episcopal Rd
Selden St
Elm St
Pascone Pl
Costello Rd
Rowley St
Webster St
Brownstone Rd
Wethersfield Rd
Worthington Ridge
School St
Patterson Way
Kensington Rd
Four Rod Rd
Norton Rd
Hudson St
Beckley Rd

**Existing New Britain Area Local Routes**

Berlin Turnpike (Cromwell)

This route provides feeder service to the busway to and from the Cromwell Wal-Mart, the Berlin Turnpike, and the southeastern neighborhoods of New Britain.

Route: This route travels a Y-shaped path between New Britain station, Wal-Mart in Cromwell, and the Berlin Turnpike in Newington. From New Britain the route proceeds south along Route 71 to Route 372 (Farmington Avenue, Mill Street), where it turns southeast toward the Berlin Turnpike. At the Berlin Turnpike this route travels south to the Cromwell Wal-Mart before proceeding north on the Berlin Turnpike to Main Street in Newington. From this point the route again reverses direction, traveling south on the Berlin Turnpike toward Route 372, by which it returns to New Britain.

Service Pattern: All trips operate in local transit service between the Cromwell Wal-Mart and New Britain station making all local stops.

One Way Travel Time: 45 minutes

One Way Mileage: 10.5 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



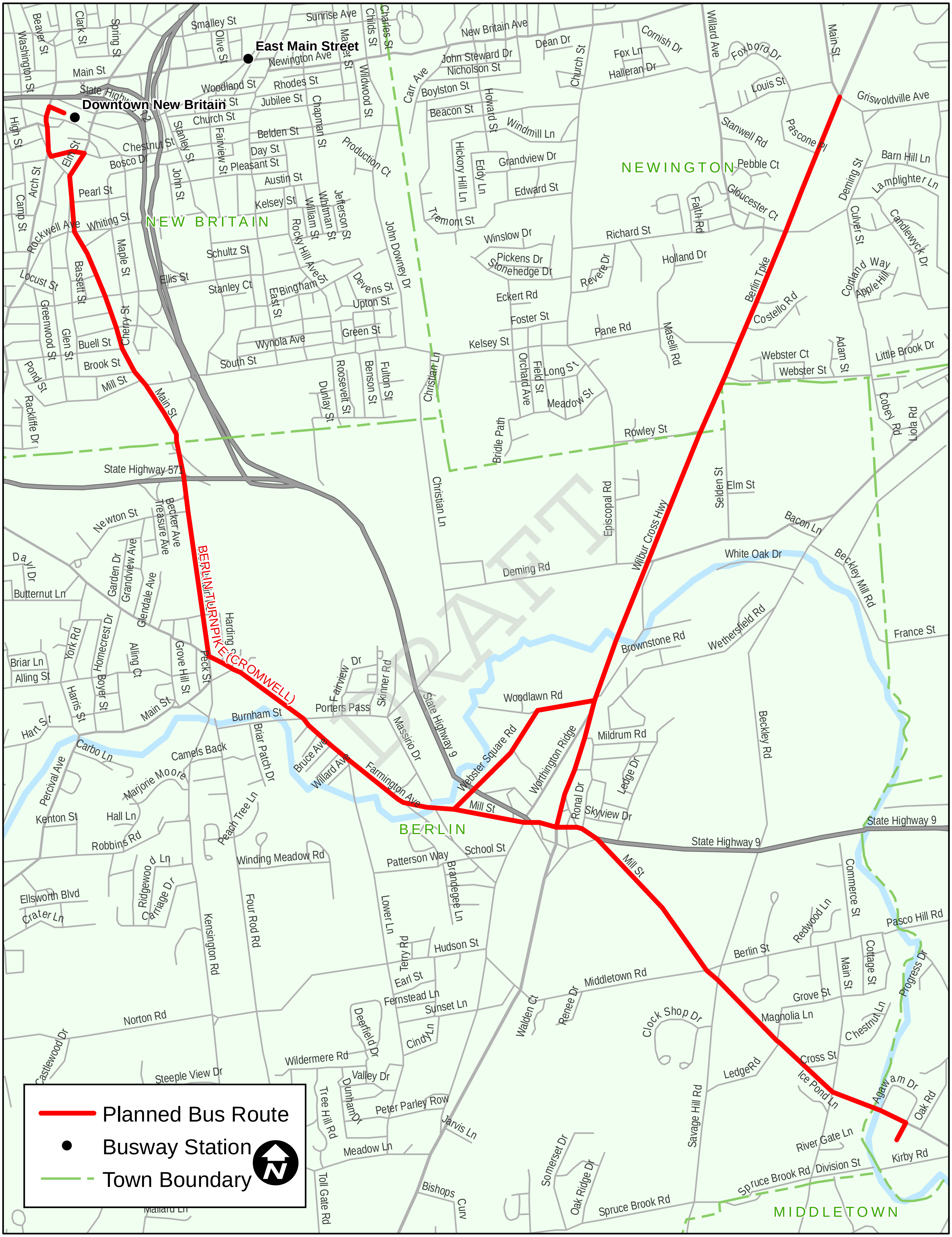
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>90</td><td rowspan="3">90</td><td rowspan="4">90</td></tr>
<tr><td>Midday</td><td>90</td></tr>
<tr><td>PM Peak</td><td>90</td></tr>
<tr><td>Evening</td><td>90</td><td>90</td></tr>
</table>

Service Plan Annual Service Hours: 4,892

Vehicle: Peak hour service on this route will require one 30ft low floor transit bus, the same number of vehicles as currently serves this route.

Modeled Weekday Boardings: —

Notes: Formal bus stop locations would be established on this route.



Planned Bus Route
Busway Station
Town Boundary
N
East Main Street
Downtown New Britain
NEW BRITAIN
NEWINGTON
BERLIN
MIDDLETOWN
BERLIN TURNPIKE (CROMWELL)
DRAFT
State Highway 571
State Highway 9
Main St
Mill St
Farmington Ave
Webster Square Rd
Woodlawn Rd
Wilbur Cross Hwy
Berlin Tpke
Christian Ln
Deming Rd
Kelsey St
Rowley St
Elm St
White Oak Dr
Griswoldville Ave
Berlin St
Middletown Rd
Spruce Brook Rd
Kirby Rd
Ice Pond Ln
Norton Rd
Kensington Rd
Four Rod Rd
Burnham St
Newington Ave
Smalley St
Stanley St
Beckley Rd
Brownstone Rd
Wethersfield Rd
Worthington Ridge
Savage Hill Rd
Toll Gate Rd

**Existing New Britain Area Local Routes**

Combined South and East Street

This route provides feeder service to and from the busway and the Berlin Turnpike and eastern neighborhoods of New Britain.

Route: This route, a combination of two existing routes, travels between New Britain and Corbin Russwin in Berlin. Beginning in New Britain the route loops through the neighborhood bounded by East Street, Dix Avenue, 5th Street, and Newington Avenue, then travels past East Main Street station. This route also stops at New Britain station before continuing south on Main Street toward Chestnut Street. At Chestnut Street the route turns east toward Stanley Street. The route proceeds toward South Street, at which point it travels east, continuing on Kelsey Street before turning south toward Corbin Russwin. On the return trip the route follows the same path until Rocky Hill Avenue, where it turns north, turning again on Ellis Street to return to New Britain via Stanley Street.

Service Pattern: All trips operate in local transit service between Corbin Russwin and New Britain station and on to East Street making all local stops.

One Way Travel Time: 30 minutes

One Way Mileage: 7.6 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



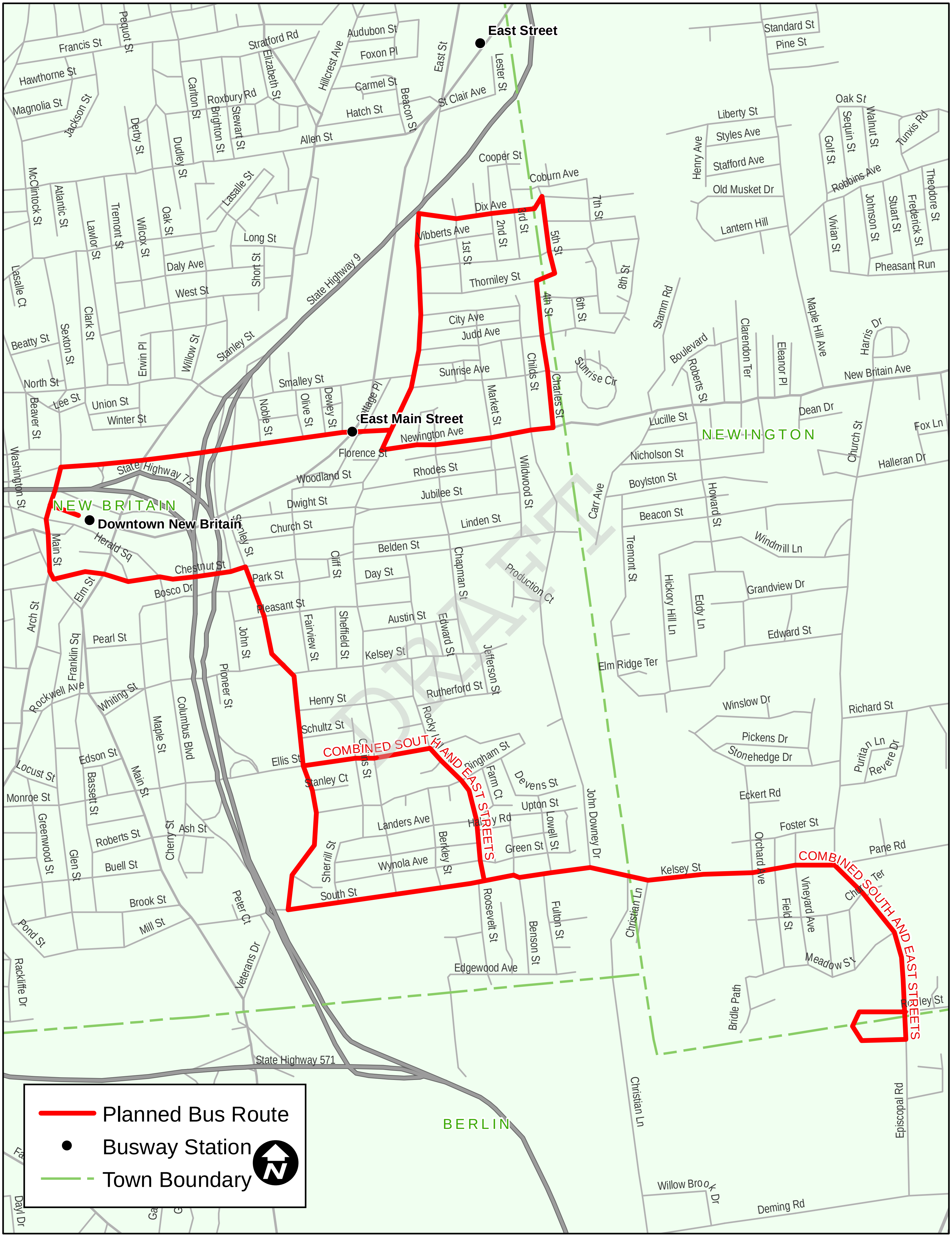
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>60</td><td rowspan="3">60</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>60</td></tr>
<tr><td>PM Peak</td><td>60</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 6,204

Vehicle: Peak hour service on this route will require one 30ft low floor transit bus, one fewer vehicles than the existing independent East and South routes.

Modeled Weekday Boardings: 582

Notes: This route is made up of the combination of the previous East and South Street routes. The path of the route is simplified to make it easier to understand and more direct. Formal bus stop locations would be established along the route.



East Street
East Main Street
Downtown New Britain
NEW BRITAIN
NEWINGTON
BERLIN
COMBINED SOUTH AND EAST STREETS
COMBINED SOUTH AND EAST STREETS
DRAFT
State Highway 9
State Highway 72
State Highway 571
Francis St
Pequot St
Stratford Rd
Audubon St
Foxon Pl
Carmel St
Hatch St
Hillcrest Ave
Elizabeth St
Hawthorne St
Magnolia St
Jackson St
Carlton St
Roxbury Rd
Brighton St
Stewart St
Allen St
Beacon St
East St
Lester St
St Clair Ave
Cooper St
Coburn Ave
Dix Ave
Vibberts Ave
1st St
2nd St
3rd St
5th St
7th St
8th St
4th St
6th St
Thornlley St
City Ave
Judd Ave
Sunrise Ave
Childs St
Charles St
Sunrise Cir
Market St
Newington Ave
Florence St
Smalley St
Noble St
Olive St
Dewey St
Cottage Pl
McClintock St
Atlantic St
Lawlor St
Tremont St
Wilcox St
Oak St
Lasalle St
Long St
Daly Ave
West St
Short St
Derby St
Dudley St
Lasalle Ct
Beatty St
Sexton St
Clark St
Erwin Pl
Willow St
Stanley St
North St
Lee St
Union St
Winter St
Beaver St
Washington St
Woodland St
Rhodes St
Jubilee St
Dwight St
Church St
Linden St
Wildwood St
Belden St
Chapman St
Production Ct
Main St
Herald Sq
Chestnut St
Park St
Cliff St
Day St
Bosco Dr
Elm St
Arch St
Pleasant St
Austin St
Edward St
Pearl St
Franklin Sq
John St
Fairview St
Sheffield St
Kelsey St
Jefferson St
Rockwell Ave
Whiting St
Maple St
Columbus Blvd
Pioneer St
Henry St
Rutherford St
Schultz St
Ellis St
Rocky Hill Ave
Bingham St
Farm Ct
Devens St
Upton St
Lowell St
Locust St
Edson St
Monroe St
Bassett St
Main St
Stanley Ct
Landers Ave
Berkley St
Halsey Rd
Green St
Greenwood St
Glen St
Roberts St
Ash St
Cherry St
Buell St
Sherrill St
Wynola Ave
South St
Brook St
Mill St
Pond St
Peter Ct
Roosevelt St
Benson St
Fulton St
Edgewood Ave
Veterans Dr
Rackliffe Dr
John Downey Dr
Christian Ln
Kelsey St
Carr Ave
Lucille St
Nicholson St
Boylston St
Beacon St
Tremont St
Howard St
Windmill Ln
Hickory Hill Ln
Eddy Ln
Grandview Dr
Edward St
Elm Ridge Ter
Winslow Dr
Pickens Dr
Stonehedge Dr
Richard St
Puritan Ln
Revere Dr
Eckert Rd
Foster St
Orchard Ave
Pane Rd
Field St
Vineyard Ave
Meadow St
Bridle Path
Episcopal Rd
Christian Ln
Willow Brook Dr
Deming Rd
Standard St
Pine St
Liberty St
Styles Ave
Henry Ave
Stafford Ave
Old Musket Dr
Lantern Hill
Stamm Rd
Boulevard
Roberts St
Clarendon Ter
Eleanor Pl
Maple Hill Ave
Oak St
Sequin St
Walnut St
Tunxis Rd
Golf St
Robbins Ave
Theodore St
Vivian St
Johnson St
Stuart St
Frederick St
Pheasant Run
Harris Dr
New Britain Ave
Dean Dr
Church St
Fox Ln
Halleran Dr
Planned Bus Route
Busway Station
Town Boundary
N

**Existing Hartford Area Local Routes**

West Hartford Place via Park

This route provides urban trunkline service to and from the West Hartford Place mall on New Park Avenue and downtown Hartford with a connection to the busway at Flatbush and Park Street. It travels roughly parallel to the busway provide supplemental local transit service in this highly transit oriented neighborhood.

Route: This route travels between downtown Hartford and West Hartford Place along Park Street and New Park Avenue. From Main Street in downtown Hartford the route travels south to Park Street, then turns west to New Park Avenue. Traveling southwest on New Park the route terminates at West Hartford Place.

Service Pattern: All trips operate in local transit service from West Hartford Place mall to downtown Hartford making all local stops.

One Way Travel Time: 25 minutes

One Way Mileage: 3.8 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.

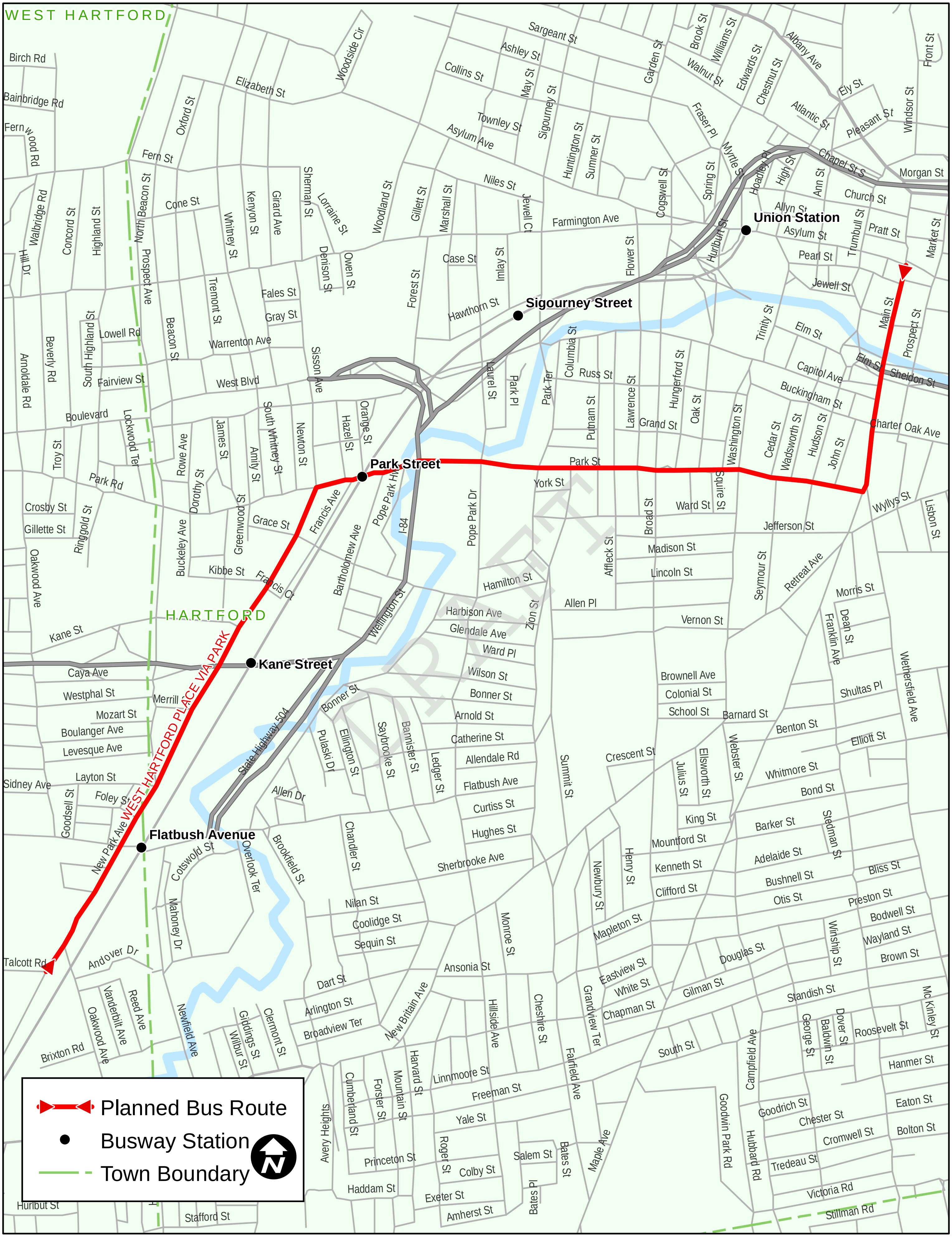
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>20</td><td rowspan="3">30</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>40</td></tr>
<tr><td>PM Peak</td><td>20</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 8,946

Vehicle: Peak hour service on this route will require three 40ft low floor transit buses, the same number of vehicles as currently serve this route.

Modeled Weekday Boardings: 1,876

Notes: None


WEST HARTFORD
HARTFORD
Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
WEST HARTFORD PLACE VIA PARK
I-84
State Highway 504
DRAFT
Planned Bus Route
Busway Station
Town Boundary
N

**Existing Hartford Area Local Routes**

West Hartford Place via Park and Kane St

This route provides supplemental midday transit service to and from the West Hartford Place mall on New Park Avenue and downtown Hartford with a connection to the busway at Flatbush and Park Street. It travels roughly parallel to the busway provide supplemental local transit service in this highly transit oriented neighborhood.

Route: This route travels between downtown Hartford and West Hartford Place along Park Street, New Park Avenue, Kane Street, and Prospect Avenue. From Main Street in downtown Hartford the route travels south to Park Street, then turns west to New Park Avenue. Traveling southwest on New Park the route continues Kane Street, where it turns west. At the intersection of Kane and Prospect Avenue the route turns south toward New Park, where it again travels southwest, terminating at West Hartford Place.

Service Pattern: All trips operate in local transit service between West Hartford Place mall and downtown Hartford making all local stops.

One Way Travel Time: 29 minutes

One Way Mileage: 4.1 miles

Service Span: This service operates only during midday periods only (9am – 3pm) Monday through Friday.



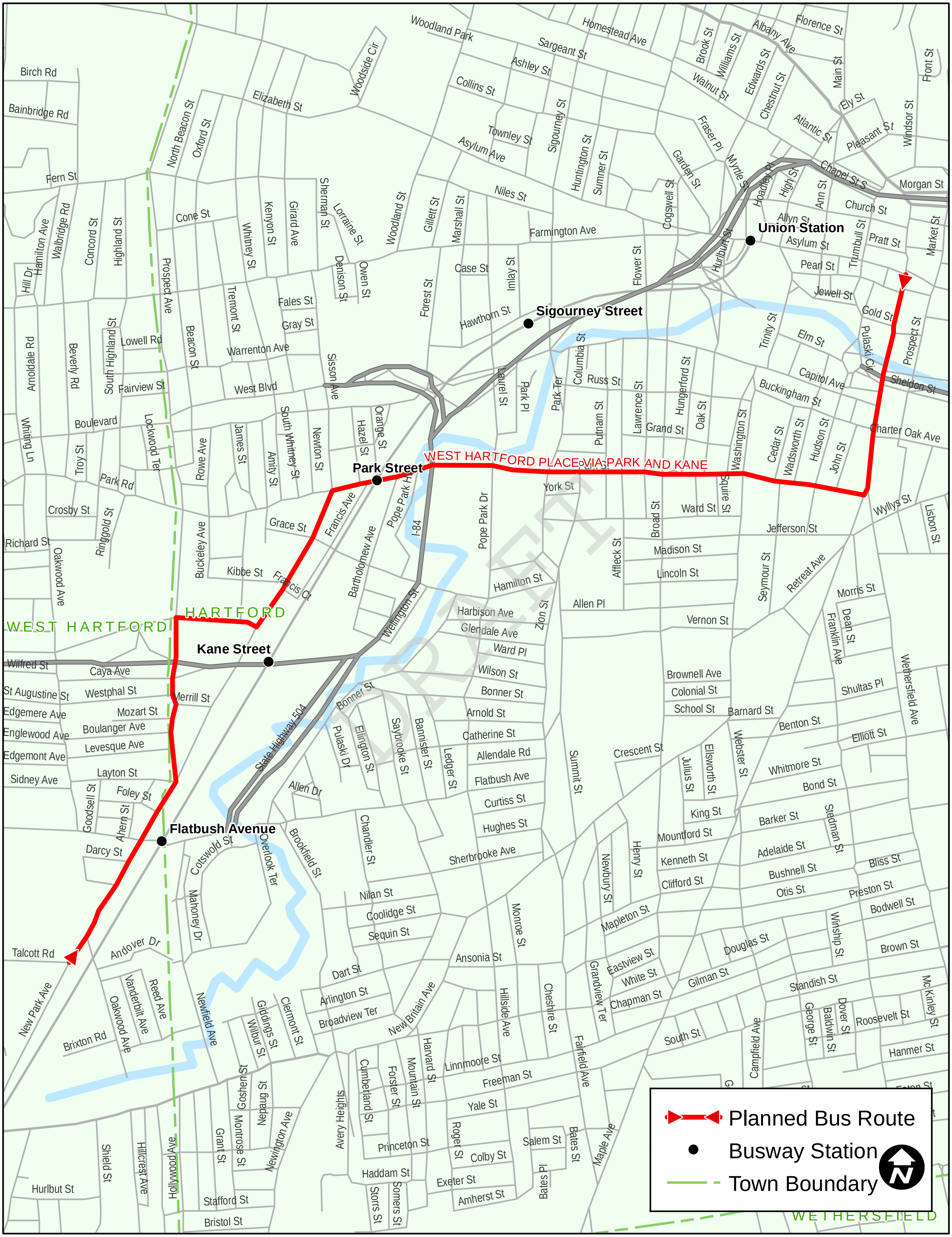
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>—</td><td rowspan="3">—</td><td rowspan="4">—</td></tr>
<tr><td>Midday</td><td>40</td></tr>
<tr><td>PM Peak</td><td>—</td></tr>
<tr><td>Evening</td><td>—</td><td>—</td></tr>
</table>

Service Plan Annual Service Hours: 2,162

Vehicle: This route does not operate during peak periods and so does not require any additional vehicles to operate.

Modeled Weekday Boardings: —

Notes: None



WEST HARTFORD PLACE VIA PARK AND KANE
Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
WEST HARTFORD
HARTFORD
WETHERSFIELD
DRAFT
Planned Bus Route
Busway Station
Town Boundary

**Existing Hartford Area Local Routes**

Westfarms via Park

This route provides urban trunkline service to and from the Westfarms Mall and downtown Hartford with a connection to the busway at Park Street.

Route: This route travels between downtown Hartford and Westfarms Mall in West Hartford. Beginning at the intersection of Asylum Street and Main Street in Hartford, this route travels south on Main to Park Street, where it turns west. Traveling west on Park, the route continues on Sedgwick Road to Ridgewood Road, where it turns south, terminating at Westfarms Mall.

Service Pattern: All trips operate in local transit service between Westfarms Mall and downtown Hartford making all local stops.

One Way Travel Time: 50 minutes

One Way Mileage: 7.1 miles

Service Span: This route operates Monday through Saturday from 6am to 6pm.



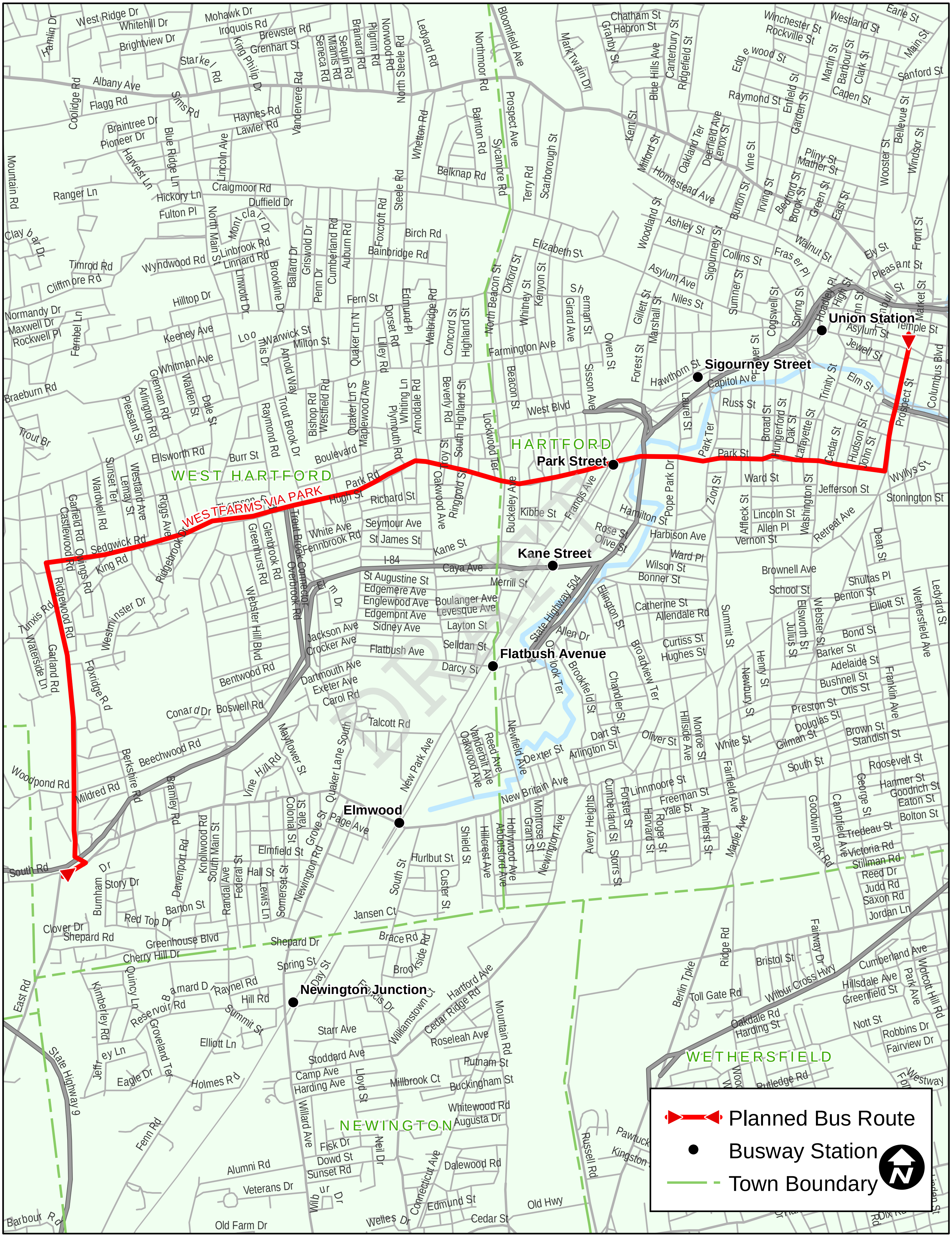
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>40</td><td rowspan="3">30</td><td rowspan="4">—</td></tr>
<tr><td>Midday</td><td>40</td></tr>
<tr><td>PM Peak</td><td>40</td></tr>
<tr><td>Evening</td><td>—</td><td>—</td></tr>
</table>

Service Plan Annual Service Hours: 9,544

Vehicle: Peak hour service on this route will require three 40ft low floor transit buses, two fewer vehicles than currently serve this route. This reduction is possible due to increased parallel service provided by the busway and routes BW3 and BW4 to Westfarms Mall.

Modeled Weekday Boardings: 2,673

Notes: None



WESTFARMS VIA PARK
WEST HARTFORD
HARTFORD
NEWINGTON
WETHERSFIELD
Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
Newington Junction
I-84
State Highway 504
State Highway 9
DRAFT
Planned Bus Route
Busway Station
Town Boundary

**Existing Hartford Area Local Routes**

Hartford Newington Local

This route provides urban trunkline service to and from downtown Newington and downtown Hartford.

Route: This route travels between downtown Hartford and Newington. From the intersection of Asylum Street and Main Street in Hartford, this route travels south on Main to Retreat Avenue, where it heads southwest. At Washington Street the route turns south toward New Britain Avenue. At New Britain Avenue the route continues southwest to Newington Avenue. It continues traveling southwest on Newington Avenue and Hartford Avenue to Main Street in Newington, where it turns south into Newington, terminating at Northwood Plaza.

Service Pattern: All trips operate in local transit service between Newington and Hartford making all local stops.

One Way Travel Time: 30 minutes

One Way Mileage: 6.5 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>20</td><td rowspan="3">30</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>30</td></tr>
<tr><td>PM Peak</td><td>20</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 11,250

Vehicle: Peak hour service on this route will require three 40ft low floor transit buses, two fewer vehicles than were required for the previous route 41 service along this route.

Modeled Weekday Boardings: 1,284

Notes: This route is a shortened version of CT Transit route 41 Hartford-New Britain.

Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
Newington Junction
WEST HARTFORD
HARTFORD
NEWINGTON
WETHERSFIELD
HARTFORD/NEWINGTON LOCAL
DRAFT
I-84
I-91
State Highway 504
Planned Bus Route
Busway Station
Town Boundary
N

**Existing Hartford Area Local Routes**

Charter Oak Marketplace West Hartford Place via NB Ave

This route provides urban trunkline service to and from the West Hartford Place mall and Charter Oak Marketplace and downtown Hartford with a connection to the busway at Flatbush.

Route: This route travels between downtown Hartford and Charter Oak Marketplace. From the intersection of Asylum Street and Main Street in Hartford, this route travels south on Main to Jefferson Street, where it turns west. Traveling on Jefferson to Washington Street the route then turns south on Washington to New Britain Avenue. Proceeding southwest on New Britain Avenue the route turns west onto Dart Street, then north on Brookfield Street, looping around Charter Oak Marketplace and past Flatbush Avenue station and on to Oakwood Avenue before terminating at West Hartford Place.

Service Pattern: All trips operate in local transit service between West Hartford Place mall and downtown Hartford making all local stops.

One Way Travel Time: 39 minutes

One Way Mileage: 5.2 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



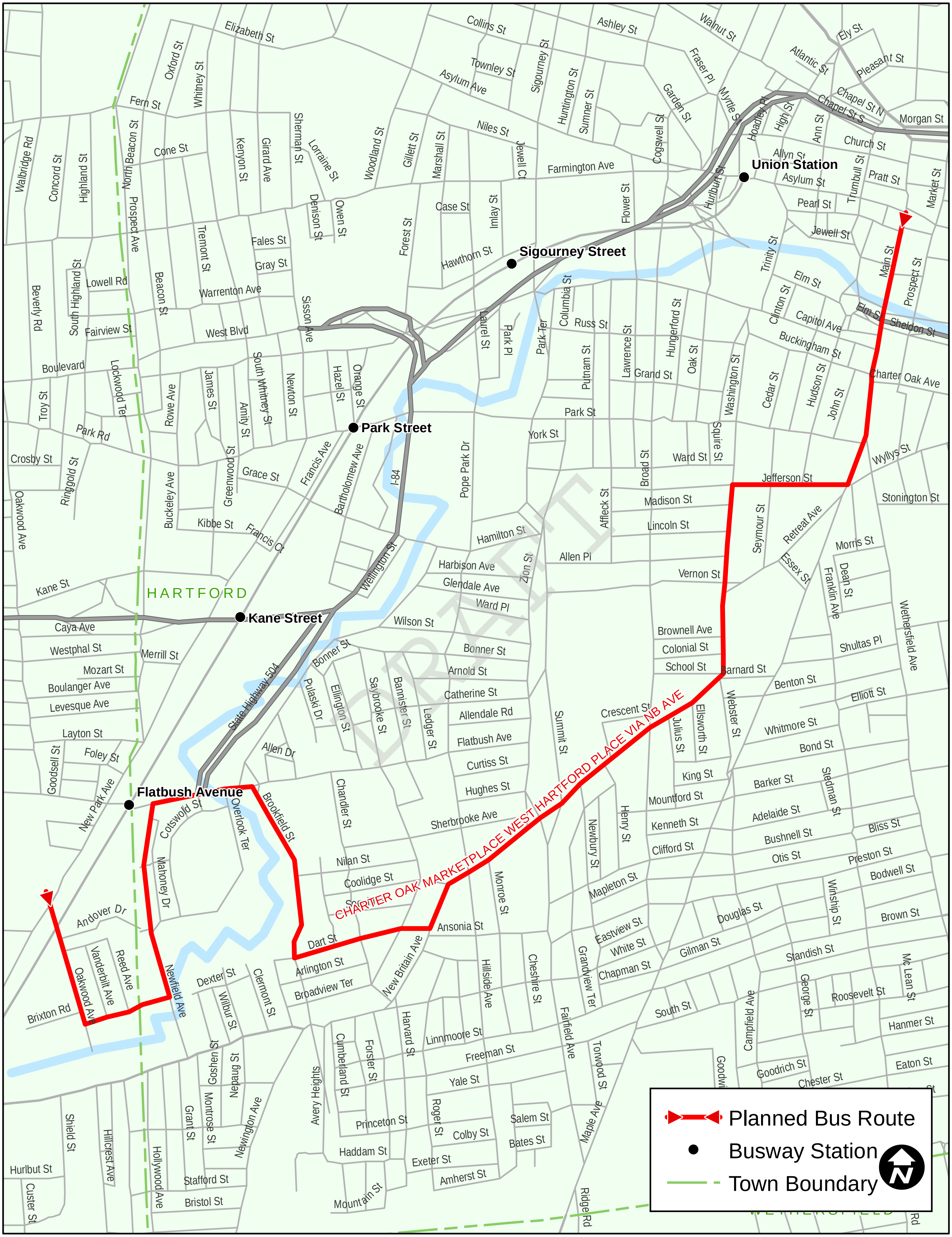
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>30</td><td rowspan="3">60</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>60</td></tr>
<tr><td>PM Peak</td><td>30</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 9,902

Vehicle: Peak hour service on this route will require four 40ft low floor transit buses, one fewer vehicles than are required to operate the existing service.

Modeled Weekday Boardings: 1,339

Notes: None



Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
HARTFORD
WETHERSFIELD
DRAFT
CHARTER OAK MARKETPLACE WEST HARTFORD PLACE VIA NB AVE
Planned Bus Route
Busway Station
Town Boundary

**Existing Hartford Area Local Routes**

Elmwood via New Britain Ave

This route provides urban trunkline service to and from Elmwood and downtown Hartford with a connection to the busway at Elmwood station.

Route: This route travels between downtown Hartford and Newington. From the intersection of Asylum Street and Main Street in Hartford, this route travels south on Main to Retreat Avenue, where it heads southwest. At Washington Street the route turns south toward New Britain Avenue. At New Britain Avenue the route continues southwest to Elmwood station before terminating near New Britain Avenue and Newington Road

Service Pattern: All trips operate in local transit service between Elmwood and downtown Hartford making all local stops.

One Way Travel Time: 34 minutes

One Way Mileage: 4.9 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



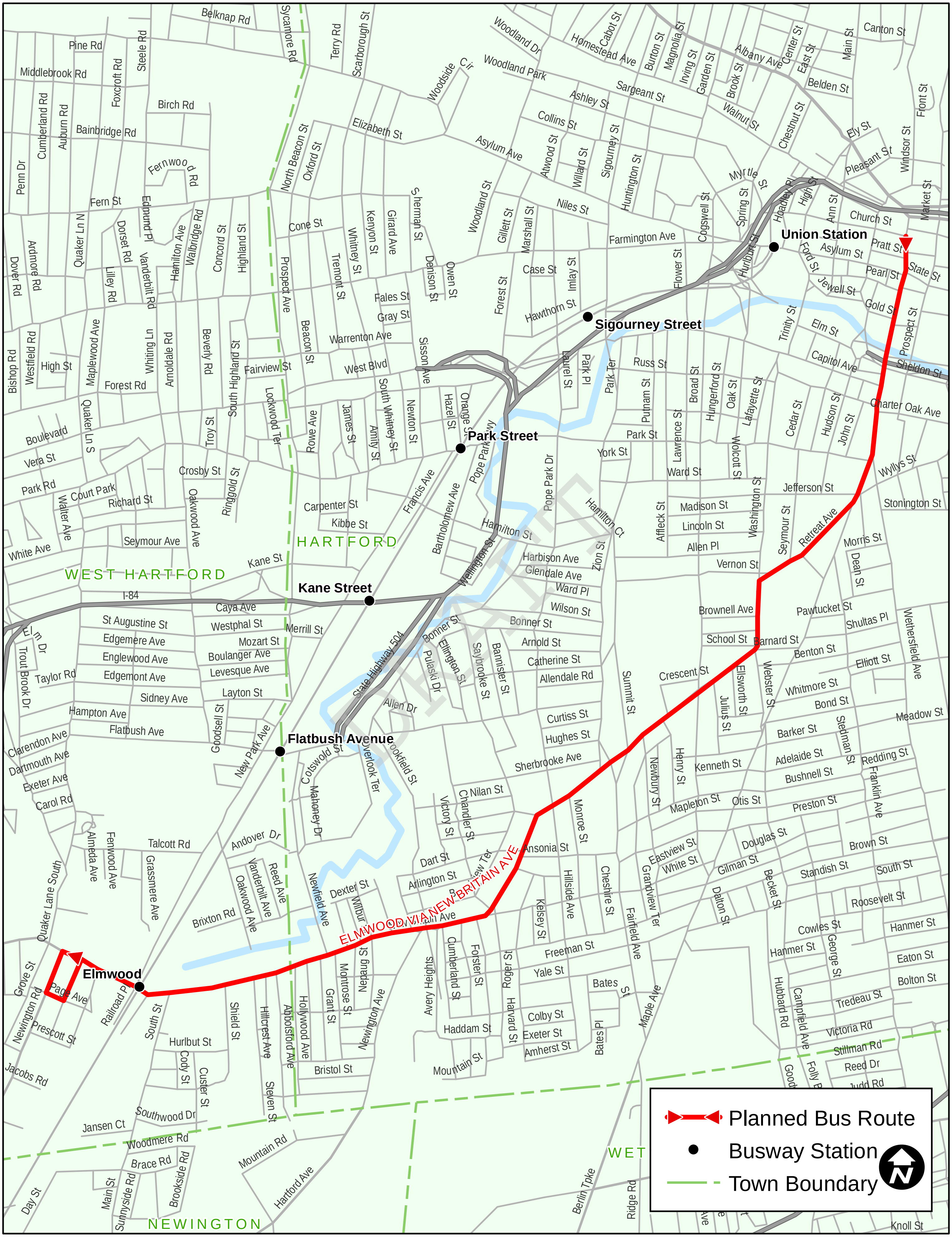
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>20</td><td rowspan="3">60</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>60</td></tr>
<tr><td>PM Peak</td><td>20</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 10,482

Vehicle: Peak hour service on this route will require five 40ft low floor transit buses, one fewer vehicles than are currently required to operate the service.

Modeled Weekday Boardings: 2,374

Notes: This route is shortened from its former terminal at Westfarms Mall which can be reached via routes BW3 Stanley Westfarms Hartford or BW4 UConn Health Westfarms Hartford in this service plan.


Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
ELMWOOD VIA NEW BRITAIN AVE
HARTFORD
WEST HARTFORD
NEWINGTON
I-84
State Highway 504
DRAFT
Planned Bus Route
Busway Station
Town Boundary
N

**Existing Hartford Area Local Routes**

Capitol - Berlin Turnpike via Willard

This route provides urban trunkline service to and from the Berlin Turnpike and downtown Hartford with a connection to the busway at Newington Junction station.

Route: This route travels between downtown Hartford and the shopping area near Willard Avenue and Berlin Turnpike in Newington. From the intersection of Asylum Street and Main Street in Hartford, this route travels south on Main to Capitol Avenue, where it turns west, proceeding along Capitol and West Boulevard to Quaker Lane, where it turns south. Proceeding along Quaker Lane, the route continues south along Newington Road and Willard to Deming Street, where it loops around on Deming and on Louis Street before returning to Hartford.

Service Pattern: All trips operate in local transit service between Berlin Turnpike and downtown Hartford making all local stops.

One Way Travel Time: 41 minutes

One Way Mileage: 11.9 miles

Service Span: Monday through Saturday from 6am to 6pm. No service during evenings and on Sundays.

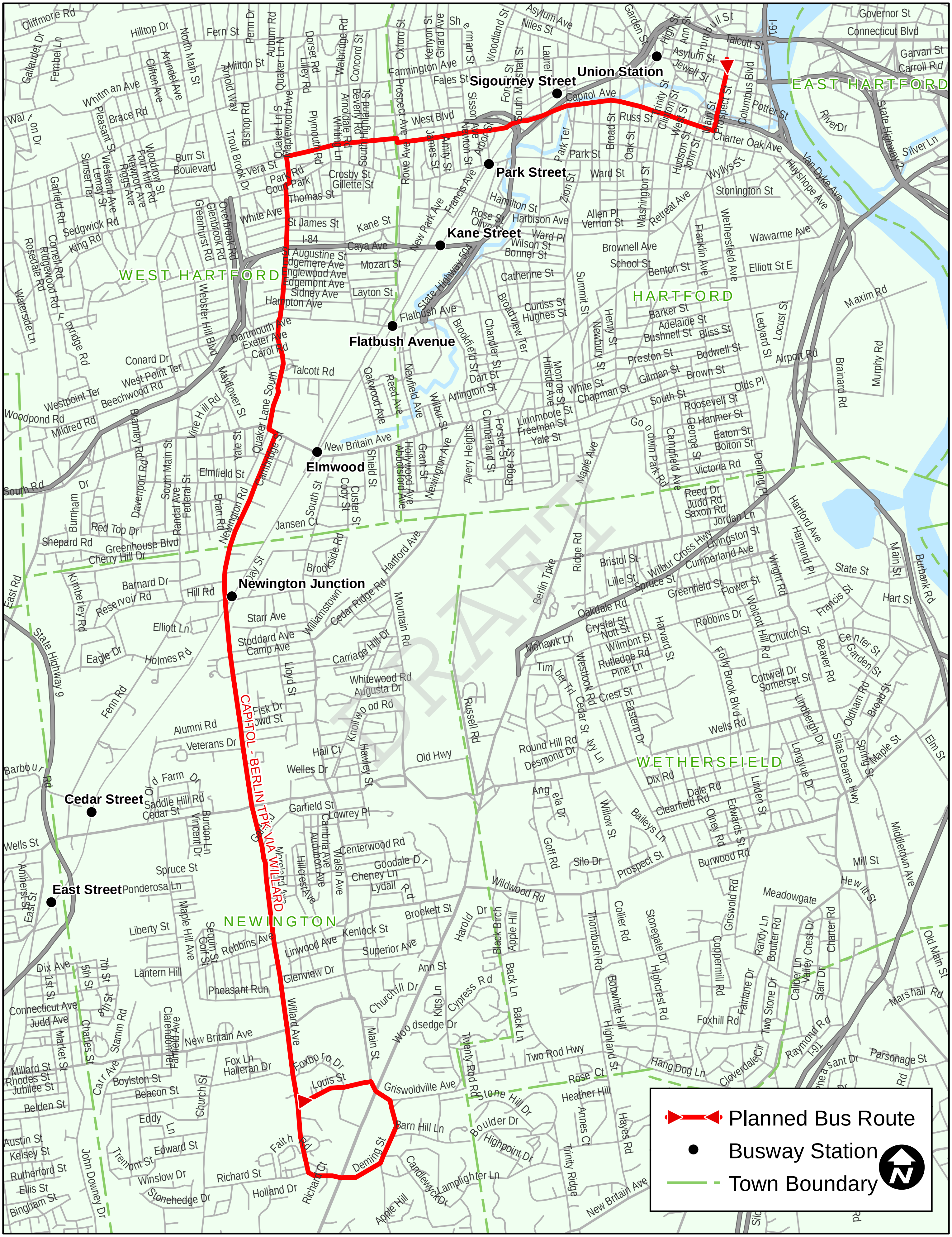
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>30</td><td rowspan="3">30</td><td rowspan="4">—</td></tr>
<tr><td>Midday</td><td>30</td></tr>
<tr><td>PM Peak</td><td>30</td></tr>
<tr><td>Evening</td><td>—</td><td>—</td></tr>
</table>

Service Plan Annual Service Hours: 9,898

Vehicle: Peak hour service on this route will require three 40ft low floor transit buses, the same number of vehicles as currently serve this route.

Modeled Weekday Boardings: 510

Notes: None


Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
Newington Junction
Cedar Street
East Street
WEST HARTFORD
HARTFORD
EAST HARTFORD
WETHERSFIELD
NEWINGTON
CAPITOL - BERLIN TPK VIA WILLARD
DRAFT
Planned Bus Route
Busway Station
Town Boundary
N

**Existing and New Express Routes**

BX1 Waterbury Express

This route provides peak hour commuter express service between downtown Waterbury and Hartford. It connects the Waterbury transit system with the New Britain and Hartford systems, making many trips that currently cannot be completed by transit possible. In addition to downtown Waterbury, the Exit 23 park-and-ride, and downtown Hartford, stops are made at the Plantsville park-and-ride and New Britain busway station.

Route: Beginning at Union Station on its way to Waterbury, this route enters the busway, making stops at Sigourney Street and at Downtown New Britain stations. After exiting the busway at New Britain, this route loops through downtown before proceeding on Route 72 westbound, then I-84 westbound. The route exits I-84 at Southington, traveling south along Main Street and Meriden Avenue and making stops at a park-and-ride facility at Plantsville before re-entering I-84 westbound. At exit 22 the route exits I-84 onto Hamilton Avenue, stopping at another park-and-ride facility near this interchange. Continuing west on Union Street and Grand Street, the route terminates at the intersection of Meadow Street.

Service Pattern: All trips operate from the Waterbury train station via the transit center, Exit 23 park and ride, Plantsville park and ride, New Britain station, Sigourney Street station and then via the downtown Hartford express bus loop (Farmington, Asylum, Main, Capitol) making all local stops when on-street. The loop would be operated clockwise in the morning and counterclockwise in the afternoon.



One Way Travel Time: 70 minutes

One Way Mileage: 34.4 miles

Service Span: This route will operate only on weekdays during AM and PM peak periods, from 6am to 9am and from 3pm to 6pm.

**Service Plan Headways**

| | *Weekday* | *Saturday* | *Sunday* |
|---|---|---|---|
| AM Peak | 30 | | |
| Midday | — | — | — |
| PM Peak | 30 | | |
| Evening | — | — | |

Service Plan Annual Service Hours: 7,056

Vehicle: This route will require five 45-foot coach vehicles.

Modeled Weekday Boardings: 1,044

Notes: The Waterbury Express and Cheshire Southington Express stop at the Plantsville park-and-ride lot providing service every 15 minutes from that location during the peak. Off-peak service is provided by the Waterbury Cheshire Off-Peak Express.


NEW HARTFORD
CANTON
SIMSBURY
BLOOMFIELD
WINDSOR
AVON
HARTFORD
WEST HARTFORD
BURLINGTON
FARMINGTON
HARWINTON
WETHERSFIELD
BRISTOL
PLAINVILLE
NEW BRITAIN
NEWINGTON
PLYMOUTH
ROCKY HILL
BERLIN
CROMWELL
SOUTHINGTON
WOLCOTT
MIDDLETOWN
WATERBURY
MERIDEN
CHESHIRE
PROSPECT
WALLINGFO
BETHANY
Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
Newington Junction
Cedar Street
East Street
East Main Street
Downtown New Britain
Plantsville P+R
Waterbury P+R
WATERBURY EXPRESS
DRAFT
Planned Bus Route
Busway Station Stop
Other Busway Station
Point of Interest
Town Boundary
N

**Existing and New Express Routes**

BX2 Cheshire Express

This route provides peak hour commuter express service between park-and-ride lots in Cheshire and Southington and Hartford.

Route: Beginning at Union Station, this route enters the busway, making stops at Sigourney Street and at Downtown New Britain stations. After exiting the busway at New Britain, this route loops through downtown before proceeding on Route 72 westbound, then I-84 westbound. The route exits I-84 at Southington, traveling south along Main Street and Meriden Avenue and making stops at Plantsville and Milldale park-and-ride facilities before re-entering I-84 westbound. The route terminates at a park-and-ride facility at exit 26 in Cheshire.

Service Pattern: All trips operate from the Exit 26 park-and-ride, Plantsville park-and-ride, New Britain station, Sigourney Street station and then via the downtown Hartford express bus loop (Farmington, Asylum, Main, Capitol) making all local stops when on-street. The loop would be operated clockwise in the morning and counterclockwise in the afternoon.

One Way Travel Time: 56 minutes

One Way Mileage: 28.5 miles

Service Span: This route will operate only on weekdays during AM and PM peak periods, from 6am to 9am and from 3pm to 6pm.

<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>30</td><td rowspan="3">—</td><td rowspan="4">—</td></tr>
<tr><td>Midday</td><td>—</td></tr>
<tr><td>PM Peak</td><td>30</td></tr>
<tr><td>Evening</td><td>—</td><td>—</td></tr>
</table>

Service Plan Annual Service Hours: 5,645

Vehicle: This route will require four 45-foot coach vehicles.

Modeled Weekday Boardings: 1,034

Notes: The Waterbury Express and Cheshire Southington Express stop at the Plantsville park-and-ride lot providing service every 15 minutes from that location during the peak. Off-peak service is provided by the Waterbury Cheshire Off-Peak Express.

**Existing and New Express Routes**

BX3 Waterbury Cheshire Off-Peak Express

This route provides off-peak express service between downtown Waterbury and park-and-ride lots in Waterbury, Cheshire, and Southington and Hartford.

Route: Beginning at Union Station, this route enters the busway, making stops at Sigourney Street and at Downtown New Britain stations. After exiting the busway at New Britain, this route loops through downtown before proceeding on Route 72 westbound, then I-84 westbound. The route exits I-84 at Southington, traveling south along Main Street and Meriden Avenue and making stops at Plantsville and Milldale park-and-ride facilities before re-entering I-84 westbound. The route then stops at a park-and-ride facility at exit 26 in Cheshire and continues along I-84 to the Exit 23 park-and-ride lot in Waterbury. The route continues into downtown Waterbury stopping at the local bus service transfer center and finally terminating at the Waterbury Metro-North train station.

Service Pattern: All trips operate between Waterbury, Exit 23 park-and-ride, Exit 26 park-and-ride, Plantsville park-and-ride, New Britain station, Sigourney Street station and then via the downtown Hartford express bus loop (Farmington, Asylum, Main, Capitol) making all local stops when on-street. The loop would be operated clockwise in the morning and counterclockwise in the afternoon and evening.



One Way Travel Time: 70 minutes

One Way Mileage: 34.4 miles

Service Span: This route will operate only during off-peak periods Monday through Sunday.

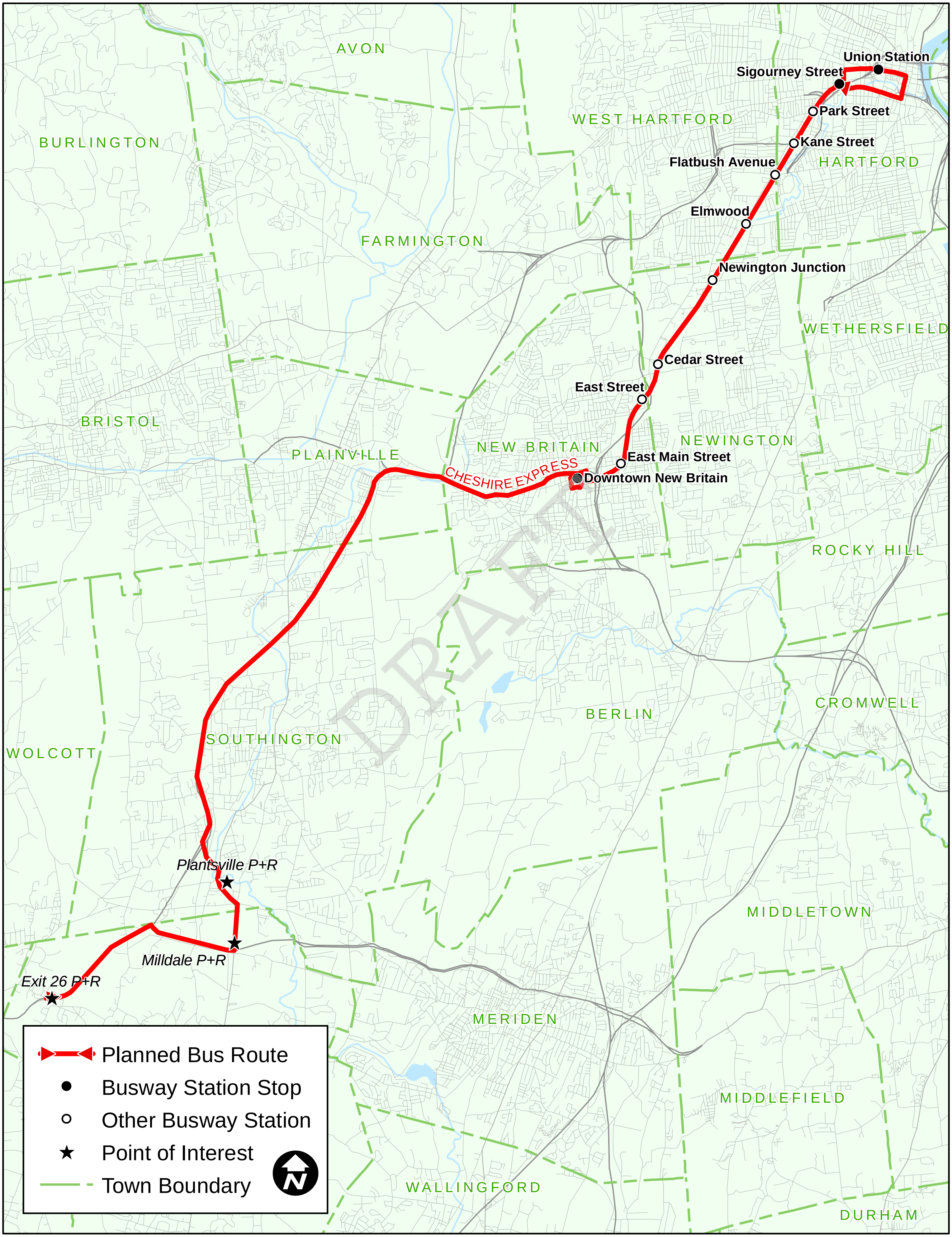
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>—</td><td rowspan="3">60</td><td rowspan="4">120</td></tr>
<tr><td>Midday</td><td>60</td></tr>
<tr><td>PM Peak</td><td>—</td></tr>
<tr><td>Evening</td><td>120</td><td>120</td></tr>
</table>

Service Plan Annual Service Hours: ??

Vehicle: As an off-peak only route, this service does not require any additional peak coaches.

Modeled Weekday Boardings: Included in Waterbury Express and Cheshire Express figures.

Notes: None



Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
Newington Junction
Cedar Street
East Street
East Main Street
Downtown New Britain
CHESHIRE EXPRESS
Plantsville P+R
Milldale P+R
Exit 26 P+R
AVON
BURLINGTON
WEST HARTFORD
HARTFORD
FARMINGTON
WETHERSFIELD
BRISTOL
PLAINVILLE
NEW BRITAIN
NEWINGTON
ROCKY HILL
CROMWELL
BERLIN
SOUTHINGTON
WOLCOTT
MIDDLETOWN
MERIDEN
MIDDLEFIELD
WALLINGFORD
DURHAM
DRAFT
Planned Bus Route
Busway Station Stop
Other Busway Station
Point of Interest
Town Boundary
N

**Busway Local Routes**

BW1 New Britain to Hartford Shuttle

The BW1 New Britain to Hartford Shuttle and BW 2 Bristol to Hartford Shuttle form the primary busway service, traveling the entire length of the facility from New Britain to Hartford. Together they provide frequent and fast service from early morning to late night, seven days a week. They create a simple, easy-to-remember service pattern for anyone interested in using the busway, in much the same way as a light rail line. Frequent service makes transferring from connecting local and circulator routes easy and convenient.

Route: This route travels from the New Britain Busway Station to Main Street in downtown Hartford via the busway, Asylum Street, and Pearl Street. Outbound it travels from Main Street via Asylum Street and the busway to New Britain Station.

Service Pattern: This route will make all local station stops along its route including: New Britain, East Main, East Street, Cedar Street, Newington Jct., Elmwood, Flatbush Avenue, Kane Street, Park Street, Sigourney Street, Union Station and in downtown Hartford, Ann Street, Trumbull Street and Main Street. The route will travel exclusively on the busway except for the downtown loop from Union Station to Main Street.

One Way Travel Time: 28 minutes

One Way Mileage: 10.1 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



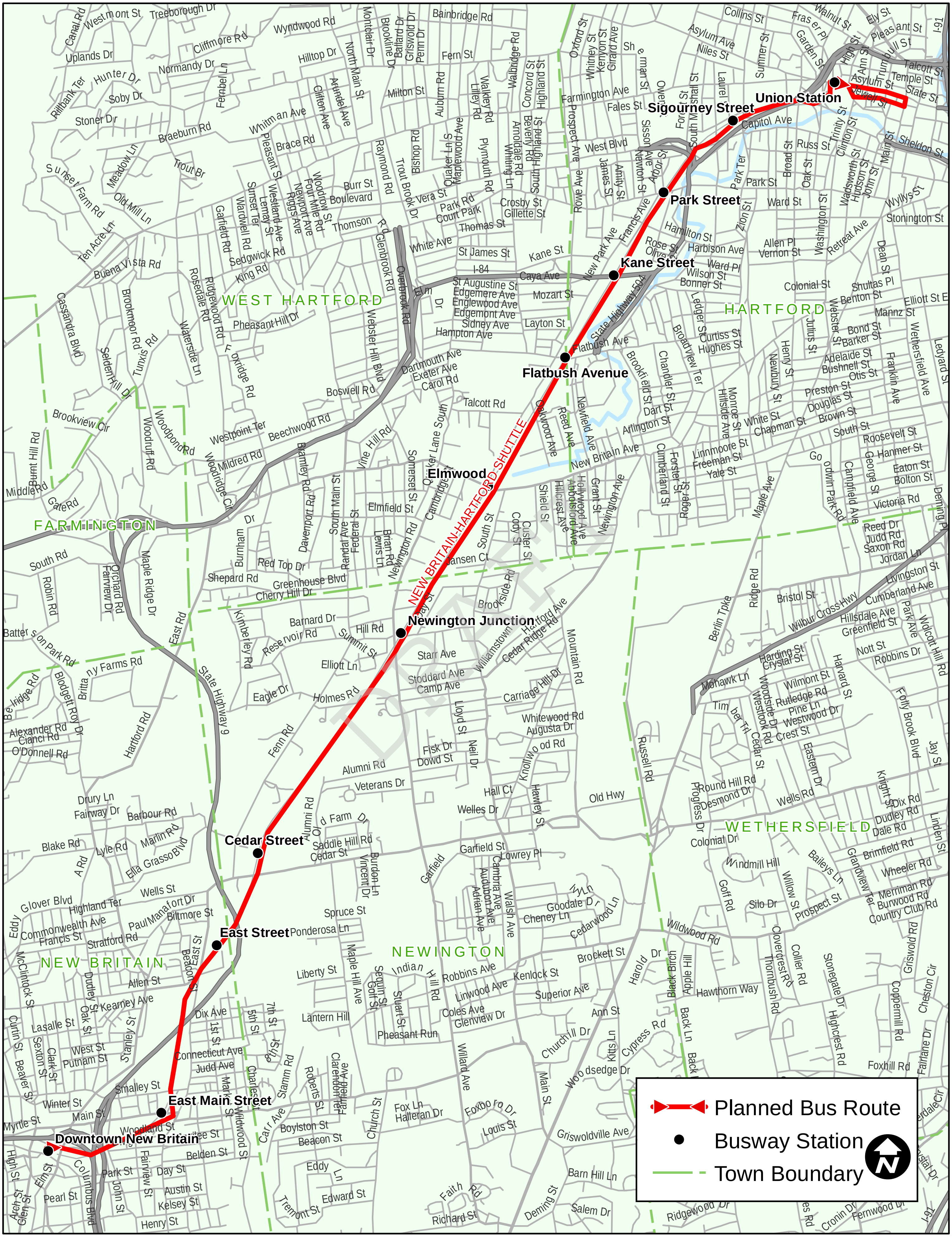
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>12</td><td rowspan="3">20</td><td rowspan="4">30</td></tr>
<tr><td>Midday</td><td>20</td></tr>
<tr><td>PM Peak</td><td>12</td></tr>
<tr><td>Evening</td><td>30</td><td>30</td></tr>
</table>

Service Plan Annual Service Hours: 17,490

Vehicle: Five 60 foot articulated BRT-styled hybrid buses branded with a unique busway color scheme and logo will be required to operate this route.

Modeled Weekday Boardings: 4,645

Notes: None



NEW BRITAIN-HARTFORD SHUTTLE
Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
Newington Junction
Cedar Street
East Street
East Main Street
Downtown New Britain
WEST HARTFORD
HARTFORD
FARMINGTON
WETHERSFIELD
NEWINGTON
NEW BRITAIN
DRAFT
Planned Bus Route
Busway Station
Town Boundary
N

**Busway Local Routes**

BW2 Bristol to Hartford Shuttle

The BW2 Bristol to Hartford Shuttle and BW 1 New Britain to Hartford Shuttle form the primary busway service, traveling the entire length of the facility from New Britain to Hartford. Together they provide frequent and fast service from early morning to late night, seven days a week. They create a simple, easy-to-remember service pattern for anyone interested in using the busway, in much the same way as a light rail line. Frequent service makes transferring from connecting local and circulator routes easy and convenient.

Route: This route travels between downtown Hartford and New Britain station. Beginning in Hartford, the route loops through downtown on Asylum and Pearl Streets, stops at Union Station, and then enters the busway. On the busway it serves all stations until it exits at New Britain station. The route leaves downtown New Britain entering Route 72 westbound. The route continues along Route 72 into Bristol, before turning north at the intersection of Main Street, where it terminates in downtown Bristol.

Service Pattern: From Bristol this route will make limited stops along Rt. 72 to New Britain and the busway. Once on the busway, this route will make all local station stops along its route including: New Britain, East Main, East Street, Cedar Street, Newington Jct., Elmwood, Flatbush Avenue, Kane Street, Park Street, Sigourney Street, Union Station and in downtown Hartford, Ann Street, Trumbull Street and Main Street. The route will travel exclusively on the busway except for the downtown loop from Union Station to Main Street.

One Way Travel Time: 50 minutes

One Way Mileage: 20.1 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



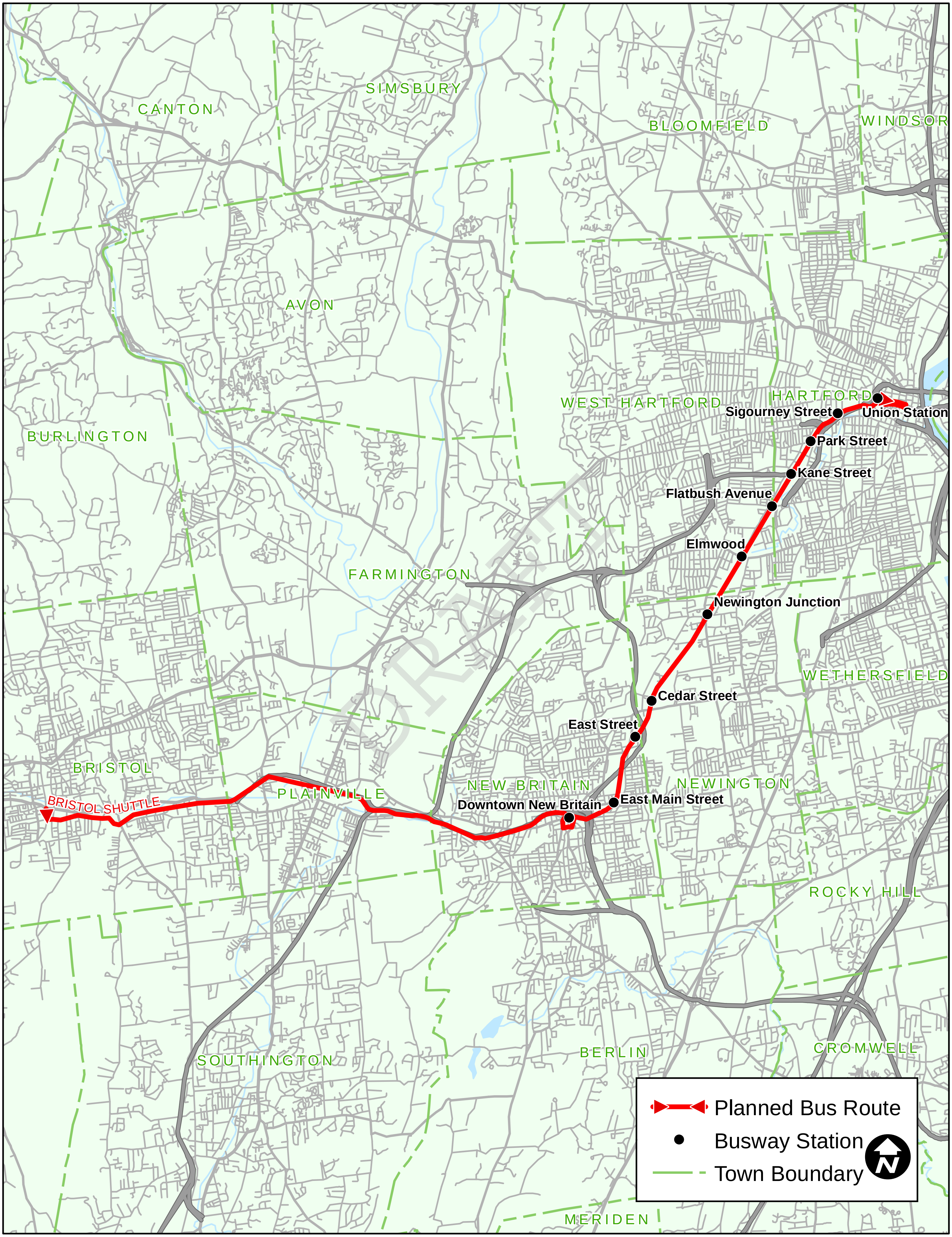
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>12</td><td rowspan="3">20</td><td rowspan="4">30</td></tr>
<tr><td>Midday</td><td>20</td></tr>
<tr><td>PM Peak</td><td>12</td></tr>
<tr><td>Evening</td><td>30</td><td>30</td></tr>
</table>

Service Plan Annual Service Hours: 31,482

Vehicle: Nine 60 foot articulated BRT-styled hybrid buses branded with a unique busway color scheme and logo will be required to operate this route.

Modeled Weekday Boardings: 5,876

Notes: None



SIMSBURY
CANTON
BLOOMFIELD
WINDSOR
AVON
WEST HARTFORD
HARTFORD
BURLINGTON
Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
FARMINGTON
Newington Junction
WETHERSFIELD
Cedar Street
East Street
BRISTOL
NEW BRITAIN
NEWINGTON
PLAINVILLE
BRISTOL SHUTTLE
Downtown New Britain
East Main Street
ROCKY HILL
SOUTHINGTON
BERLIN
CROMWELL
MERIDEN
DRAFT
Planned Bus Route
Busway Station
Town Boundary
N

**Busway Local Routes**

BW3 New Britain-Westfarms-Hartford

Routes BW3 and BW4 form a complimentary service from the busway to the major activities centers along and just off of New Britain Avenue, including Westfarms Mall, UConn Health Center, and CCSU.

Route: This route travels between downtown Hartford and New Britain station. Beginning in Hartford, the route loops through downtown on Asylum and Pearl Streets, stops at Union Station, and then enters the busway. On the busway it serves all stations until it exits at Oakwood Avenue, prior to Elmwood station. After exiting the busway this route travels south on New Park Avenue to New Britain Avenue (CT Route 71) then on Route 71 to New Britain. At the intersection of East Main Street and Martin Luther King Drive the route proceeds west, then south on Main Street to the busway station.

Service Pattern: This route will stop at all local bus stops along its route from downtown New Britain to Westfarms and then through Elmwood to the busway. After it enters the busway at Oakwood, it will make all local busway stops at Flatbush, Kane Street, Park Street, Sigourney Street, and Union Station. On-street in downtown Hartford it will stop at Anne, Trumbull, and Main Streets.



One Way Travel Time: 44 minutes

One Way Mileage: 11.5 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 16 hours (8 am to Midnight) on Sundays.

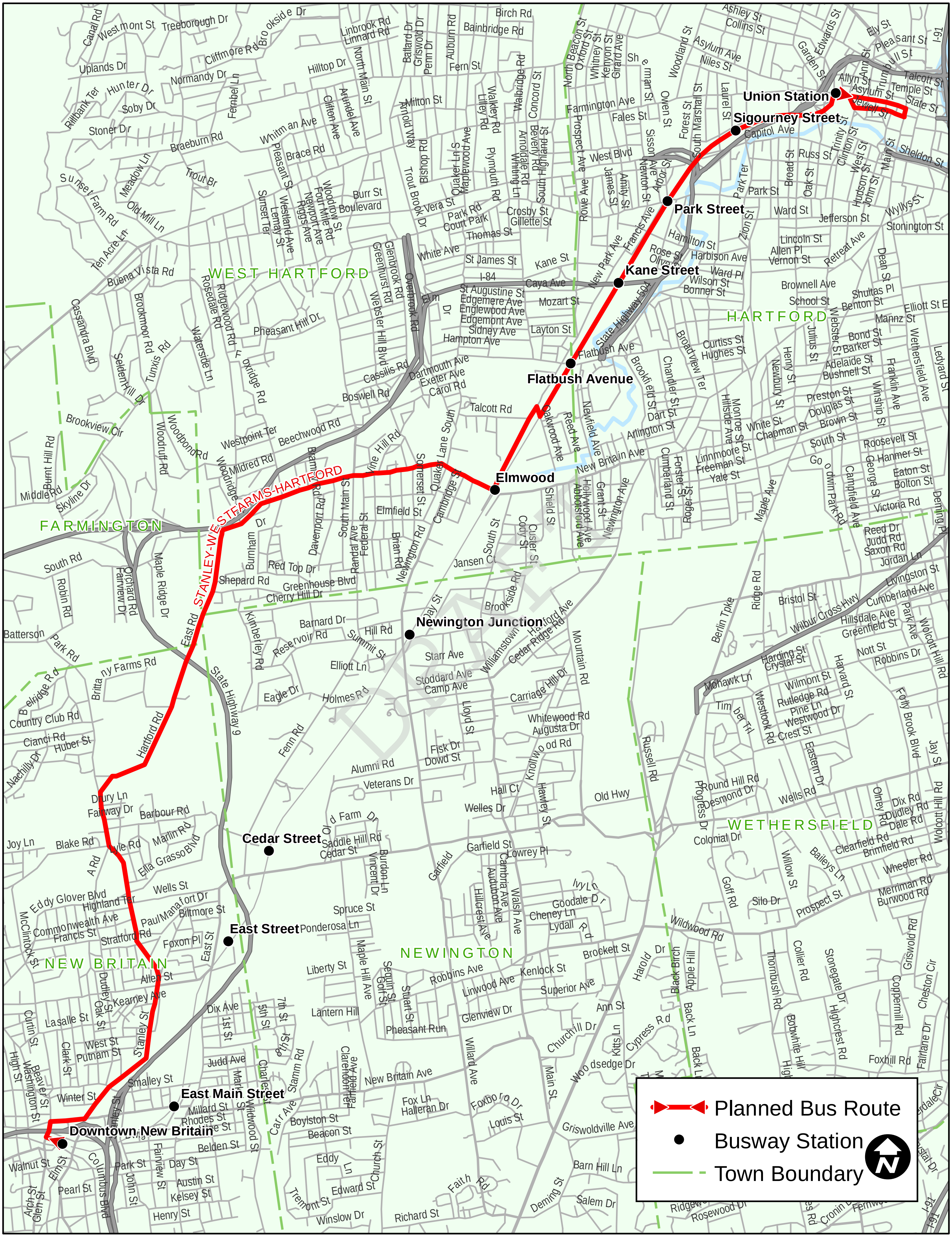
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>18</td><td rowspan="3">20</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>20</td></tr>
<tr><td>PM Peak</td><td>18</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 20,539

Vehicle: This route will require five 40-foot low-floor transit vehicles.

Modeled Weekday Boardings: 3,331

Notes: None


Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
Newington Junction
Cedar Street
East Street
East Main Street
Downtown New Britain
STANLEY-WESTFARMS-HARTFORD
WEST HARTFORD
HARTFORD
FARMINGTON
NEW BRITAIN
NEWINGTON
WETHERSFIELD
DRAFT
Planned Bus Route
Busway Station
Town Boundary
N

**Busway Local Routes**

BW4 UConn Health Center-Westfarms-Hartford

Routes BW3 and BW4 form a complimentary service from the busway to the major activities centers along and just off of New Britain Avenue, including Westfarms Mall, UConn Health Center, and CCSU.

Route: This route travels between downtown Hartford and the University of Connecticut Health Center in Farmington. Beginning in Hartford, the route loops through downtown on Asylum and Pearl Streets, stops at Union Station, and then enters the busway. On the busway it serves all stations until it exits at Oakwood Avenue, prior to Elmwood station. After exiting the busway this route travels west on New Britain Avenue and South Road to Munson Road, proceeding north to the medical center at the intersection of Middle Road and Munson Avenue.

Service Pattern: This route will stop at all local bus stops along its route from UConn Health Center to Westfarms and then through Elmwood to the busway. After it enters the busway at Oakwood, it will make all local busway stops at Flatbush, Kane Street, Park Street, Sigourney Street, and Union Station. On-street in downtown Hartford it will stop at Anne, Trumbull, and Main Streets.

One Way Travel Time: 43 minutes

One Way Mileage: 9.1 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



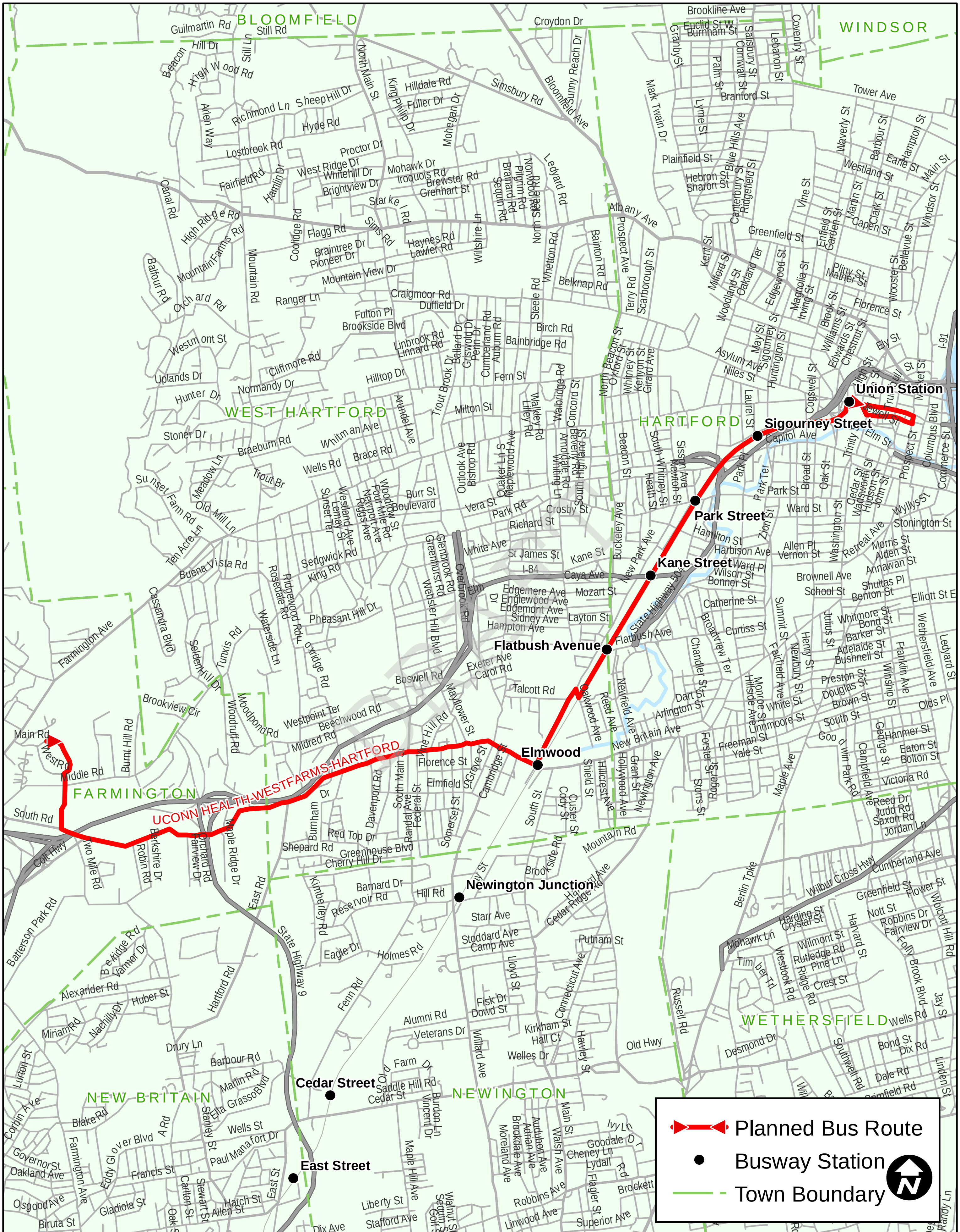
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>18</td><td rowspan="3">20</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>20</td></tr>
<tr><td>PM Peak</td><td>18</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 20,026

Vehicle: This route will require five 40-foot low-floor transit vehicles.

Modeled Weekday Boardings: 2,578

Notes: None


BLOOMFIELD
WINDSOR
WEST HARTFORD
HARTFORD
FARMINGTON
NEW BRITAIN
NEWINGTON
WETHERSFIELD
UCONN HEALTH-WESTFARMS-HARTFORD
Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
Newington Junction
Cedar Street
East Street
Planned Bus Route
Busway Station
Town Boundary

**Busway Local Routes**

BW5 Newington Junction to Hartford Shuttle

This route supplements other busway services along the busiest section of the busway between Elmwood and Hartford.

Route: This route operates between Hartford and Newington Junction on the busway.

Service Pattern: This route makes all local stops along the busway starting in Newington Junction and including Elmwood, Flatbush, Kane Street, Park Street, Sigourney Street, and Union Station. In downtown Hartford it stops on-street at Ann, Trumbull, and Main.

One Way Travel Time: 16 minutes

One Way Mileage: 6.0 miles

Service Span: This route will operate only on weekdays during AM and PM peak periods, from 6am to 9am and from 3pm to 6pm.

<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>18</td><td rowspan="3">—</td><td rowspan="4">—</td></tr>
<tr><td>Midday</td><td>—</td></tr>
<tr><td>PM Peak</td><td>18</td></tr>
<tr><td>Evening</td><td>—</td><td>—</td></tr>
</table>



Service Plan Annual Service Hours: 2,688

Vehicle: This route will require two 40-foot low-floor transit vehicles.

Modeled Weekday Boardings: 1,585

Notes: None

Union Station
Sigourney Street
Park Street
Kane Street
Flatbush Avenue
Elmwood
Newington Junction
NEWINGTON JUNCTION BUSWAY SHUTTLE
WEST HARTFORD
HARTFORD
NEWINGTON
WETHERSFIELD
DRAFT
I-84
State Highway 504
Planned Bus Route
Busway Station
Town Boundary
N

**New Connector and Circulator Routes**

C1 CCSU Connector

This route serves as a shuttle between busway stations at Cedar Street and East Street, connecting the campus to the regional transit system.

Route: This route travels in a loop around the CCSU campus area, serving Cedar Street and East Street stations. The route travels along the busway between the two stations. Through CCSU this route travels along Ella Grasso Road and Paul Manafort Drive around the perimeter of the campus.

Service Pattern: The CCSU shuttle will operate in both directions, laying over at Cedar or East depending upon the direction of travel. Bus stops will be established along the route at convenient locations near important buildings on campus.

One Way Travel Time: 13 minutes

One Way Mileage: 3.1 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.

<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>15</td><td rowspan="3">20</td><td rowspan="4">30</td></tr>
<tr><td>Midday</td><td>20</td></tr>
<tr><td>PM Peak</td><td>15</td></tr>
<tr><td>Evening</td><td>30</td><td>30</td></tr>
</table>

Service Plan Annual Service Hours: 7,891

Vehicle: This route will require two 30-foot low-floor transit vehicles.

Modeled Weekday Boardings: 205

Notes: None

DRAFT
NEW BRITAIN
NEWINGTON
CCSU CONNECTOR
Cedar Street
East Street
Par Dr
Golf Blvd
Drury Ln
Fairway Dr
Barbour Rd
Volpe Ct
Ella Grasso Rd
Ellagrasso Rd
Holly Dr
Fenn Rd
Milk Ln
Pape Rd
Dennis Dr
Marlin Rd
Hazelmere Rd
Sylvan Rd
Lyle Rd
Pendleton Rd
Ella Grasso Blvd
Kilbourne Ave
Stanley St
Cedar St
Wells St
Eddy Glover Blvd
Highland Ter
State Highway 9
Park Dr
Biltmore St
Amherst St
Hillcrest Ave
Euston St
Francis Ct
Francis St
Paul Manafort Dr
Audubon St
Recano Rd
Stratford Rd
Sefton Dr
Foxon Pl
East St
Elizabeth St
Wellington St
Lester St
Tulip St
Carmel St
Roxbury Rd
Clayton Ct
St Clair Ave
Beacon St
Hatch St
Allen St
Planned Bus Route
Busway Station
Town Boundary
N

**New Connector and Circulator Routes**

C2 Hospitals - Capitol Connector

This route will shuttle employees, patients, and visitors from the Sigourney Street station to St. Francis and Hartford Hospitals. It will also provide convenient shuttle service to the Capitol Hill and Asylum Hill areas.

Route: This route travels between Saint Francis Hospital and Hartford Hospital, connecting with Sigourney Street station. From Saint Francis Hospital to the north, the route travels south on Sigourney Street to Hawthorn, loops through Sigourney Street station, then south to Capitol Avenue. On Capitol Avenue the route travels east to Washington Street, then south to Jefferson, where it loops around the campus of Hartford Hospital.

Service Pattern: The route will operate in local service stopping at all bus stops along its route.

One Way Travel Time: 14 minutes

One Way Mileage: 3.4 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.

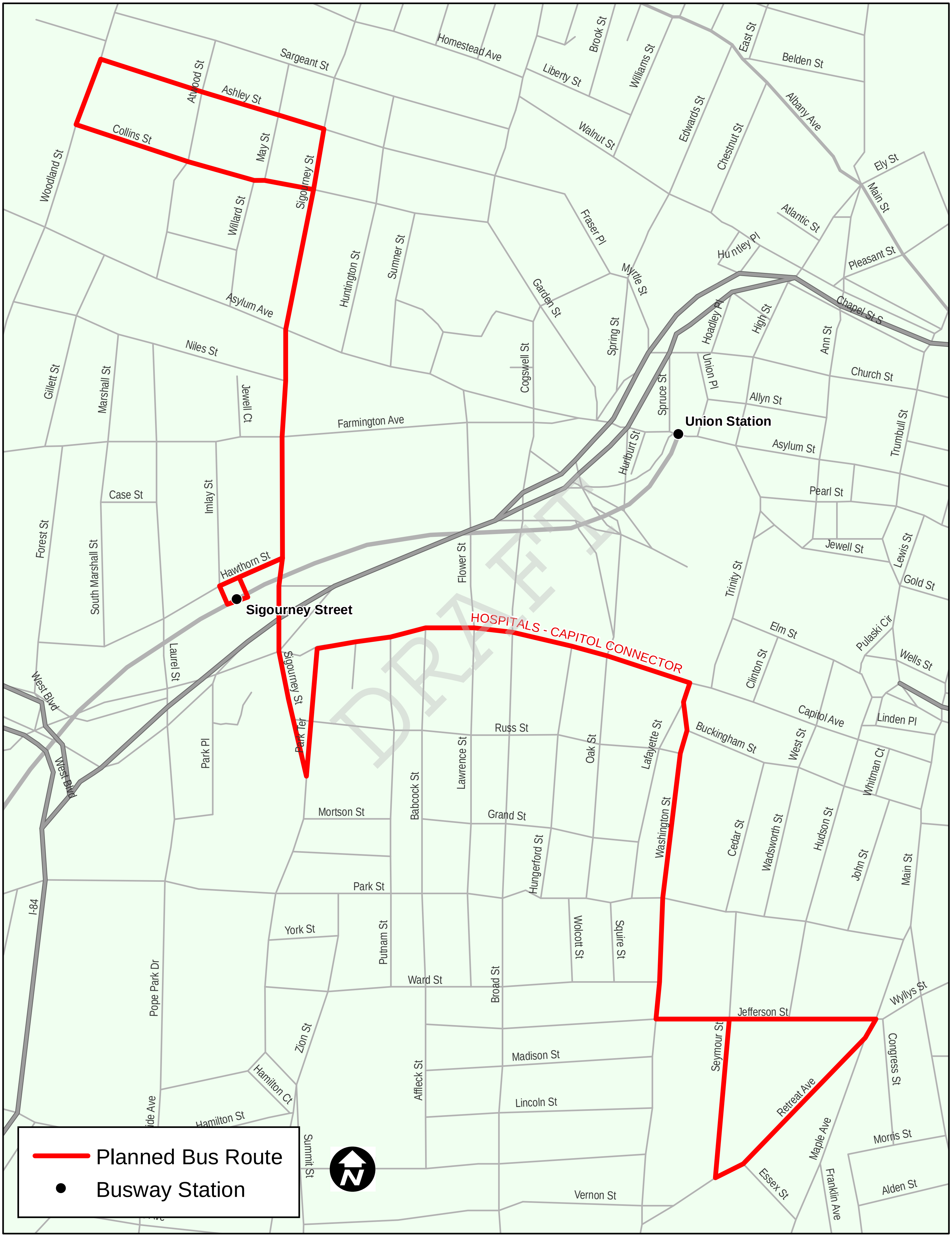
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>15</td><td rowspan="3">20</td><td rowspan="4">30</td></tr>
<tr><td>Midday</td><td>20</td></tr>
<tr><td>PM Peak</td><td>15</td></tr>
<tr><td>Evening</td><td>30</td><td>30</td></tr>
</table>

Service Plan Annual Service Hours: 8,374

Vehicle: This route will require two 30-foot low-floor transit vehicles.

Modeled Weekday Boardings: 1,868

Notes: None


HOSPITALS - CAPITOL CONNECTOR
Union Station
Sigourney Street
DRAFT
Planned Bus Route
Busway Station
N
Homestead Ave
Sargeant St
Ashley St
Atwood St
Collins St
May St
Sigourney St
Woodland St
Willard St
Liberty St
Brook St
Williams St
Walnut St
Edwards St
Chestnut St
East St
Belden St
Albany Ave
Ely St
Main St
Atlantic St
Huntley Pl
Pleasant St
Chapel St S
Fraser Pl
Myrtle St
Garden St
Huntington St
Sumner St
Asylum Ave
Niles St
Gillett St
Marshall St
Jewell Ct
Farmington Ave
Cogswell St
Spring St
Hoadley Pl
High St
Ann St
Union Pl
Spruce St
Church St
Allyn St
Trumbull St
Asylum St
Hurlburt St
Pearl St
Case St
Imlay St
Forest St
South Marshall St
Hawthorn St
Flower St
Jewell St
Lewis St
Gold St
Trinity St
Elm St
Pulaski Cir
Wells St
Clinton St
Capitol Ave
Linden Pl
Laurel St
West Blvd
Park Pl
Park Ter
Russ St
Oak St
Lafayette St
Buckingham St
West St
Whitman Ct
Babcock St
Lawrence St
Mortson St
Grand St
Washington St
Cedar St
Wadsworth St
Hudson St
John St
Hungerford St
Park St
I-84
York St
Putnam St
Wolcott St
Squire St
Pope Park Dr
Ward St
Broad St
Wyllys St
Jefferson St
Zion St
Seymour St
Congress St
Madison St
Hamilton Ct
Affleck St
Retreat Ave
Lincoln St
Hamilton St
Maple Ave
Morris St
Summit St
Essex St
Franklin Ave
Alden St
Vernon St

**New Connector and Circulator Routes**

C3 Newington Circulator

This route provides local transit service in Newington, connecting the Township to the busway at three stations and to other transit routes at New Britain station and in downtown Newington. It also provides an internal circulator function, giving residents another transportation option to get to shopping, recreation, medical appointments and other activities within Newington. It serves the Veterans Hospital.

Route: This route travels between Cedar Street station and Downtown New Britain Station, also serving Newington Junction Station. From Cedar Street station the route proceeds northeast along Fenn Road and Hill Road to Newington Junction station. From there it proceeds south along Willard Avenue to Alumni Road, where it passes through the Newington Veterans Hospital campus. Turning east on Cedar Street this route travels to Constance Leigh Drive, where it loops back to Main Street, then south to Robbins Avenue. From Robbins Avenue this route turns south at Maple Hill Avenue to New Britain Avenue. The route travels east along New Britain Avenue, Newington Avenue, Church Street, and Chestnut Street before terminating at New Britain station.

Service Pattern: The route will operate in local service stopping at all bus stops along its route.



One Way Travel Time: 30 minutes

One Way Mileage: 10.7 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.

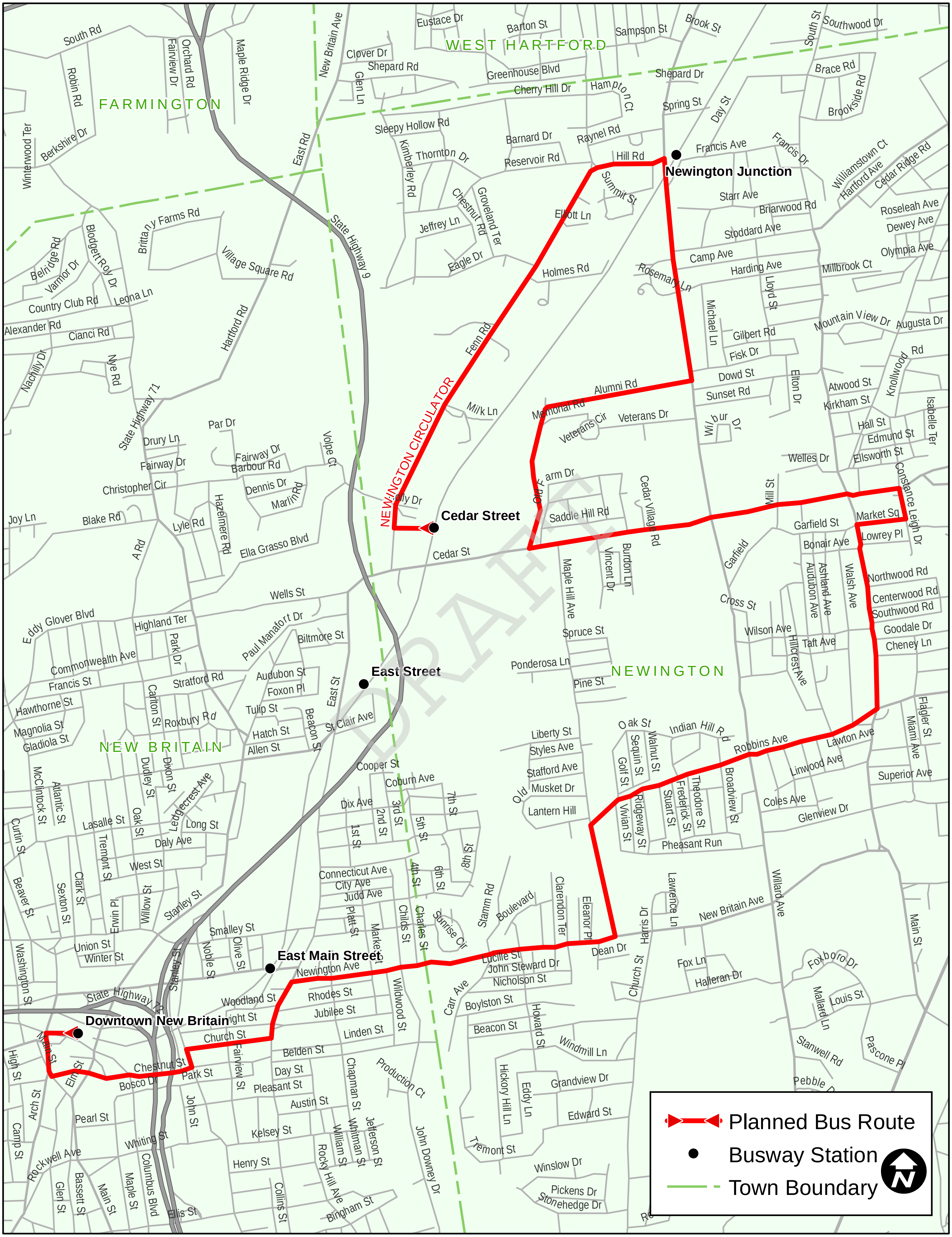
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><td></td><td>Weekday</td><td>Saturday</td><td>Sunday</td></tr>
<tr><td>AM Peak</td><td>30</td><td rowspan="3">60</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>60</td></tr>
<tr><td>PM Peak</td><td>30</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 7,716

Vehicle: This route will require two 30-foot low-floor transit vehicles.

Modeled Weekday Boardings: 1,176

Notes: This route replaces part of the routing of CT Transit routes 41 Hartford New Britain and 69 Capitol Avenue.



WEST HARTFORD
FARMINGTON
NEWINGTON
NEW BRITAIN
NEWINGTON CIRCULATOR
Newington Junction
Cedar Street
East Street
East Main Street
Downtown New Britain
DRAFT
Planned Bus Route
Busway Station
Town Boundary
N

**New Connector and Circulator Routes**

C4 West Hartford - Bishops Corner Connector

This route links Flatbush station with downtown West Hartford and Bishops Corner, where onward connections with other CT Transit routes are available. It provides a new north-south route to the west of downtown Hartford, which is currently not available in the CT Transit system.

Route: This route travels between the Flatbush Avenue busway station to Bishops Corner shopping area, traveling west from the station along Flatbush Avenue. This route proceeds north on Quaker Lane, then west on Park Road, and finally north on Main Street to the intersection of Albany Avenue before looping through the shopping center on Starkel Road.

Service Pattern: This route would operate in local service stopping at all bus stops along its routing.

One Way Travel Time: 21 minutes

One Way Mileage: 5.4 miles

Service Span: Seven days a week, 18 hours a day on Monday to Saturday (6am to Midnight) and 12 hours (8 am to 8pm) on Sundays.



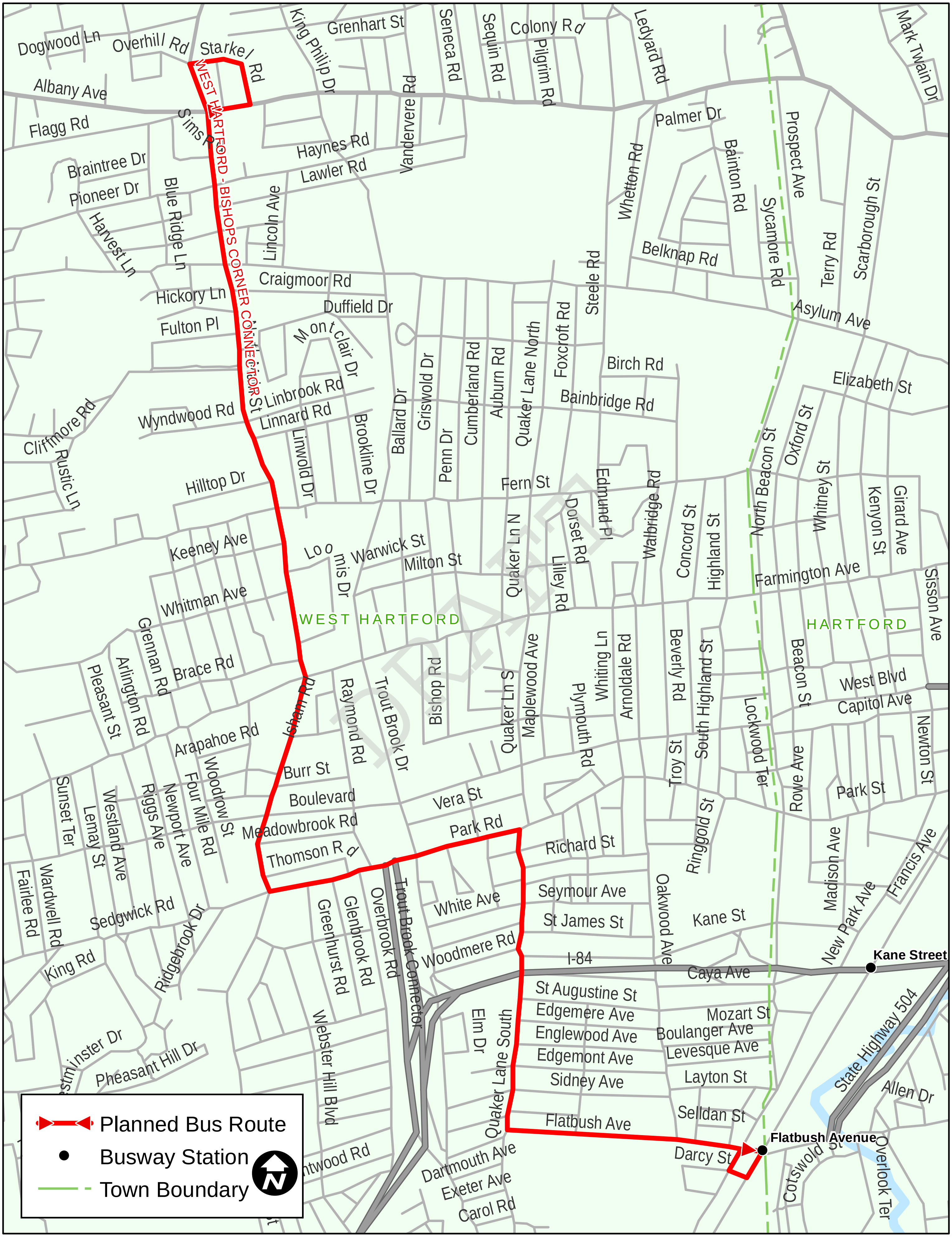
<table>
<tr><th colspan="4">Service Plan Headways</th></tr>
<tr><th></th><th>Weekday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>AM Peak</td><td>60</td><td rowspan="3">60</td><td rowspan="4">60</td></tr>
<tr><td>Midday</td><td>60</td></tr>
<tr><td>PM Peak</td><td>60</td></tr>
<tr><td>Evening</td><td>60</td><td>60</td></tr>
</table>

Service Plan Annual Service Hours: 5,518

Vehicle: This route will require one 30-foot low-floor transit vehicle.

Modeled Weekday Boardings: 859

Notes: None



Planned Bus Route
Busway Station
Town Boundary
WEST HARTFORD - BISHOPS CORNER CONNECTOR
WEST HARTFORD
HARTFORD
DRAFT
Kane Street
Flatbush Avenue
I-84
State Highway 504
Trout Brook Connector
Dogwood Ln
Overhill Rd
Starkel Rd
King Philip Dr
Grenhart St
Seneca Rd
Sequin Rd
Colony Rd
Pilgrim Rd
Ledyard Rd
Mark Twain Dr
Albany Ave
Flagg Rd
Sims Rd
Vandervere Rd
Palmer Dr
Prospect Ave
Haynes Rd
Lawler Rd
Braintree Dr
Pioneer Dr
Blue Ridge Ln
Harvest Ln
Lincoln Ave
Whetten Rd
Bainton Rd
Sycamore Rd
Belknap Rd
Terry Rd
Scarborough St
Craigmoor Rd
Hickory Ln
Duffield Dr
Steele Rd
Asylum Ave
Fulton Pl
Montclair Dr
Foxcroft Rd
Quaker Lane North
Auburn Rd
Cumberland Rd
Griswold Dr
Ballard Dr
Birch Rd
Elizabeth St
Linbrook Rd
Linnard Rd
Wyndwood Rd
Cliffmore Rd
Rustic Ln
Bainbridge Rd
Linwold Dr
Brookline Dr
Penn Dr
Oxford St
North Beacon St
Hilltop Dr
Fern St
Edmund Pl
Walbridge Rd
Whitney St
Kenyon St
Girard Ave
Dorset Rd
Concord St
Highland St
Keeney Ave
Loomis Dr
Warwick St
Milton St
Quaker Ln N
Lilley Rd
Farmington Ave
Sisson Ave
Whitman Ave
Grennan Rd
Arlington Rd
Pleasant St
Brace Rd
Maplewood Ave
Whiting Ln
Arnoldale Rd
Beverly Rd
South Highland St
Beacon St
West Blvd
Capitol Ave
Isham Rd
Raymond Rd
Trout Brook Dr
Bishop Rd
Quaker Ln S
Plymouth Rd
Lockwood Ter
Newton St
Arapahoe Rd
Burr St
Troy St
Rowe Ave
Park St
Sunset Ter
Westland Ave
Riggs Ave
Newport Ave
Four Mile Rd
Woodrow St
Boulevard
Vera St
Ringgold St
Lemay St
Meadowbrook Rd
Park Rd
Richard St
Madison Ave
Francis Ave
Thomson Rd
Fairlee Rd
Wardwell Rd
Sedgwick Rd
Ridgebrook Dr
Greenhurst Rd
Glenbrook Rd
Overbrook Rd
White Ave
Seymour Ave
Oakwood Ave
Kane St
New Park Ave
St James St
King Rd
Woodmere Rd
Caya Ave
St Augustine St
Elm Dr
Edgemere Ave
Mozart St
Englewood Ave
Boulanger Ave
Levesque Ave
Edgemont Ave
Pheasant Hill Dr
Webster Hill Blvd
Quaker Lane South
Sidney Ave
Layton St
Allen Dr
Flatbush Ave
Selldan St
Darcy St
Cotswold St
Overlook Ter
Dartmouth Ave
Exeter Ave
Carol Rd

## Service Design Issues

### Operating Cost

The annual operating cost for each route in the service plan was calculated using a cost model developed for the busway based on scheduled service hours and local CT Transit Hartford unit operating costs. Service hours were based on the number of one-way trips as determined by the proposed headways by day of week, estimated running times, and a layover factor of 10%. The formula for calculating service hours is:

((Weekday Trips * 252 + Saturday Trips * 52 + Sunday Trips * 61) * OW Running Time (min) * 1.1) / 60

The local CT Transit cost per hour was calculated using (ConnDOT to provide)

Running time was estimated using existing transit scheduled running times, busway running times based on estimated average speed and backed up by VISSIM modeling, and Google Maps estimated driving times factored for additional transit running time.

### Peak Hour Capacity

This is an important statistic because the peak hour demand determines the maximum number of buses that are required to be in service at any one time, and therefore the capital cost of vehicles for the project. The CRCOG travel demand model provides estimates of daily boarding rides on the busway, but does not break them down by time of day. In order to estimate the number of boardings during the busiest one hour of the day, CT Transit Hartford completed an analysis of weekday inbound and outbound boarding riders by hour for both local and express routes. The ridership profile was very different for the two types of route, as would be expected. The peak hour and direction for local routes was outbound at 4 pm when 5.8% of local riders boarded. The peak hour and direction for express routes was 7am in the morning, when 22% of riders boarded. To estimate the peak one hour single direction ridership on the busway, these figures were rounded up to 25% and 6% and assumed to occur during the same hour, resulting in a combined peak hour peak direction percentage of 7.2%, a relatively low number.

Given the likelihood that a high quality transportation service like the busway will attract a higher proportion of commuters who choose to take transit, a larger sample of BRT and BRT peak factors was collected from Seattle, Toronto, Edmonton, and Calgary. Peak factors in the 11% to 17% range were common. The average of these factors was 15.1%. To adequately assure that the service plan was capturing the effects of this change in travel patterns due to the opening of the busway, the two numbers, 7.2% and 15.1% were averaged and 11.1% was used to calculated necessary peak hour peak direction capacity at the peak load point. The service plan was designed to accommodate 1,349 passengers between Sigourney and Union Station during the peak hour in the peak direction. See the *One-Way Peak-Hour Busway Volume by Station* table at the end of this section for more information on capacity and bus volumes along the busway.

## Downtown Circulation

The downtown circulation routes in the service plan are based on data contained in the *Hartford Downtown Circulation Study Draft Report* showing high concentrations of jobs along Asylum and Main Streets in downtown, with smaller concentrations in Asylum Hill and Capitol Hill.  This study also found that a majority of local bus riders transfer to other routes downtown and so direct routes to their transfer points, mostly on Main Street, provide significant benefits.  To provide the most capacity and convenience in terms of directness and frequency to where riders want to go, the service plan proposed a direct route to Main Street for the five shuttle routes (BW1, BW2, BW3, BW4, BW5) via Asylum and Pearl.  Commuter express routes, which are more oriented to park-and-ride commuters, leave the busway at Sigourney to serve the large employers on Asylum Hill more directly.

A downtown transfer center had been proposed for the area behind Union Station near the intersection of Church and Spruce.  If this project moves forward, the downtown circulation plan can be updated at that time.

## Routes with Reduced Service

23 Bristol Express – The Bristol Express is replaced by the BW2 Bristol to Hartford Shuttle for service to park-and-ride lots in Bristol and Plainville.  Even though the shuttle makes a number stops along its route, the use of the busway will make it as fast as, and more reliable than, the current express service.  Added service frequency and longer span of service will reduce waiting time and improve convenience.

2 Corbins Express – The Corbins Express is replaced by routes BW 3 and BW4, both of which serve the Westfarms Mall area.  Riders of the Corbins Express can also drive to park-and-ride lots at Elmwood or Newington Jct. stations on the busway.

BP Bristol Plainville – This route is paralleled by the faster and more frequent BW2 Bristol to Hartford Shuttle in the service plan.   Shortening the route to Forestville to New Britain eliminates the area where the two routes most closely duplicate each other.  The Bristol Plainville will continue to serve downtown Plainville.

41 New Britain – The need for this route to operate through from Hartford to New Britain is eliminated by the construction of the busway, which provides a much faster trip between the two cities.  In its place, a shortened version will operate between Newington and Hartford providing local transit service along Main, Hartford, and New Britain.  The outer end of route 41 is replaced by the Newington Circulator which provides convenient service from most points in Newington to the busway at Newington Junction and Cedar Street as well as a connection to downtown New Britain.

31/33 Park Street/New Park Avenue – This route closely parallels the busway in Hartford.  Service frequency will be reduced slightly to account for riders choosing to ride the busway rather than routes 31 and 33.  Still, the high density residential neighborhoods that it travels through will require good local service, which will continue to be provided.

37/39 New Britain Avenue – Routes BW3 and BW4 will provide frequent service along New Britain Avenue from Elmwood to the Westfarms Mall continuing through to Hartford via the busway. To avoid unnecessary service duplication, all buses on route 39 will terminate in Elmwood, rather than Westfarms Mall.

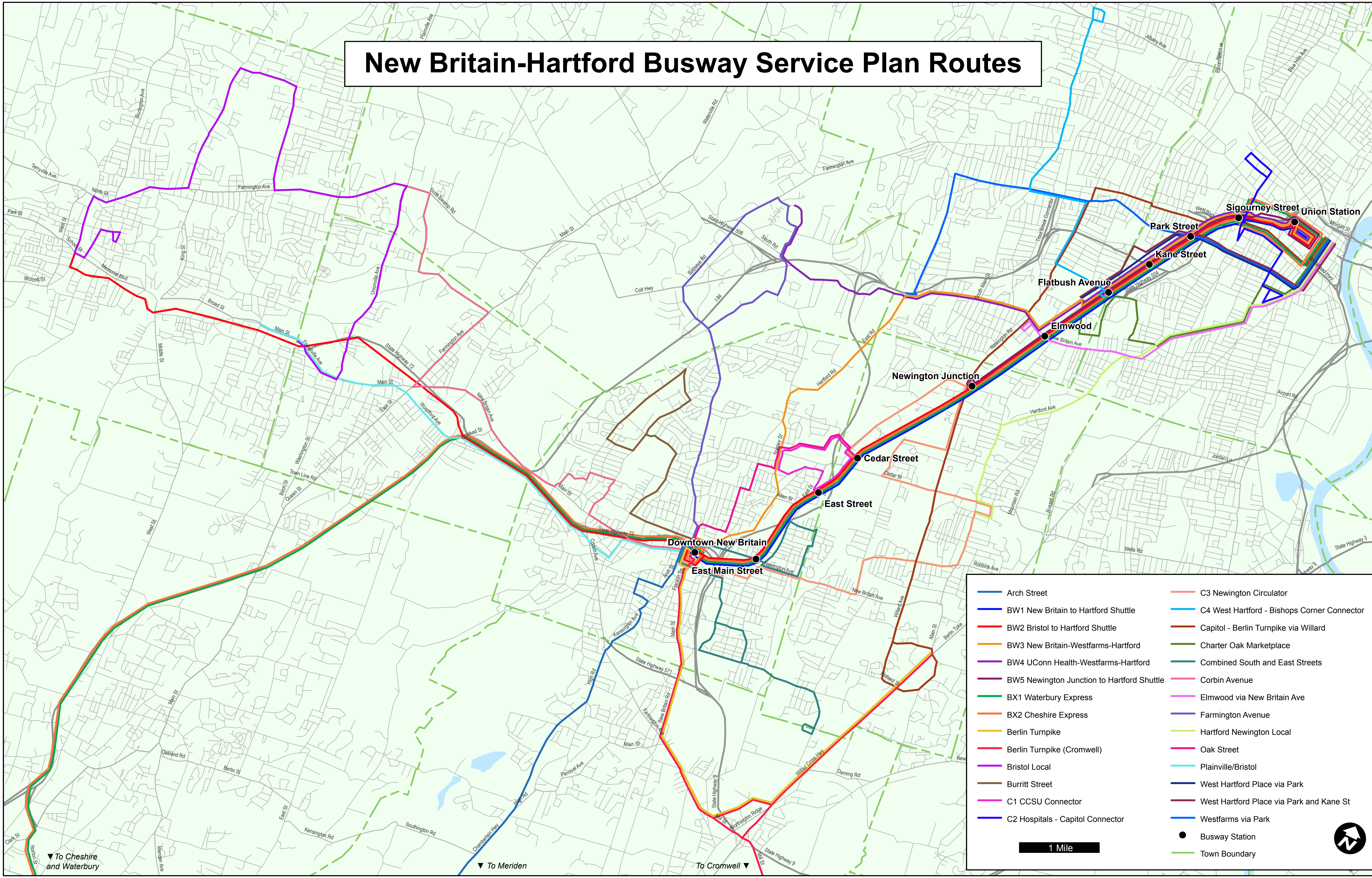
East and South – These two low-ridership routes can adequately serve demand in their service area at a lower headway, a situation that will not change when the busway opens based on ridership estimates. The plan proposes that they be combined and operate every 60 minutes rather than every 30 minutes. Other options, such as the busway and the Newington Circulator also serve parts of their catchment area and provide alternatives for many passengers.

**One-Way Peak-Hour Busway Volume by Station**

| *Peak Headway (min)* | *30* | | *30* | | *12* | | *12* | | *18* | | *18* | | *18* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Busway Station** | Waterbury Express | | Cheshire Express | | New Britain to Hartford Shuttle | | Bristol to Hartford Shuttle | | New Britain-Westfarms-Hartford | | UConn Health Center-Westfarms-Hartford | | Newington Junction to Hartford Shuttle | | **Total** | |
| | *Buses* | *Rider Cap.* | *Buses* | *Rider Cap.* | *Buses* | *Rider Cap.* | *Buses* | *Rider Cap.* | *Buses* | *Rider Cap.* | *Buses* | *Rider Cap.* | *Buses* | *Rider Cap.* | *Buses* | *Rider Cap.* |
| Union Station | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | 3.3 | 164 | 3.3 | 164 | 3.3 | 164 | ***24*** | ***1,455*** |
| Sigourney Street | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | 3.3 | 164 | 3.3 | 164 | 3.3 | 164 | ***24*** | ***1,455*** |
| Park Street | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | 3.3 | 164 | 3.3 | 164 | 3.3 | 164 | ***24*** | ***1,455*** |
| Kane Street | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | 3.3 | 164 | 3.3 | 164 | 3.3 | 164 | ***24*** | ***1,455*** |
| Flatbush Avenue | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | 3.3 | 164 | 3.3 | 164 | 3.3 | 164 | ***24*** | ***1,455*** |
| Elmwood | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | — | — | — | — | 3.3 | 164 | ***17*** | ***1,127*** |
| Newington Junction | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | — | — | — | — | 3.3 | 164 | ***17*** | ***1,127*** |
| Cedar Street | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | — | — | — | — | — | — | ***14*** | ***963*** |
| East Street | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | — | — | — | — | — | — | ***14*** | ***963*** |
| East Main Street | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | — | — | — | — | — | — | ***14*** | ***963*** |
| Downtown New Britain | 2.0 | 110 | 2.0 | 110 | 5.0 | 371 | 5.0 | 371 | — | — | — | — | — | — | ***14*** | ***963*** |

# APPENDIX A: ROUTE MAP

# New Britain-Hartford Busway Service Plan Routes



# APPENDIX B: ROUTE CHARACTERISTICS

# DRAFT Final Build Model Network

Date: August 13, 2009

| Route | Plan Route Number | Terminal 1 | Terminal 2 | Service Plan WD AM Peak Headway | Plan WD Midday Headway | WD PM Headway | WD Evening Headway | Sat Daytime Headway | Sat Evening Headway | Sunday All Day Headway | OW Route Miles | Annual Vehicle Miles | Average Speed | Service Plan Annual Service Hours | Per Hour Cost | Plan Annual Operating Cost | Existing Annual Service Hours | Existing Annual Operating Cost | Plan Peak Vehicle Requirement | Existing Peak Vehicle Requirement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Existing New Britain Area Local Routes** | | | | | | | | | | | | | | | | | | | | |
| Arch Street | AR | New Britain Station | Meriden | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 10.1 | 125,078 | 22.2 | 6,204 | | $0 | 5,008 | $0 | 1 | 1 |
| Burritt Street | B | New Britain Station | Slater and Long Swamp | 30 | 60 | 30 | 60 | 60 | 60 | 60 | 5.6 | 86,150 | 17.6 | 5,396 | | $0 | 5,083 | $0 | 2 | 1 |
| Corbin Avenue | C | New Britain Station | Tunxis CC | 30 | 60 | 30 | 60 | 60 | 60 | 60 | 9.4 | 144,610 | 20.6 | 7,716 | | $0 | 4,859 | $0 | 2 | 1 |
| Farmington Avenue | F | New Britain Station | UConn Health | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 7.0 | 86,688 | 15.4 | 6,204 | | $0 | 4,934 | $0 | 1 | 1 |
| Oak Street | O | New Britain Station | Westfarms Mall | 30 | 60 | 60 | 60 | 60 | 60 | 60 | 3.8 | 52,759 | 10.7 | 5,448 | | $0 | 4,934 | $0 | 1 | 1 |
| Plainville/Bristol | PB | New Britain Station | Forestville | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 6.6 | 81,734 | 14.5 | 6,204 | | $0 | 3,785 | $0 | 1 | 1 |
| Stanley Street | S | New Britain Station | Westfarms Mall | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0.0 | 0 | | $0 | 5,029 | $0 | 0 | 1 |
| Berlin Turnpike | TPK | New Britain Station | Berlin Tpk & Main | 60 | 0 | 60 | 0 | 0 | 0 | 0 | 7.4 | 22,200 | 16.2 | 1,512 | | $0 | 4,084 | $0 | 1 | 1 |
| Berlin Turnpike (Cromwell) | BK | New Britain Station | Cromwell Walmart | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 10.5 | 86,688 | 15.4 | 6,204 | | $0 | 3,738 | $0 | 1 | 1 |
| South Street | South | New Britain Station | Corbin Russwin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0.0 | 0 | | $0 | 3,486 | $0 | 0 | 1 |
| East Street | East | New Britain Station | Dix & 5th | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0.0 | 0 | | $0 | 3,588 | $0 | 0 | 1 |
| Combined South and East Street | N/A | Corbin Russwin | Dix & 5th | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 7.6 | 94,118 | 16.7 | 6,204 | | $0 | 0 | $0 | 1 | 0 |
| Category Total | | | | | | | | | | | | 780,026 | 16.8 | 51,092 | | $0 | 48,528 | $0 | | |
| **Existing Hartford Area Local Routes** | | | | | | | | | | | | | | | | | | | | |
| West Hartford Place via Park | 31 | West Hartford Place | Hartford | 20 | 40 | 20 | 60 | 30 | 60 | 60 | 3.8 | 80,302 | 9.9 | 8,946 | | $0 | | $0 | 3 | 3 |
| West Hartford Place via Park and Kane St. | 31A | West Hartford Place | Hartford | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 4.1 | 18,450 | 9.4 | 2,162 | | $0 | | $0 | 0 | 0 |
| Park Rd and S Quaker via Park | 33 | Park Rd and S. Quaker | Hartford | 40 | 40 | 40 | 0 | 0 | 0 | 0 | 3.5 | 31,500 | 8.3 | 4,158 | | $0 | | $0 | 2 | 0 |
| Westfarms via Park | 33W | Westfarms Mall | Hartford | 40 | 40 | 40 | 0 | 30 | 0 | 0 | 7.1 | 81,622 | 9.4 | 9,544 | | $0 | 24,008 | $0 | 3 | 5 |
| Hartford Newington Local | 41 | Newington | Hartford | 20 | 30 | 20 | 60 | 30 | 60 | 60 | 6.5 | 147,108 | 14.4 | 11,250 | | $0 | 0 | $0 | 3 | 0 |
| Hartford to NB via Newington | 41 | New Britain Station | Hartford | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0.0 | 0 | | $0 | 12,870 | $0 | 0 | 5 |
| Charter Oak Marketplace West Hartford Place via NB Ave | 37 | West Hartford Place | Hartford | 30 | 60 | 30 | 60 | 60 | 60 | 60 | 5.2 | 79,997 | 8.9 | 9,902 | | $0 | 21,120 | $0 | 3 | 4 |
| Elmwood via New Britain Ave | 39 | Elmwood | Hartford | 20 | 60 | 20 | 60 | 60 | 60 | 60 | 4.9 | 90,082 | 9.5 | 10,482 | | $0 | | $0 | 4 | 5 |
| Capital - Berlin Turnpike via Willard | 69 | Berlin Tpk & Deming | Hartford | 30 | 30 | 30 | 0 | 30 | 0 | 0 | 11.9 | 172,502 | 19.2 | 9,898 | | $0 | 6,270 | $0 | 3 | 3 |
| Category Totals | | | | | | | | | | | | 701,562 | 11.6 | 66,343 | | $0 | 64,268 | $0 | | |
| **Existing and New Express Routes** | | | | | | | | | | | | | | | | | | | | |
| Waterbury Express | BX1 | Waterbury | Hartford | 30 | 0 | 30 | 0 | 0 | 0 | 0 | 34.4 | 206,400 | 32.2 | 7,056 | | $0 | 0 | $0 | 5 | 0 |
| Waterbury Cheshire Off-Peak Express | BX3 | Waterbury | New Britain | 0 | 60 | 0 | 120 | 120 | 120 | 120 | 34.4 | 179,981 | 35.9 | 5,510 | | $0 | 0 | $0 | 0 | 0 |
| Corbins Express | 2 | Corbins P&R | Hartford | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0.0 | 0 | | $0 | 3,812 | $0 | 0 | 3 |
| Cheshire Express | BX2 | Cheshire | Hartford | 30 | 0 | 30 | 0 | 0 | 0 | 0 | 28.5 | 171,000 | 33.3 | 5,645 | | $0 | 3,588 | $0 | 4 | 3 |
| Bristol Express | 24 | Bristol | Hartford | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0.0 | 0 | | $0 | 7,176 | $0 | 0 | 6 |
| Category Totals | | | | | | | | | | | | 557,381 | 33.7 | 18,211 | | $0 | 14,576 | $0 | | |
| **Busway Local Routes** | | | | | | | | | | | | | | | | | | | | |
| New Britain to Hartford Shuttle | BW1 | Hartford | New Britain | 12 | 20 | 12 | 30 | 20 | 30 | 30 | 10.1 | 383,962 | 24.1 | 17,490 | | $0 | 0 | $0 | 5 | 0 |
| Bristol to Hartford Shuttle | BW2 | Hartford | Downtown Bristol | 12 | 20 | 12 | 30 | 20 | 30 | 30 | 20.1 | 764,122 | 26.7 | 31,482 | | $0 | 0 | $0 | 9 | 0 |
| New Britain-Westfarms-Hartford | BW3 | New Britain Station | Hartford | 18 | 20 | 18 | 60 | 20 | 60 | 60 | 11.5 | 320,620 | 17.2 | 20,539 | | $0 | 0 | $0 | 5 | 0 |
| Uconn Health Center-Westfarms-Hartford | BW4 | UConn Health | Hartford | 18 | 20 | 18 | 60 | 20 | 60 | 60 | 9.1 | 253,708 | 13.9 | 20,026 | | $0 | 0 | $0 | 5 | 0 |
| Newington Junction to Hartford Shuttle | BW5 | Newington Jct. | Hartford | 18 | 0 | 18 | 0 | 0 | 0 | 0 | 6.0 | 60,000 | 24.6 | 2,688 | | $0 | 0 | $0 | 2 | 0 |
| Category Totals | | | | | | | | | | | | 1,782,411 | 21.3 | 92,225 | | $0 | 0 | $0 | | |
| **New Connector and Circulator Routes** | | | | | | | | | | | | | | | | | | | | |
| CCSU Connector | C1 | Cedar Street | East Street | 15 | 20 | 15 | 30 | 20 | 30 | 30 | 3.1 | 108,550 | 15.1 | 7,891 | | $0 | 0 | $0 | 2 | 0 |
| Hospitals - Capitol Connector | C2 | St. Francis Hospital | Hartford Hospital | 15 | 20 | 15 | 30 | 20 | 30 | 30 | 3.4 | 119,054 | 15.6 | 8,374 | | $0 | 0 | $0 | 2 | 0 |
| Newington Circulator | C3 | New Britain Station | New. Jct. Station | 30 | 60 | 30 | 60 | 60 | 60 | 60 | 10.7 | 164,609 | 23.5 | 7,716 | | $0 | 0 | $0 | 2 | 0 |
| West Hartford - Bishops Corner Connector | C4 | Flatbush Station | Bishop's Corner | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 5.4 | 66,874 | 13.3 | 5,518 | | $0 | 0 | $0 | 1 | 0 |
| Category Totals | | | | | | | | | | | | 459,086 | 17.1 | 29,499 | | $0 | 0 | $0 | | |
| | | | | | | | | | | | | | | | | | | | | |
| Busway System Totals | | | | | | | | | | | | 4,280,467 | 18.3 | 257,370 | | $0 | 127,371 | $0 | 74 | 48 |

**Operating Cost and Vehicle Fleet Attributable to New Busway Service**

Increase in Vehicle Service Hours: **129,999**

Increase in Annual Vehicle Operating Cost: **$0**

**26** Increase in peak vehicles required.

With 5% Deadhead: **$0**

**32** Increase in peak vehicles including 20% spares.

Connecticut Department of Transportation

# NEW BRITAIN-HARTFORD BUSWAY OPERATIONS PLAN

DRAFT REPORT

AUGUST 26, 2009

IBI GROUP

# DOCUMENT CONTROL

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# TABLE OF CONTENTS (CONT'D)

# 1. INTRODUCTION

The purpose of the *Operations Plan* is to develop an organizational structure that will operate the New-Britain-Hartford Busway facility once it is opened. This will assure a smooth transition from the construction phase to the operations phase of the project and will assure the safe and effective operation of the busway out into the future. The *Operations Plan* is required by the Federal Transit Administration as part of ConnDOT's application for federal funding for the project through the "New Starts" program.

The plan establishes a structure of roles and responsibilities and where possible, assigns these responsibilities to existing agencies, institutions, municipalities, and other organizations. Sometimes this is not possible since adequate knowledge of the nature of the responsibilities or what organization might best complete them is not yet available. In these cases, the plan establishes a process to make these decisions before the busway is completed.

The plan includes the following systems and topics:

**Transit Operations**

*Central Dispatch*
*Radio Systems*
*Field Supervision*
*Traffic Signal Coordination*
*Fare Policy*
*Fare Collection Procedures*
*Service Plan Integration*
*Private Operator Access*
*Station Operations*
*Parking Lot Operations*
*Service Monitoring*
*Training and Procedures*

**Facility Maintenance**

*Roadway Maintenance*
*Station Maintenance*
*Traffic Signal Maintenance*
*Busway and Railroad Grade Crossings*
*Structures*
*Ticket Vending Machines and Fareboxes*
*Radio System*
*Procedures and Training*

### Safety and Security

*Patrol of Busway Roadway*
*Patrol of Busway Stations*
*Emergency Services Jurisdiction*
*Use of Busway by Emergency Services*
*Restricting Access to the Busway*
*Multi-Use Train Security*
*Fare Enforcement*
*Security Training and Procedures*

### Intelligent Transportation Systems (ITS)

*CAD/AVL*
*Real -Time Information*
*Telephone and Internet Access – 511*
*Fare Collection*
*Security Technology*
*Traffic Signals and TSP*
*Central Dispatch and Communications*

# 2. PROJECT BACKGROUND

The New Britain-Hartford Busway was first proposed as part of a major investment study in the I-84 corridor, completed in the late 1990s. Several modes were looked at to reduce traffic congestion and improve transportation services including roadway expansion, light rail, commuter rail and high-occupancy vehicle lanes, in addition to the busway. The busway was selected as the locally preferred alternative because of its relatively high ridership and relatively low cost compared to the other alternatives. The busway also provided a number of unique service advantages over other transit options including more frequent service, the ability to provide service to locations not directly on the busway, flexibility to change routes when necessary, and the ability to operate local and express services along the same right-of-way.

The New Britain-Hartford Busway project has progressed through environmental assessment, preliminary engineering, and final design to the point where it is ready to be presented to the Federal Transit Administration for a Full Funding Grant Agreement (FFGA), which commits the FTA to funding through to completion. This Operations Plan is part of that presentation.

# 3. PROCESS

The key decision-making group for the Operations Plan was the Operations Planning Committee. This group of stakeholders from local and state organizations oversaw the development of a plan for operational and maintenance responsibilities for the busway.

Four subcommittees were created within the Operations Planning Committee: transit operations; facility maintenance; safety and security; and intelligent transportation systems (ITS) and communications. An executive committee received subcommittee reports and adopted recommendations.

Four meetings were held to discuss various aspects of the plan. The first meeting, in February 2009, provided an introduction to the operations planning process to the full committee. The second, in March, provided more detailed presentations to the subcommittees. That meeting included a peer review of other BRT systems, a presentation of preliminary recommendations and comments, a discussion of additional issues necessary for the Operations Plan, and interaction with the various subcommittees.

The third meeting, in April with each subcommittee individually, discussed previous comments and invited additional suggestions for improvements in the final *Operations Plan*. A fourth meeting of the full committee was held in June to review all recommendations to date and summarize key findings.

| **2009 January** | **February** | **March** | **April** | **May** | **August** |
|---|---|---|---|---|---|
| | First Committee Meeting: introduction to Operation Planning | Second Subcommittee Meeting: Peer Review | Third Subcommittee Meeting: Comments, Revisions and Discussion | Fourth Committee Meeting: Wrap-Up | Draft *Operations Plan* Completed |

This Operations Plan is based on extensive research and analysis of BRT systems throughout North America. It incorporates many comments and suggestions from Operations Planning

Committee members and other stakeholders involved in the process. Some of these many agencies and organizations committed to developing a successful operations plan include ConnDOT, who has overseen the busway project; CTTRANSIT, CRCOG, the Connecticut State Police; and the municipalities of Hartford, New Britain, West Hartford, and Newington.

Some of the basic guidelines that were followed in developing the Operations Plan include:

- The implementation of a major new facility like the busway is an opportunity to consider new ways of providing transit service in the busway corridor.
- On the other hand, if systems are working well, there is no need to change them, but rather to harness them and use them to create an effective and efficient operations plan.
- There are other busway operators that have a great deal of experience in day to day operations. Their experience should be applied to the Operations Plan, after careful consideration of how local circumstances affect the way it is interpreted.
- It is important to define roles and responsibilities, even if a final decision on what organization or institution would serve that role when the busway opens could not yet be made.

# 4. PRIMARY RECOMMENDATIONS AND ISSUES

This Operations Plan is the first version of a plan that will evolve as the design of the busway is completed, construction is implemented and all of the participants develop a better understanding of the roles and responsibilities required to operate the busway. This version sets the overall framework for the organizational structure, establishes the organizations that will be involved in creating the final plan, creates a forum for discussion, and sets milestones for its development.

Like the overall CT Transit system, the busway plan is a diverse decentralized structure that builds on the strengths of the many organizations involved. In the case of the busway, this diversity will be coordinated through a state-of-the-art ITS system. The primary recommendations and elements of this organization are:

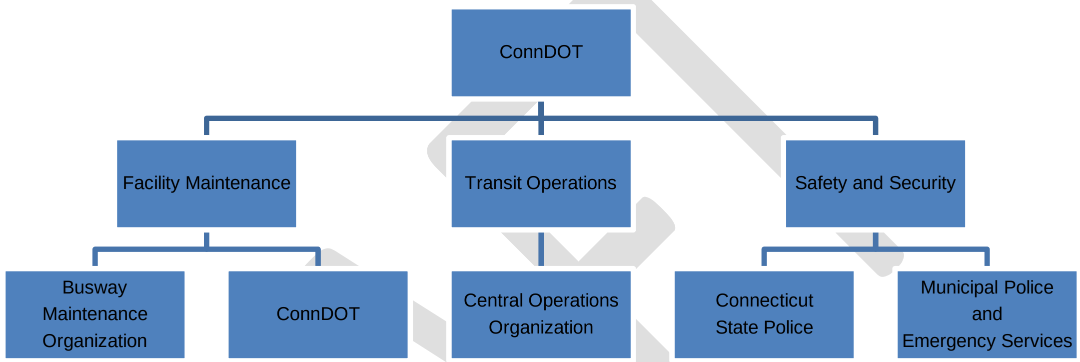
- ConnDOT has been and will continue to be the primary owner and manager of the New Britain-Hartford Busway. They will see the busway project through to completion and will retain ownership after it goes into operation. ConnDOT will remain ultimately responsible for the level of service provided, planning of specific services, selecting and coordinating operators, facility maintenance, and community relations.
- Bus service on the busway will be operated by multiple organizations including CT Transit Hartford, CT Transit New Britain through New Britain Transportation, DATTCO, CCSU, and possibly other contract operators for new transit services such as Peter Pan. A Central Operations Organization (COO) organization will be established to dispatch and monitor the busway and coordinate between this diversity of operators. The COO could be established as a division of ConnDOT, could be contracted to one of the operators, or could be set up as an independent organization like some traffic operations centers are organized in Connecticut. In order to adequately prepare for the opening of the busway, the COO should be designated at least 18 months prior to its opening.
- ConnDOT will maintain the busway roadway and bridges directly like any other state highway. At stations, the services of a Busway Maintenance Organization (BMO) will be required. Similar to the COO, the BMO is a placeholder for an organizational responsibility that will be assigned to a specific organization as the design and function of the busway are developed. The BMO will be responsible for transit specific aspects of the busway like station maintenance and servicing, park-and-ride maintenance and servicing, technology maintenance and servicing, and responding to maintenance issues as they arise. In order to adequately prepare for the opening of the busway, the BMO should be designated at least 12 months prior to its opening.
- Safety and security will be provided along the busway roadway, at stations, and on buses by a new division of the Connecticut State Police, if that division is officially established. Other emergency services will be provided by municipal police, fire and EMS.
- The desire of ConnDOT and the Operations Committee is to be aggressive with intelligent transportation systems (ITS) features on the busway to provide a high level of active management, monitoring, information provision, and response to incidents. ITS provides an overarching framework within which to implement many of the recommendations in this operations plan. ITS will support the operations, maintenance, and safety and security functions. Developing a final plan for responsibilities for ITS functions will be completed as part of the development of an ITS plan for the busway, which should begin in the fall of 2009. The diverse matrix of operating organizations on the busway will present unique challenges to the development of the ITS plan.

Other related issues included in the Operations Plan that were addressed by the Operations Planning Committee include vehicle types, scheduling, and central dispatch operations management.

## 4.1 Report Structure

The report is divided up into four main sections for the work of each of the subcommittees, Transit Operations, Facility Maintenance, Safety and Security and Intelligent Transportation Systems (ITS). Each section contains discussion of a number of important topic areas which cover a general discussion, a recommended organizational policy statement and a number of specific issues related to how the organizational structure should be structured and implemented. Many of the specific topic areas still require certain issues to be worked out before a final organizational structure can be decided upon.

**Figure 1: Overall Busway Organizational Structure**

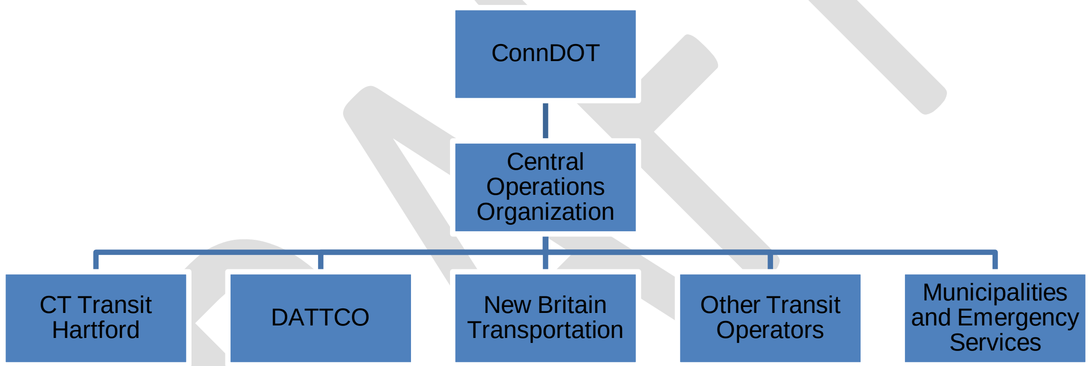


# 5. TRANSIT OPERATIONS

Transit operations refer to the activities related to the dispatch and operation of buses on the busway. They include dispatch, field supervision, scheduling, service monitoring and planning, maintenance of schedules and headways, fare collection, and the operation of the signal system. A large part of a customer's daily experience with the busway will be related to the success, or lack of success, of those responsible for operations to provide the proper type of bus at the scheduled time and get them to their destination on time on a regular basis.

The Transit Operations section of the Operations Plan will be developed in greater detail by the Transit Operations Subcommittee over the course of the four years between the plan's preparation and the opening of the busway. Their initial tasks will include assisting with the procurement of the many ITS systems which support operations and the selection of the organization to serve as the COO. They will meet on a regular basis until the busway opens.

**Figure 2: Busway Transit Operations Organizational Structure**




## 5.1 Central Dispatch

### 5.1.1 DISCUSSION

A central dispatch center would monitor, manage, coordinate, and respond to incidents on the busway. Not all busways have a central dispatch function. Some function just like any public highway, with each operator using the same dispatch system they use for routes that do not serve the busway.

A central dispatch function offers several benefits that encourage efficient busway operations. It establishes a clear line of responsibility for the coordinated operations of the busway. Through working relationships with the busway operators it allows flexibility to accommodate their various service structures. It would not dispatch buses while they are operating off of the busway, although it would be advantageous to monitor their approach. This would enable busway dispatchers to plan in advance for early or late buses so that headways could be maintained on the main line.

A central dispatch facility manages overall busway service quality, which includes the adjustments to service necessary to maintain headways, such as by turning back and adding trippers as needed. Central dispatch coordinates the response to issues that may arise, which requires prompt communication with other stakeholders. The central dispatch facility follows any incidents or emergencies with contact with the appropriate police, fire, and EMS personnel. Central dispatch also provides for communication with transit users, notifying them of service disruptions and delays, no matter which operator's services they use.

#### 5.1.2 POLICY AND ROLES

Operations on the busway will be coordinated by a central authority, called Central Operations Organization (COO). This organization will communicate with transit providers and serve as a point of contact with municipalities and local emergency services when necessary. The dispatch facility will monitor operations along the busway for both revenue-service and maintenance vehicles.

#### 5.1.3 ISSUES AND FOLLOW-UP

- The specific organization that will fill the COO role has not been determined. It will depend upon the final decisions made on the design of the CAD/AVL system.
- It is expected that the work of the transit operations subcommittee of the Operations Planning Committee will continue through the beginning of busway operations to facilitate continued coordination among stakeholders.
- The design of the CAD/AVL system is part of the larger issue of ITS planning and implementation that will be addressed starting in the fall of 2009.
- Other considerations to be determined in the creation of a central dispatch facility are its location and how it will track and control non-transit vehicles using the busway (e.g. maintenance vehicles and emergency services).
- The busway CAD/AVL system could be used as a model for improvements to off-busway dispatch in the Hartford region.

## 5.2 Radio System

#### 5.2.1 DISCUSSION

The radio system forms a critical element of the CAD/AVL system. All vehicles operating on the busway must be able to hear voice communications and send and receive data communications at all times for other systems to work properly. An integrated radio system is essential for communication between the dispatch center and vehicles on the busway. Operators, dispatch staff and supervisors, and maintenance personnel must be able to communicate with compatible radio equipment.

#### 5.2.2 POLICY AND ROLES

The busway radio system will be operated and maintained by Busway Central Operations with the exception of the on-vehicles aspects of the system.

#### 5.2.3 ISSUES AND FOLLOW-UP

- The radios used by field personnel must be compact and easy to use, with sufficient battery life, while those used at facilities and in vehicles must be compatible with existing equipment at those locations.
- This system may involve fiber-optic equipment, radio antennas and repeaters to enable communication in all locations along the busway.
- The system must have adequate capacity to handle all communications necessary on a daily basis and also must provide a recording system to preserve all communication for a certain period of time.

## 5.3 Field Supervision of Operations

### 5.3.1 DISCUSSION

Field supervisors, working with dispatchers, manage busway service quality to ensure an optimal riding experience for users. Under their supervision transit operations are observed and modified to ensure efficient operations. Supervisors carry out dispatch instructions from the central dispatch facility in person to increase their comprehension and effectiveness. They respond directly to incidents and emergencies and communicate directly with drivers. Each supervisor manages multiple operators, enforcing common operating procedures and providing an interface between busway and roadway operations. Supervisors oversee a shift of drivers and operations personnel, ensuring compliance with rules and procedures, maintaining schedules, monitoring communications, and route staffing. Supervisors may be required to operate buses, train subordinate personnel, and to respond to inquiries from various agencies.

### 5.3.2 POLICY AND ROLES

The COO will hire and train a team of supervisors to oversee operations in the field.

### 5.3.3 ISSUES AND FOLLOW-UP

- Hiring of supervisors must occur far enough in advance of the busway opening to assure proper training.
- To ensure consistency common operations procedures must be developed.
- It will also be necessary to hire supervisors capable of performing the duties required, including the oversight of multiple operators and operation of transit vehicles as needed.

## 5.4 Traffic Signal Priority

### 5.4.1 DISCUSSION

Most transit signal priority systems are integrated with CAD/AVL systems. AVL provides information to the signal system on the bus's whereabouts and communicates with the signal controller when priority is necessary for the bus to cross a side street. On the busway the signal priority system will work something like a railroad grade crossing signal system, giving approaching buses priority to the cross the intersecting street as they approach. The busway system will be different in that the amount of green time that buses are allowed is limited. If several buses arrive at once, from either the same or different directions, they will get a limited amount of green time before the signal will turn back to the cross street to prevent unreasonable delay to traffic crossing the busway. If another bus approaches within a certain amount of time, it will wait. The exact timings for these features will be determined by analysis of traffic volumes just before the busway opens.

Railroad grade-crossing signals where they are located next to busway at Hamilton and Oakwood Streets will always get priority over road and busway traffic, as they do now. Both railroad and busway grade-crossing signals will be interconnected with nearby roadway intersections to optimize traffic flow through the intersection and to prevent backups across the busway or the railroad.

### 5.4.2 POLICY AND ROLES

ConnDOT, working with municipalities and Amtrak, will be responsible for the development of a practical and effective traffic signal system that includes busway grade crossing signals, entrance and exit signals, and pedestrian signals. The COO will operate the system on a day-to-day basis, monitoring its status, collecting data on its performance and reporting any problems to the BMO for resolution.

#### 5.4.3 ISSUES AND FOLLOW-UP

- Grade-crossing signals on the busway will be interconnected with nearby intersections to optimize traffic flow, and will be coordinated with existing Amtrak signals at those locations.

## 5.5 Busway Signal System for Single-Lane Section

#### 5.5.1 DISCUSSION

The single lane section of the busway between Sigourney Street and Flower Street requires the installation of a signal system to regulate the flow of buses onto and off of the section at either end. The AVL system will alert the system to a bus's approach and provide a green signal if the section is empty or a red signal if a bus has already entered from the other end. Under normal operating conditions buses will arrive in a relatively even spacing at both ends of the single lane and will enter with little delay. In cases where backups occur, the system may limit the number of buses in the queue that pass though the single lane section in order to avoid delaying buses traveling in the other direction. VISSIM traffic simulations have indicated that the volume of buses proposed for the busway will not result in significant delay on the single lane section.

#### 5.5.2 POLICY AND ROLES

ConnDOT will develop a signal system for the single lane section as part of the creation of an ITS plan for the busway. The COO will operate the system on a day-to-day basis, monitoring its status, collecting data on its performance and reporting any problems to the BMO for resolution.

#### 5.5.3 ISSUES AND FOLLOW-UP

- The single lane signal system will be developed as part of the ITS plan and procured along with the TSP and CAD/AVL systems.

## 5.6 Fare Policy

#### 5.6.1 DISCUSSION

Clear and consistent fare policy encourages transit ridership by making service easier to use, by making the fares consistent with the way the system is used, and by delivering good perceived value for the service provided. Fare policy for the busway will be the same as for the overall CT Transit network. Local and express fares, zone fares, pass discounts, park-and-ride fees, and special discounts will all be the same. In designing a fare policy for the busway it is important to have clear expectations for how the busway fare policy integrates with that of the overall system.

The busway will use POP fare collection system, a new technology for CT Transit which may warrant a review of certain aspects of the fare system. For instance, might this new system work better if the day pass was more heavily discounted? Should transfer restrictions be relaxed to encourage more short distance riding?

#### 5.6.2 POLICY AND ROLES

ConnDOT will be responsible for setting fare policy for the busway. A review of the effects that the busway and its new POP fare collection system will have on ridership patterns and fare revenue will be made and policy updated as necessary.

#### 5.6.3 ISSUES AND FOLLOW-UP

- Fare system must be interoperable with all operators of the busway. The POP vending machines and on board fare boxes must work together.
- It is recommended that a full analysis be conducted to determine how fares and pass media collected at busway station vending machines are distributed among the participating transit operators.
- Agreements should be prepared and executed between transit agencies clearly specifying responsibilities and fare distribution policies.

## 5.7 Fare Collection System Operation

#### 5.7.1 DISCUSSION

Efficient operation of the busway requires a well-designed fare collection system. Preliminary analysis has concluded that a proof-of-payment (POP) fare collection system will be beneficial for the busway, reducing dwell time and overall travel time. Proof-of-purchase fare systems consist of ticket vending machines where passengers purchase tickets using cash, debit or credit cards. These tickets are validated either at the time of purchase or by another machine, and are subject to inspection by fare enforcement personnel.

The POP system would only be used when boarding buses at a busway station and the downtown Hartford loop. Many busway routes travel partially on the busway and partially on street. Riders boarding on-street before the bus enters the busway would pay their fare at the farebox just as they do today. They would then be issued a ticket by the farebox as their proof of payment.

POP requires a regular process of ticket inspection to convince passengers who might be tempted to cheat that there is a good chance that they will be caught and fined. The responsibility for enforcing POP must be determined and the appropriate number of fare inspectors hired and trained for the opening of the busway.

#### 5.7.2 POLICY AND ROLES

The design of a fare collection system for the busway will be completed by ConnDOT, working closely with individual operators to ensure compatibility with existing practices and an overall successful implementation. This group will be responsible for supporting the procurement and installation of fare collection equipment. The Central Operations Organization will perform day-to-day servicing, refilling tickets in ticket vending machines, and removing of cash for processing. Individual operators will be responsible for the operation and maintenance of the new fare collection equipment on their vehicles.

#### 5.7.3 ISSUES AND FOLLOW-UP

- Enforcement of the fare collection system will be carried out by the Transit Unit of the Connecticut State Police.
- Collected fare revenue must be securely collected, transported and processed, which will require a vault or other secure room for its counting and storage.

- As the procurement of fare collection equipment is based on the fare collection policy established for the busway this must be codified to ensure compatible systems are designed and implemented.
- This procurement process requires a long lead time, which must be considered in future planning activities.
- A systematic evaluation of the fare collection system's impacts on other issues, such as revenue, yield management, and fare evasion should be performed.
- The selection of equipment from among competing technologies and vendors, as discussed in the following text with ITS issues, must be carefully decided.
- There is a maintenance aspect to the responsibilities associated with the fare collection system, which is discussed in the Facility Maintenance section.

## 5.8 Service Plan Integration

### 5.8.1 DISCUSSION

The efficient operation of the busway requires that the schedules of all operators using the busway and its stations be coordinated. This coordination needs to be maintained in the future as schedules change for various reasons, routes are modified, and vehicles are updated. Busway operations will be integrated with an overall service plan for those routes operating on it. This central service planning is required for the busway to operate at maximum efficiency.

Even headways provide the best service to the public and ensure that busway stops, stations, and berths are productively used and not overcrowded. The various service providers will schedule their services to provide consistent headways along the busway and to minimize transfer time between routes.

### 5.8.2 POLICY AND ROLES

This activity will be the responsibility of the Central Operating Organization. Working with ConnDOT, CTTRANSIT, New Britain Transportation, Central Connecticut State University (CCSU), DATTCO and any other new operators, the COO will coordinate service planning for the routes and schedules of all bus service using the busway.

## 5.9 Private Operator Access Policy

### 5.9.1 DISCUSSION

In addition to public transit providers who will use the busway, it may be desirable for private intercity bus operators, such as Greyhound, Peter Pan, megabus, and BoltBus, to use the busway. These private operators pose challenges for efficient busway operations, however, and must be able to safely and effectively traverse the busway with minimal delay to regular service.

The unusual layout of some stations may require special training for drivers using the busway. The CAD/AVL system selected for the busway may require the installation of expensive radio system equipment in any bus that uses the busway and given than most intercity bus companies dispatch buses throughout their systems, this could mean the need to equip hundreds of buses that seldom use the busway.

#### 5.9.2 POLICY AND ROLES

ConnDOT will be responsible for determining a policy on private, non-contract operations on the busway, and will update it on a regular basis.

#### 5.9.3 ISSUES AND FOLLOW-UP

- Private operators will initially not be allowed to use the busway. After a one to two year period where ConnDOT develops experience in the characteristics and challenges of busway operations, this policy will be reviewed.
- Other issues must also be explored, such as the need for automatic vehicle location (AVL) systems on all buses using the busway and the communication system requirements necessary to coordinate with the Central Operating Organization.

## 5.10 Station Operations

#### 5.10.1 DISCUSSION

Station operations procedures include provisions for stopping at stations, layovers, parking locations, and the use of break rooms for drivers. They ensure a clear understanding of practices, avoiding conflicts between operators for station space and for the productive and safe use of boarding and alighting berths and layover space. Available station space will have an effect on service planning because adequate layover space is necessary establish a route terminal at any given station.

#### 5.10.2 POLICY AND ROLES

The Central Operating Organization will be responsible for creating and implementing station operations procedures. Station operations will be a topic included during regular meetings with busway service operators on service planning issues.

#### 5.10.3 ISSUES AND FOLLOW-UP

- In order to for the Central Operating Organization to effectively create and implement station operations procedures it is necessary to first determine the locations of route terminals, the operating companies using a station, and the space available at each station for layovers.
- The demand for layover space will influence the selection of appropriate stations for layovers, to be coordinated with the primary operator of stations and with the BMO.

## 5.11 Parking Lot Operations

#### 5.11.1 DISCUSSION

Parking lots must offer convenient access and provide safe access to busway stations. As most parking lots will be self-service few ongoing operations requirements are needed. Collection of cash from parking vending machines, if needed, and traffic direction during busy travel times are the main operations activities. Snow plowing will be handled as part of station maintenance.

#### 5.11.2 POLICY AND ROLES

Parking lot operations will be the responsibility of the Central Operations Organization. This is only necessary if lots have ongoing operating requirements, such as the collection of parking fees or the need for an attendant to direct traffic.

#### 5.11.3 ISSUES AND FOLLOW-UP

- Special operations may be needed during special events that bring unusual volumes of riders to park-and-ride stations or which attract significant numbers of riders who are unfamiliar with the busway.
- Parking fee vending machines and ticket vending machines would be serviced as part of the same activity.

## 5.12 Performance Monitoring

#### 5.12.1 DISCUSSION

To sufficiently plan for busway demand will require constant monitoring of service levels. Automatic passenger counters, ticket vending machine records, and video archives will provide an accurate record of the number of people riding the busway, their boarding and alight stations and the time of the trip for analysis. This analysis will enable the BCO to adjust service levels as necessary to better match demand.

In addition to day-to-day operations, capital improvement planning for the busway will benefit from accurate information on ridership patterns. Planning for these improvements will ensure that the busway functions as intended and has the capacity to support ridership demand.

Community outreach is also a key part of operations planning activities. Communicating with riders and non-riders alike offers feedback about how busway operations are meeting community needs. These exchanges can provide a continuously updated list of strengths and weaknesses to be addressed in ensuring quality transit service.

#### 5.12.2 POLICY AND ROLES

The Central Operating Organization will be responsible for busway operations planning activities, supported by ConnDOT and by individual service operators.

#### 5.12.3 ISSUES AND FOLLOW-UP

- This ongoing planning will also ensure that adequate capacity is available for special events and extraordinary circumstances that result in unusual ridership, such as concerts, festivals and sports events.
- Ongoing monitoring will be the key to achieving a goal of quality service.

## 5.13 Operations Training and Procedures Development

#### 5.13.1 DISCUSSION

To create a safe and efficient culture for operators, transit operations are formalized through a series of written procedures specific to each agency's unique circumstances. The development of these procedures and subsequent training and instruction for staff responsible for their knowledge is an integral part of successful transit operations, especially for a new start up service like the New

Britain-Hartford Busway. Formal procedures for transit operations are incorporated into rule books and standard operating procedures.

All operators on the busway will be required to use a common set of operating rules and dispatch protocols, as well have all buses equipped with the same radio communications system.

#### 5.13.2 POLICY AND ROLES

The Central Operating Organization will be responsible for the development of written operations material and standard procedures, with support from the various transit operators using the busway. All staff will be trained in their respective areas of responsibility, including dispatchers, field supervisors, and drivers. All operators on the busway will receive instruction and training on proper procedures, including safety training and service interruption and recovery training.

#### 5.13.3 ISSUES AND FOLLOW-UP

- It is important to note that, since training on equipment such as buses, ticket vending machines, and dispatch systems must involve the actual equipment this activity can only be completed after the equipment has been procured.
- Equipment vendors will be involved to a significant extent in this activity, with the final development of training procedures and written manuals to be completed in cooperation with them and with equipment manufacturers. This training should be included in procurement contracts with vendors.
- Training must begin well in advance of the opening of the busway to ensure a seamless transition to the new facility.

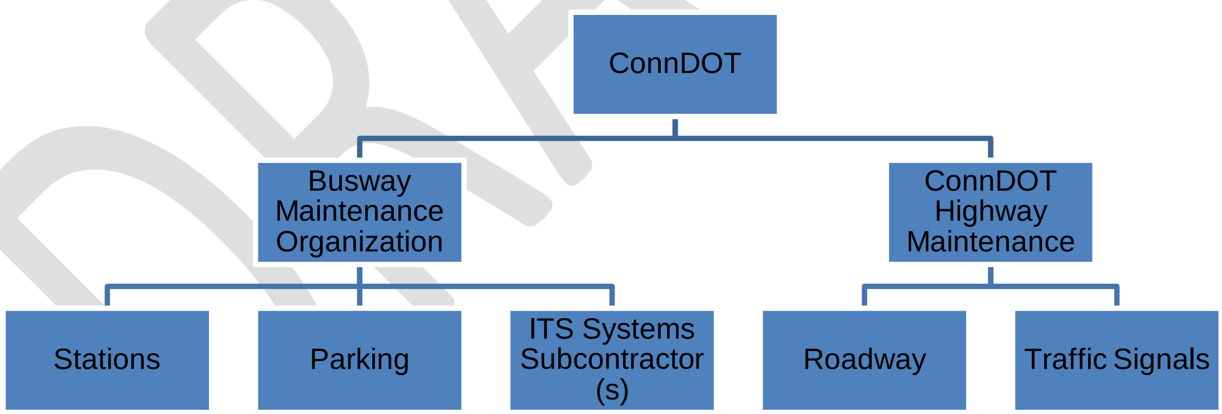
# 6. FACILITIES MAINTENANCE

It is recommended that facility maintenance for certain parts of the busway – roads and traffic signals – will be completed by ConnDOT. Maintenance of on-site busway assets – station structures, parking and ITS components – are recommended to be administered by a newly established responsibility: a busway maintenance organization (BMO). This organization will assume responsibility for these maintenance requirements together with ConnDOT. A decision on what organization should take on the BMO responsibility, ConnDOT, CT Transit, a new public entity or a private contractor, will need to be made within the next 18 months.

As with the Central Operating Organization, a BMO offers several benefits necessary for efficient busway operations. A BMO also provides clear lines of responsibility, with defined roles for various stakeholders. Such an organization utilizes regional transportation facility expertise, providing thorough inspections and service at required intervals for busway assets. In addition, this organization will provide capabilities where they are most needed.

In order to successfully implement the BMO it is expected that the work of the Facility Maintenance Subcommittee of the Operations Planning Committee will continue through the beginning of busway operations to carry on its work. As with the Central Operating Organization a physical location must be established for the BMO's offices. To adequately prepare for the opening of the busway, the BMO's responsibilities should be assigned no later than 18 months before opening day.

**Figure 3: Facility Maintenance Organization Chart**




## 6.1 Roadway Maintenance

### 6.1.1 DISCUSSION

The busway will be constructed in accordance with ConnDOT highway design and construction specifications. The busway will be two lanes with passing lanes at most stations to permit express buses to overtake local buses. The busway will include a one-lane section between Sigourney Street and Flower Street.

The ConnDOT Maintenance Division currently has trained and skilled personnel along with equipment to maintain state highways. Given that the busway is owned by the agency and similar in design to state highways, agency personnel are most qualified to maintain the busway.

#### 6.1.2 POLICY AND ROLES

ConnDOT will be responsible for the maintenance of the roadway, curbs, structures, operational signage, and other physical infrastructure. Also, the agency will be responsible for maintenance of lighting, signals, roadway loop detectors, transit priority and related equipment. When necessary, the agency will perform busway snow removal operations.

ConnDOT will handle the response to emergency roadway occurrences. The operating procedure for busway emergencies will be in accordance with ConnDOT's established response to incidents on state highways. Also, it will be important to secure a contractor to provide 24-hour on-call towing services for disabled buses and other vehicles.

#### 6.1.3 ISSUES AND FOLLOW-UP

- The busway will have grade crossings and transitions with local streets and roadways.
- It is recommended that ConnDOT coordinate efforts with local jurisdictions for roadway maintenance at the crossings.
- It will be necessary to ensure that maintenance responsibilities, standard highway maintenance procedures and all other requirements be clearly specified in written agreed upon directives.
- Coordination will be required with Amtrak and its maintenance division clearly specifying maintenance responsibilities where the busway and railroad right-of-way abut, or in shared areas adjacent to the roadway.
- ConnDOT does have the option to contract for all or portions of maintenance duties, including emergency road maintenance.
- The agency will have to fully analyze its options, including personnel, maintenance vehicle requirements, and financial impacts in providing maintenance to determine the best approach.
- Additional equipment, parts and supply needs to cover busway maintenance must be resolved prior to opening day.

## 6.2 Station Maintenance

#### 6.2.1 DISCUSSION

Research of agencies in the country that operate busways has revealed that often the organization that maintains the roadway also maintains the stations along the route. This is due to the more common organizational structure where ownership, operation, and maintenance of the busway are consolidated in the hands of a regional transit authority.

In Connecticut, the existing structure where ConnDOT serves as a coordinating umbrella organization overseeing the work of a number of organizations specialized by geography, mode, and area of expertise provides more flexibility. Station maintenance differs from roadway maintenance in both the nature of the structures concerned in the way that they are used. The roadway interfaces primarily with transit vehicles and operations personnel whereas the station interfaces with individual passengers as the walk to the platform and wait for their buses.

Parking lots, walkways, and station platforms are similar in that the riders of the system will walk along them, sit down on a bench or stand to wait, perhaps drop something and need to pick it up, and generally be in close regular contact with these spaces.

As far as the roadway is concerned, there is a clear local precedence for ConnDOT-owned roadways to be maintained by the agency, taking advantage of expertise, experience, equipment and facilities already in existence. On station maintenance, a new organization set up specifically to maintain the busway stations, a new type of facility in Connecticut, is proposed.

#### 6.2.2 POLICY AND ROLES

The BMO's responsibilities will include maintenance of station platforms, passenger shelters, lighting, communications, security cameras, emergency call boxes, real-time passenger information display boards (including next bus information), and other electronic services. The BMO will be responsible for updating signage both in and out of the stations including parking lots. The BMO will remove graffiti from all surfaces of the building, platforms, trash containers, lighting fixtures and signs. The BMO will be responsible for removal of snow from platforms to ensure the safety of transit patrons.

#### 6.2.3 ISSUES AND FOLLOW-UP

- The primary BMO must have the expertise and knowledge to provide the services and amenities to encourage transit ridership. In the case of the busway, the BMO should analyze the most efficient and cost effective means of providing services and maintenance for the stations.
- The service provider can be either the BMO itself or the third-party contractors for all or portions of the services and maintenance tasks.
- Equipment, parts and supply needs to cover busway maintenance must be resolved prior to opening day.

## 6.3 Parking Lots and Driveways

#### 6.3.1 DISCUSSION

Effectively managing and maintaining the stations and the adjacent parking lot areas is essential to ensure a pleasing and safe environment for transit patrons. Providing station and parking lot cleanliness is one of many critical elements to encourage people to become regular transit patrons. Many stations and parking lots will be adjacent to private businesses and residences. It will be critical that each facility be well maintained and complementary to the adjacent neighborhood.

#### 6.3.2 POLICY AND ROLES

The BMO will be responsible for routine parking lot and driveway maintenance, including pavement sweeping and cleaning. BMO staff will perform routine landscape maintenance in and around the parking lot and stations. The BMO will maintain and repair parking lot lighting and signage. The BMO will also be responsible for parking lot snow removal to ensure that lots are clear for patron use during bus operating hours.

#### 6.3.3 ISSUES AND FOLLOW-UP

- As with station maintenance, in the case of the New Britain station another party could be responsible for routine station maintenance only.
- The arrangement to have the BMO responsible for both the station and parking lots areas will provide flexibility and consistency.

- It is suggested that the BMO research other transit agencies along with conducting a full analysis of tasks and expenses associated with the annualized costs to determine the best approach to providing the service.
- Once the analysis is complete, it must be determined if it is cost effective for the BMO staff to perform the maintenance duties or to contract all or portions of the duties to an outside third party.

## 6.4 Traffic Signal Coordination and Priority

### 6.4.1 DISCUSSION

The busway will require traffic signals and signage at grade crossings, bus entrances, and exits, along with control signals and regulatory signage along the busway. It will be necessary to install equipment that detects buses approaching grade crossings. Signal control at grade crossings will interface with adjacent vehicular traffic control at the crossing, nearby street intersections, and buses on the busway. Signals will also be installed for controlling pedestrian traffic crossing the busway.

Procurement of appropriate equipment and software will be necessary for compatibility with local jurisdictional traffic signal systems. This equipment will require regular monitoring, servicing and repair when necessary to keep the busway functions in service. This equipment is highly specialized and will require the hiring and training of qualified staff.

### 6.4.2 POLICY AND ROLES

ConnDOT will be responsible for maintenance of busway signals, traffic signals where the busway crosses streets at grade, and signage while Amtrak will be responsible for maintenance of signals and signage at railroad grade crossings. ConnDOT, Amtrak and the local municipalities will prepare coordinated maintenance procedure guidelines defining responsibilities of each agency. The CBO will monitor the operation of signal equipment and report problems to the BMO.

It will be necessary for each agency to determine responsibility and procedures for routine and emergency maintenance and repairs. Emergency notification procedures should be established to ensure coordination efforts are conducted in a safe and timely manner.

### 6.4.3 RECOMMENDATION

- It is suggested that all agencies determine if their staffs should perform the tasks or contract all or a portion of duties to independent third parties.
- A thorough analysis should be conducted by the agencies to determine the best cost effective approach in meeting these responsibilities.

## 6.5 Parallel Busway/Railroad Crossings

### 6.5.1 DISCUSSION

At two locations the busway crosses local street while it is operating closely parallel to the Amtrak railroad: at Oakwood Avenue and at Hamilton Street. At these locations it is necessary to install both busway and railroad crossing signal equipment. The railroad must be protected both from cross street traffic and buses turning off of the busway onto the railroad. Both the railroad and busway single systems must be set up to avoid cross street traffic blocking the other while waiting for buses or trains to pass. The design of the signal systems will need to take these contingencies into consideration to provide safe operation of all transportation systems.

Historically, railroad rights-of-way and crossings are managed and maintained by the railroad. Given strict federal guidelines governing railroad operations, Amtrak must be the responsible party for the maintenance, repair and oversight of railroad crossing signals, signs and the adjacent rights-of-way.

#### 6.5.2 POLICY AND ROLES

ConnDOT will be responsible for the design, construction, and maintenance of intersections where the busway crosses local streets at grade. Amtrak will continue to be responsible for maintenance of their crossings of public streets. Busway signals and equipment maintenance will be the responsibility of ConnDOT with coordinated maintenance and repair efforts with Amtrak. Signal controls should be monitored by the busway dispatch control center. Interlocks between the railroad grade crossing signals busway signals, and adjacent street intersections signal will be included to assure that general traffic will not block the busway while waiting for a train to pass.

#### 6.5.3 ISSUES AND FOLLOW-UP

- The signals and software installed should be compatible with all other signals that are part of the busway project and existing Amtrak equipment.
- If applicable, the crossing equipment should also be compatible with local jurisdictions signal and safety software equipment.

## 6.6 Structures

#### 6.6.1 DISCUSSION

Structure maintenance includes cleaning, painting, and repairing major structures along the busway like bridges, culverts, abutments, retaining walls, shelters, and platforms.

#### 6.6.2 POLICY AND ROLES

All busway structures related to the roadway will be the responsibility of ConnDOT to maintain. Routine maintenance of passenger shelters and platforms will be the responsibility of the BMO.

#### 6.6.3 RECOMMENDATION

- It is recommended that ConnDOT perform a full analysis of the life of each structure and establish a maintenance and replacement schedule before the busway opens.
- It is important that station structures and all other components of the stations and rights-of-way complement the surrounding neighborhood.
- ConnDOT should analyze options to determine the most cost effective approach and the party to perform structure maintenance duties.
- Additional equipment, parts and supply needs to cover busway maintenance must be resolved prior to opening day.

## 6.7 Ticket Vending Machines and Fare System

### 6.7.1 DISCUSSION

Fare machines commonly used by various transit agencies in the country include paper ticket vendors, magnetic stripe, and smart card readers. CT Transit currently uses a magnetic stripe card system with registering fareboxes in Hartford, a paper transfer system with manual fareboxes in New Britain and a "cash-to-driver" system for contracted express buses. These systems will need to be consolidated and new maintenance procedures implemented across all operators when the busway opens.

Vending machine maintenance includes routine repair, preventative maintenance, and cleaning. Each station will be equipped with at least two fare vending machines to reduce the likelihood that breakdowns would result in a station having no ticket vending machines available for patrons. All machines will be monitored in the dispatch center by the CBO.

The development of a new busway fare collection system will depend on CT Transit and ConnDOT plans for future fare collection equipment improvements and how they will be phased in throughout the system.

### 6.7.2 POLICY AND ROLES

The BMO will establish machine maintenance and fare collection procedures and will service the fare collection equipment on a regular basis to assure its reliable function. ConnDOT will continue to be responsible for fare policy with the BMO responsible for busway vending machine maintenance, repair, servicing, and fare collection. Given the specialized nature of the fare collection technology, this may be an area that is contracted out to vendors to manufacture.

### 6.7.3 ISSUES AND FOLLOW-UP

- The fare vending machines will be purchased by ConnDOT as part of the busway project construction and implementation budget.
- Based upon budget and compatibility with all transit operators, it will be necessary to determine the proper fare vending machines to be purchased for the project.
- The Facility Maintenance Subcommittee should take part in the development of the fare system procurement to be sure that maintenance issues are properly considered.

## 6.8 Radio System Antennas and Equipment

### 6.8.1 DISCUSSION

In researching transit agencies that have BRT roadway systems, it is most common that one control center provide the dispatch function with use of AVL equipment. Also, if stations are equipped with security cameras and emergency call boxes, the control center can be responsible for monitoring station activity with direct access to law enforcement. It will be important to consider this approach for the busway given that more than one transit agency and possibly emergency vehicles will be using the busway at a time. Management and control of busway operations by one dispatch center ensures safe and efficient operations while maintaining proper headways.

Establishing a control center is complex and will require agreement among all participating parties. Also, establishing a central dispatch will require changes to how each transit agency operates their systems including modification to the respective agency buses and bus maintenance procedures.

#### 6.8.2 POLICY AND ROLES

The BMO will be responsible for facility equipment maintenance. COO control center staff and respective operators will coordinate maintenance of radio and if applicable, AVL equipment on buses.

#### 6.8.3 RECOMMENDATION

- Given that a number of participating transit agencies will be using the busway, a maintenance program should be established for all radio system equipment and facilities.
- The maintenance programs should be in accordance with participating agencies policy and procedures and manufacture specifications.
- The radio communication system will be designed and implemented as part of the CAD/AVL system.

## 6.9 Maintenance Procedures and Training

#### 6.9.1 DISCUSSION

The busway project is very complex, from construction of the roadway and structures to maintenance and operation. The project requires ConnDOT, BMO, Amtrak, operators and local municipalities to coordinate use of their equipment and interface with one another on a daily basis. The project also requires the agencies to establish busway procedures and policies that guide the agencies in performing their respective duties and responsibilities.

#### 6.9.2 POLICY AND ROLES

The BMO will be responsible for creating training programs—including, but not be limited to--repair and maintenance of the bus roadway, snow removal, lighting and signals, buildings and shelters, landscaping, fare vending machines, security cameras, passenger real-time information boards, vehicles and electronic equipment to name a few. Also, special training will need to be conducted for personnel working in the busway rights-of-way to ensure safety procedures are employed. The BMO may work closely with equipment vendors and manufactures to set up the training programs and may contract out some of the training to these entities.

#### 6.9.3 RECOMMENDATION

- Training programs should be developed for the numerous tasks to be performed including equipment maintenance and operation in accordance with manufacture specifications.
- It will also be necessary to determine what agencies are best suited to perform specific training sessions.
- Programs must be developed in advance of busway opening to assure a fully staffed BMO when the busway opens.

# 7. SAFETY AND SECURITY

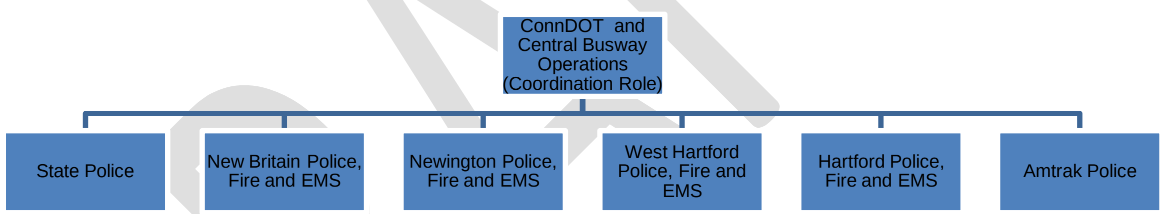
Transit's appeal, especially to choice riders, depends heavily on its image as safe and convenient.

While busway facilities must be safe and secure they must also remain open and accessible. It is not possible to regulate all access to busway facilities without impeding the function of the busway itself. These competing interests of safety, security, and accessibility must be addressed passively, primarily through observation and awareness. A holistic approach to the safety and security of the busway requires thoroughly considered procedures, effective measures to deter unwanted behavior, and properly trained staff to implement.

Some specific tasks within this subject area, discussed in the following paragraphs, include patrolling the busway right-of-way and adjacent station areas, video surveillance, fare enforcement and emergency response efforts. It is also necessary to establish a legal basis for exclusive use of the busway by buses and authorized personnel, as well as a legal basis for fare enforcement.

The Operations Committee ITS Subcommittee will continue to meet regularly as the busway is designed and ITS systems are implemented to support the coordination of all systems.

**Figure 4: Safety and Security Organization Chart**




## 7.1 Patrol of Busway Roadway

### 7.1.1 DISCUSSION

The designation of the busway as a state highway means that the Connecticut State Police have jurisdiction for security along the busway, providing patrols and emergency response services along the roadway. Amtrak already provides police patrols for their right-of-way parallel to the future busway.

The Connecticut State Police are considering the creation of a Transit Unit to patrol public transit stations, rights-of-way, and vehicles around the state. Discussions on a decision may take some time. If this force is set up, then it would be charged with security along the busway, at stations, and in parking lots. If the transit unit is not established, then the roadway will be patrolled by the State Police and by municipal police at stations and parking lots.

### 7.1.2 POLICY AND ROLES

Connecticut State Police will have primary responsibility for patrolling the busway roadway. Amtrak police will have responsibility for safety and security tasks along their portion of the shared right-of-way. Municipal police, fire and EMS staff of New Britain, Newington, West Hartford and Hartford will respond to emergencies within their jurisdictions. Their combined efforts will be coordinated by the CBO dispatch center. They will be assisted by municipal police in the enforcement of traffic laws on cross streets and in station areas, especially at intersections where grade crossings will exist.

#### 7.1.3 RECOMMENDATION

- Active and ongoing coordination with Amtrak and among local and state police agencies is recommended to focus personnel deployment and minimize redundant police activity.
- The Safety and Security Subcommittee will continue to meet until the busway is open and all subsequent issues are worked out.

## 7.2 Patrol of Busway Stations and Parking Lots

#### 7.2.1 DISCUSSION

The purpose of police patrols is to deter illegal activity, such as parking violations, theft, vandalism and more serious offenses. The patrols also serve as a visible indication of the overall safety of the busway to riders. Busway station security, unlike that of the busway right-of-way itself, is generally provided by the transit agency either through a transit police force or through a private security firm. The same is generally true of stations in light rail transit systems.

#### 7.2.2 POLICY AND ROLES

Municipal police forces will provide security patrols and respond to emergencies at station and parking lots.

#### 7.2.3 ISSUES AND FOLLOW-UP

- If its development is approved, the State Police Transit Unit will have primary responsibility for this activity, assisted by municipal police.

## 7.3 Video Surveillance

#### 7.3.1 DISCUSSION

Video surveillance is a versatile component of the safety and security aspects of busway operations. Closed-circuit television cameras are inherently related to the ITS technologies discussed later; they may be used for operations purposes, as well as for security. Installing surveillance cameras at busway stations and at other key locations along the busway allows it to be monitored continually, supplementing physical patrols.

#### 7.3.2 POLICY AND ROLES

The Central Operating Organization will have responsibility for monitoring surveillance cameras and for coordinating with appropriate law enforcement personnel.

#### 7.3.3 ISSUES AND FOLLOW-UP

- Hours of operation of the security camera will need to be worked out. The busway will be in use 18 to 20 hours per day. The means of monitoring the security cameras during the 4 to 6 hours when central dispatch staff are not required will be a topic for the operations subcommittee.

## 7.4 Emergency Services Jurisdiction

### 7.4.1 DISCUSSION

To respond to incidents that may occur on the busway or at its facilities, emergency services jurisdictions are defined as the areas to which specific responders will reply in the event of fire or a medical emergency, a crash, natural disaster, or other emergency. These areas correspond with the areas in each municipality through which the busway will pass.

### 7.4.2 POLICY AND ROLES

Each municipality will respond to emergencies within their jurisdiction along the busway. Each municipality will have access to the busway at one or more locations.

### 7.4.3 ISSUES AND FOLLOW-UP

- Given busway access locations it might be beneficial in certain cases for an adjacent municipality to respond to an emergency in a particular spot on the busway. The potential for this situation will have to be resolved before the busway opens.

## 7.5 Use of Busway by Emergency Vehicles

### 7.5.1 DISCUSSION

In case of an emergency, either on the busway or off, it may be expeditious to use the busway for certain types of emergency travel. The use of a busway for emergency travel is common, but must be carefully coordinated to ensure safe passage for both emergency and transit vehicles. There may be benefits to allowing emergency vehicles to use the busway for more direct travel routes to respond to emergencies.

### 7.5.2 POLICY AND ROLES

ConnDOT will develop a policy for the use of the busway for non-busway related travel. The initial policy when the busway opens will be that no non-busway travel is allowed, which will be reviewed within six months for emergency services.

### 7.5.3 ISSUES AND FOLLOW-UP

- To allow the use of the busway by emergency vehicles a policy must be developed defining the conditions during which non-busway vehicles may travel on the busway.
- Operations and safety aspects of operating non-transit vehicles that may not be equipped with AVL systems or have direct contact with the Central Operating Organization should be determined.

## 7.6 Restricting Access to Busway

### 7.6.1 DISCUSSION

As a limited-access state highway intended only for the use of buses, regulations must be enacted to prohibit its unauthorized use. The best means of establishing a legal basis for restricting the busway only to buses and a mechanism for enforcement is likely in the form of state legislation making it illegal to operate an unauthorized vehicle on the busway and setting a specific fine for violating this regulation. Existing legislation may be in existence that would cover the issue of unauthorized access to the busway, such as laws banning unauthorized entry.

#### 7.6.2 POLICY AND ROLES

ConnDOT will be responsible for taking the appropriate steps necessary to enact legislation establishing a violation and fine for unauthorized use of the busway.

#### 7.6.3 RECOMMENDATION

- There may be laws already on the books that could be used to provide this enforcement tool.

## 7.7 Multi-Use Trail Security

#### 7.7.1 DISCUSSION

The mixed use trail that parallels the busway from New Britain to Newington Junction requires security services. Almost all of the trail is either within view of the busway or of adjacent businesses and residences which will provide passive surveillance. In some places a more active presence might be necessary to provide a sense of security to trail users. Response to any incidents is necessary. Security patrols and emergency services along the trail will be the responsibility of municipal police, coordinated with the Central Operating Organization.

#### 7.7.2 POLICY AND ROLES

Each municipality will provide security and emergency services along the trail within their respective boundaries. COO will support with reports from bus operators and monitoring by security cameras.

## 7.8 Fare Enforcement

#### 7.8.1 DISCUSSION

With a proof-of-payment (POP) fare collection system, the busway will require consistent enforcement efforts to discourage fare evasion. POP fare collection requires a transit rider to purchase and validate a ticket prior to boarding a transit vehicle. Proof-of-payment fare collection serves as alternative to barrier-entry systems (turnstiles), where a rider must pay before entering the transit vehicle boarding area. These payment systems are especially popular on light rail systems and BRT systems where boarding platforms are generally open to the street, making the installation of turnstiles impossible.

Fare collection procedures represent a balance of positive public perception and revenue maximization. A decision is required of whether to emphasize a friendly, open atmosphere where fare violations – intentional or not – are tolerated to encourage higher ridership or whether to implement a more rigid, disciplined policy that emphasizes revenue over ridership. In either case, the authority to enforce fare regulations and to punish violations is intended to minimize revenue loss from intentional violators. A survey of North American transit agencies conducted by York Region Transit found that those using proof-of-payment systems generally experienced fare evasion rates of between 1 and 2 percent, with a 5 percent inspection rate (where 5 percent of all transit riders are checked for valid fares) providing an optimum balance between the cost of enforcement and additional revenue collected.

Fare enforcement is provided for in a wide variety of arrangements on different busway systems in the United States and Canada. Generally, in cases where a busway operates exclusively within one municipality the municipal police provide fare enforcement under contract with the transit authority operating the busway. Where multiple jurisdictions are involved the transit agency provides enforcement through its own police force, or with contracted security or operations personnel. In some cases, such as in Los Angeles, fare enforcement is provided by a regional law enforcement agency under contract with a transit authority.

A legal basis for enforcing the POP fare system must be established. The Connecticut State Legislature will need to create a violation and fine for riding transit without paying the proper fare, if no such legislation already exists.

#### 7.8.2 POLICY AND ROLES

The Transit Unit of the Connecticut State Police will be responsible for fare enforcement on the busway. ConnDOT will be responsible for working with the State Legislature to establish a legal basis for the POP fare system.

#### 7.8.3 ISSUES AND FOLLOW-UP

- Since it passes through multiple municipalities an appropriate multi-jurisdictional law enforcement agency will be required to enforce fare collection on the New Britain-Hartford Busway.
- If the Transit Unit is not established, ConnDOT, with the involvement of the Transit Operations and Safety and Security Subcommittees will determine the best means of providing fare enforcement.

## 7.9 Security Training and Procedures

#### 7.9.1 DISCUSSION

To successfully implement a comprehensive set of safety and security procedures for the busway requires an equally comprehensive training program for those who must respond to incidents. Procedures and training must be developed for all busway security functions in advance of the opening of the busway.

#### 7.9.2 POLICY AND ROLES

ConnDOT will develop a training program for all police, fire, and emergency services personnel who will provide services to the busway. Such training will familiarize emergency service personnel with the physical layout of busway facilities, as well as with busway operations and service patterns.

#### 7.9.3 ISSUES AND FOLLOW-UP

- To assist in the process of planning and training for safety and security issues FTA offers resources and assistance with transit safety and security issues, which should be utilized. It will also be helpful to present a series of case studies from the issues faced by other busway systems.
- Agencies develop crisis management protocols for addressing safety and security incidents and prepare for circumstances, however unlikely.
- Drivers may be considered an element of the safety and security function, extending their role to include the detection of and communication to security of suspicious activity.
- Successfully addressing safety and security along the busway requires building on existing local organizations, such as police, fire and EMS.

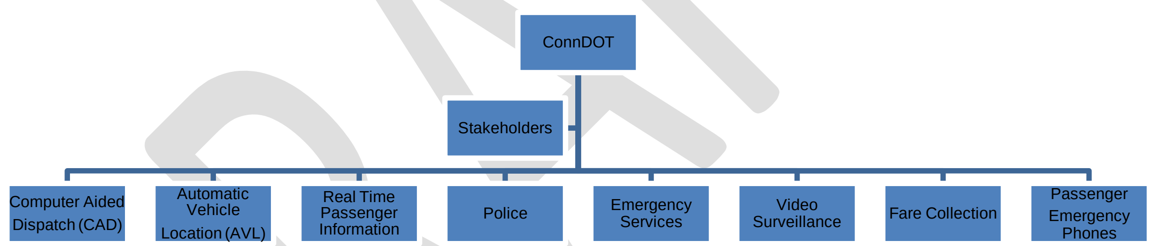
- Ensuring the implementation of these tasks will be the responsibility of the Safety and Security Subcommittee, which will facilitate continued coordination through opening day.

# 8. INTELLIGENT TRANSPORTATION SYSTEMS (ITS)

The fourth major focus area addressed by this operations plan is in intelligent transportation systems (ITS). The various technologies that make up this subject area allow for a wide array of services important for successful busway operations. One issue, common to all operations plan subject areas, is that the busway passes through multiple jurisdictions; coordination, therefore, is critical to the success of the busway. ITS technologies will enable the rapid distribution of accurate information on all aspects of busway operations. Also, since multiple operators will use the busway, their communications systems and information technology must be compatible with that used by the Central Operating Organization (COO), the Busway Maintenance Organization (BMO), and state, local and Amtrak police and emergency services. The importance of this coordination cannot be underestimated; it forms a backbone on which all other aspects of operations will depend.

Several technologies are involved in the implementation of a successful ITS strategy for the busway, including computer-aided dispatch (CAD), automatic vehicle location (AVL), real-time station information, real-time internet and phone access, 511 coordination, emergency station phones, fare collection, surveillance, and traffic signals. All of these technologies are united by a common goal of keeping busway service safe and convenient, and will be discussed individually in the following paragraphs.

**Figure 5: ITS Organization Chart**




## 8.1 Computer-Aided Dispatch (CAD)

### 8.1.1 DISCUSSION

Tying all of the various ITS functions together will be the central dispatch and communications system, operated by the COO. This system will serve as an umbrella for many operating functions and be capable of communicating with local street dispatch functions and with all of the operators who will use the busway. All dispatch and communications equipment and procedures must be compatible across all operators.

Most bus routes traveling over the New Britain-Hartford Busway will operate off of the busway for part of their journeys, serving important destinations that are not located near a busway station. Several different ConnDOT operating contractors will operate these services, each of which currently dispatches their own vehicles. When service on the busway is inaugurated, this system will remain in place for local street operations, but a new central busway dispatch control center will be implemented to coordinate services on the busway. Buses will continue to be dispatched as they are now off the busway, but will transfer to the busway operations center as they enter the busway. COO dispatchers will be able to track all buses using the busway throughout their journeys. This will enable them to determine when a bus will enter the busway and whether it is on-time, late, or early and in need of operational intervention. If desired, contractors will also be able to determine where vehicles are via access to a CAD computer display, but will only have access to information on buses that they are directly operating.

Since the busway operations center will be equipped with CAD, all busway buses will be required to be equipped with AVL. Since the busway will be served by a dedicated fleet of stylized 40-foot and articulated vehicles, this will not present a significant challenge. The fleet of 45-foot buses that provide park-and-ride service beyond New Britain will also be equipped with AVL.

#### 8.1.2 POLICY AND ROLES

The COO will be responsible for operating and maintaining the CAD system and for assuring that all operators on the busway follow correct procedures.

#### 8.1.3 ISSUES AND FOLLOW-UP

- The decision of what organization will be designated as the COO and where the operations center will be located will be decided over the next 24 months as the system is designed. Once the design is complete, the organization designated, and the location determined, the CAD system can be procured and installed.
- The ITS Subcommittee will provide input and feedback in the process and a sizable group of ITS users, service providers and vendors will have to coordinate the many technologies and standards involved.
- The BMO will also provide support functions for various maintenance requirements.
- The goal of the operations plan in this subject area is to provide a multi-faceted program with state-of-the-art ITS systems, one which supports the operations, facility maintenance, and safety and security components of the plan.

## 8.2 Automated Vehicle Location (AVL)

#### 8.2.1 DISCUSSION

To effectively take advantage of the benefits of central CAD on the busway, all vehicles traveling on it must be equipped with AVL. In addition to CAD, AVL is a means of determining a transit vehicle's location for reliability management, scheduling, real-time information and emergency services purposes. For buses this is typically achieved through the use of global positioning system (GPS) receivers located on each vehicle. AVL provides a vehicle's location to central dispatch, which can use that information to direct drivers to speed up, hold back, or turn short in case of delays, to add extra buses into service in case of unusual demand or long delays, to coordinate and direct emergency services if need be, or to update passengers waiting at stations. AVL is also used for on-board passenger information systems, announcing next stops and arrival times based on a vehicle's current location. These automated stop announcements increase passenger comfort with riding transit, reduce the need for operators to shift their attention to making announcements, and address Americans with Disabilities Act requirements.

Non-revenue vehicles such as maintenance trucks, tow trucks, and security patrol cars will also be equipped with the same AVL equipment as the busway bus fleet so that the dispatcher is aware of their locations.

#### 8.2.2 POLICY AND ROLES

- The CBO will be responsible for operating the busway AVL system and assuring that all operators maintain their equipment in good working order. All buses using the New Britain-Hartford Busway will be equipped with an AVL system compatible with the Computer Aided Dispatch (CAD) system. This will allow all vehicles to be tracked by the Central Operating Organization as they move along the busway. ConnDOT will take responsibility for designing, procuring, and installing the AVL system.

#### 8.2.3 ISSUES AND FOLLOW-UP

- It is important that the equipment selected is compatible with other ITS technologies chosen for the operations center, real-time station monitors, TSP and other ITS features that depend on AVL for functional data, and vehicles.
- These compatibilities will be worked out over the next 12 months as the busway ITS plan is completed. ConnDOT and the COO will work with transit providers using the busway – CTTRANSIT, New Britain Transportation, and DATTCO, among others – to develop the best possible system.

## 8.3 Real-Time Passenger Information

#### 8.3.1 DISCUSSION

Real-time passenger information systems provide travelers with an up-to-the-minute status of the arrival of their buses. This gives them the ability to better use their time, make alternate plans if need be, and provides the peace of mind to know that their bus is coming. Closely linked with the implementation of AVL is its coordination with station displays, internet, and phone systems, such as 511 systems, to provide real-time information to the public. This is especially important to maintain the image of the busway as a convenient and reliable mode of transport, one where passengers have up-to-the-minute information on the status of their services. Many options exist for the distribution of travel information, with a range of customization available. One emerging service, Google Transit, provides online maps and schedule information for several transit systems across the United States, and is an excellent example of the pace of this rapidly advancing area of transit information.

The real-time information system must have access to the schedule database for all operators' services so that accurate information can be provided to the public. This will require the development of a central schedule coordination entity, likely the COO.

##### *8.3.1.1 Telephone and Internet Information*

The busway will use the latest telephone and internet info services, linked to CAD/AVL. The implementation of telephone and internet access to real-time information on the busway will coordinate AVL data with telephone and internet systems, such as the ConnDOT traffic website or the announcements section of the CTTRANSIT webpage. The system will also transmit data directly to PDAs. A traveler information telephone number, commonly 511, has gained widespread use in many states – including Massachusetts, Rhode Island, and New York -- as an easily remembered source for traveler information. Such a system could be implemented in the Hartford region or statewide to provide passengers with more information when making travel decisions. Interoperability is crucial, as it will be necessary for to feed accurate, timely transit data to the system according to a prescribed 511 interface format.

#### *8.3.1.2 Real-Time Information Displays*

At stations, ITS technologies will be used to provide updates and information to waiting passengers via electronic displays on each platform. These transit traveler information systems directly impact the quality of the customer service experience and reducing uncertainty. The necessary equipment at stations includes, at minimum, a public address system and electronic display. These may also be used for emergencies, general announcements, and for service updates and planned changes.

### 8.3.2 POLICY AND ROLES

ConnDOT will develop and procure the real-time passenger information as part of the process of designing CAD/AVL and other systems on which it relies for data. The system will be operated by the Central Operating Organization.

### 8.3.3 ISSUES AND FOLLOW-UP

- In addition to regular automated updates on vehicles status, COO dispatchers will enter appropriate messages related to delays, service changes, construction, public events and other subjects as necessary.
- ITS features will be capable of interfacing with devices providing information to the public.

## 8.4 Emergency Phones

The provision of emergency phones on station platforms gives waiting passengers a means of contacting 911 immediately in case of emergency, expediting rapid response to any issues that may arise. Emergency phones also provide an added level of comfort for riders, making it clear that any emergencies will be responded to quickly and efficiently.

### 8.4.1 POLICY AND ROLES

The COO will monitor the emergency phone system to be sure it is operating properly and to track when calls are made. All calls will be answered by 911 operators. If an actual emergency is reported, the COO will coordinate with emergency services personnel to assure a prompt response.

### 8.4.2 ISSUES AND FOLLOW-UP

- Emergency phones will be provided at both platforms at every busway station.
- These phones will be accessible to passengers, who will be able to communicate directly with 911 operators.
- In certain cases, emergency phones may be desirable in parking lots if they are not easily monitored from public areas.

## 8.5 Fare Collection

### 8.5.1 DISCUSSION

Many modern transit systems rely on the proof-of-payment (POP) system to provide efficient fare collection. This system relies on ticket vending machines installed at stations to sell tickets and sometimes passes as well. By asking passengers to buy tickets in advance, boarding takes less time and occur both at the front and rear doors, reducing dwell time and increase average travel speeds. This reduction in travel time results in a reduction in operating cost and an increase in total ridership. POP requires robust ticket vending machines (TVM) be installed on station platforms, able to withstand the elements, hard use, and vandalism. These machines have been in use at other transit authorities for decades and have reached a high level of refinement. Various levels of complexity are possible, from single ticket vending to a full range of tickets and passes for multiple operators and from cash only machines to cash, credit, and debit card machines. It also requires roving ticket inspectors to check tickets and passes to discourage fare evasion.

The busway fleet will be equipped with fare boxes to collect fares at stops off of the busway to act as back-up in case of failure of both of the TVM's at any particular station.

#### 8.5.2 POLICY AND ROLES

The New Britain-Hartford Busway will rely on proof-of-payment (POP) fare collection to speed fare collection and reduce running times, increasing the productivity of the service provided. ConnDOT will develop and procure the POP system equipment as part of the development of other ITS features. The COO will monitor ticket vending machines, stock them with tickets, remove cash, and respond to issues related to machines being out-of-service.

#### 8.5.3 ISSUES AND FOLLOW-UP

- It is necessary to connect ticketing machines with the COO and to the BMO to monitor their use and repair status.
- In the event of a ticket vending machine malfunction or tampering, the COO will notify the appropriate parties – the BMO or law enforcement – who can assess the situation and take necessary remedial action.
- In the event of a significant malfunction or outage it will be necessary to inform drivers and fare inspectors of the problem to avoid unwarranted fines.

## 8.6 Safety and Security

#### 8.6.1 DISCUSSION

The busway will be equipped with a variety of security features, such as closed-circuit video surveillance and emergency alarms. These features will be connected with the Central Operating Organization, which can monitor and respond to incidents in a timely manner, communicating with police, fire and EMS personnel as needed.

#### 8.6.2 POLICY AND ROLES

Security cameras will be located at places where accidents or criminal activity may occur, such as stations, and parking lots, and at locations where monitoring of the busway operations is important, such as the roadway where it passes through stations and the entrances and exits to the busway. Security cameras and alarms will be monitored by the COO dispatchers at the busway operations center, who will respond as necessary to road operations, police or emergency services, and busway maintenance.

## 8.7 Traffic Signal Systems

#### 8.7.1 DISCUSSION

Transit signal priority (TSP) and signal optimization allow for more reliable service by synchronizing traffic signals at grade crossings along the busway to ensure a smooth progression of buses, minimizing delays while also providing for conflicting vehicle movements. TSP is a cost-effective means of providing for the needs of both buses and vehicles crossing the busway.

As applied to the busway, TSP will be similar to railroad crossing signals, where approaching buses will be given green signals at the cross street allowing them to proceed without delay. Unlike rail signals, this will not be unconditional priority. If cross street traffic has not been given a certain minimum amount of green time after the previous bus has passed, the next approaching bus will wait unit this has happened.

While effective, coordinating signals along the busway requires a close working relationship with the traffic authority in each municipality where grade crossings exist, as well as with the ConnDOT traffic engineering division. A new signal system will be designed to meet the requirements of the busway while accommodating existing signalization at adjoining intersections and providing for preemption by emergency service vehicles.

To implement TSP in the busway corridor it is necessary to consider four components of the technology: a detection system (often provided by AVL); a priority request generator; priority control strategies; and control management software. Each piece of this system will require consultation with vendors and with users to choose the most appropriate combination of solutions for the busway. Since all of the intersections being equipped along the busway are new, the sometimes complicated issue of interfaces between different manufacturers equipment will not be a problem.

Implementing a traffic signal strategy for the busway also includes coordinating existing crossings currently used by Amtrak. At two crossings existing Amtrak railroad signals will be coordinated with busway operations. This coordination is critical to prevent buses operating on the busway from conflicting with oncoming Amtrak trains while turning.

#### 8.7.2 POLICY AND ROLES

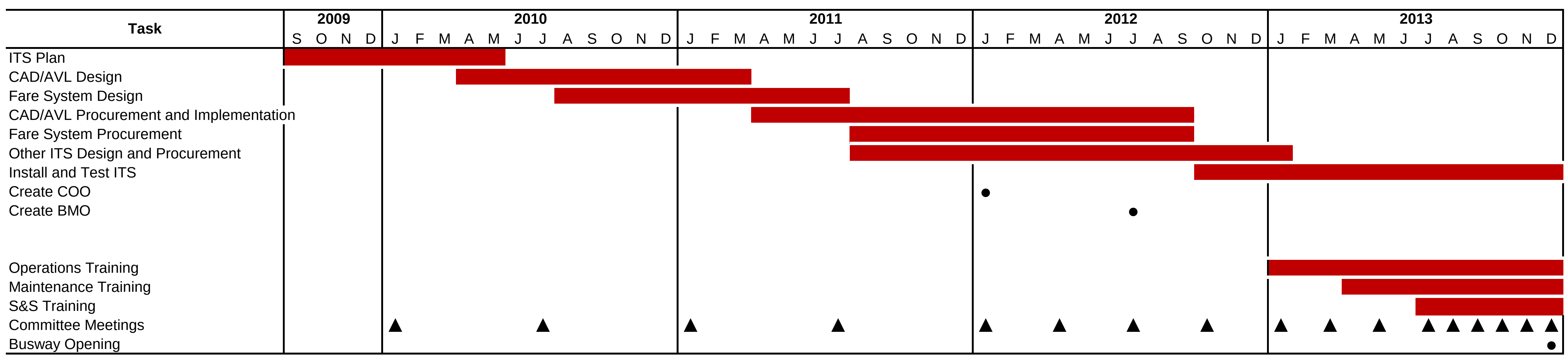
The New Britain-Hartford Busway will use transit signal priority technology at locations where the busway crosses public streets. The system will give busway buses priority over cross street traffic within certain limits, avoiding undue delays to general traffic.

ConnDOT will be responsible for designing the TSP system in cooperation with the operating contractors and local municipalities and will procure the equipment and have it installed as part of the construction of the busway. The operation and maintenance of the line-side elements of the TSP system will be the responsibility of ConnDOT Highway Operations in their role as maintainer of the busway roadway, in cooperation with municipal signal maintainers. On-vehicle system maintenance will be the responsibility of the individual operating contractors. Amtrak will be responsible for maintaining all railroad grade crossing equipment on their property.

#### 8.7.3 ISSUES AND FOLLOW-UP

- The TSP system will interact with the CAD and AVL systems and will need to be developed in coordination with them as part of the busway ITS plan.

# APPENDIX A: BUSWAY OPERATIONS PLAN IMPLEMENTATION SCHEDULE


Task
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2010
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S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
ITS Plan
CAD/AVL Design
Fare System Design
CAD/AVL Procurement and Implementation
Fare System Procurement
Other ITS Design and Procurement
Install and Test ITS
Create COO
Create BMO
Operations Training
Maintenance Training
S&S Training
Committee Meetings
Busway Opening

# APPENDIX B: PRIMARY BUSWAY RESPONSIBILITIES MATRIX

IBI GROUP

**DRAFT - Primary Busway Responsibilities - DRAFT**

Organizations

COO – Central Operations Organization

BMO – Busway Maintenance Organization

ConnDOT – Connecticut Department of Transportation

| Subject Area | Activity | Tasks | Schedule | Responsible Organization | Support Responsibility | Issues and Dependencies |
|---|---|---|---|---|---|---|
| Operations | Central Dispatch | • Monitor operations along the busway for both revenue service and maintenance vehicles<br>• Manage busway service quality<br>• Turn back and add trippers as needed to maintain headways<br>• Coordinate response to issues<br>• Respond to incidents<br>• Respond to emergencies<br>• Communicate with all busway users<br>• Coordinate with Amtrak/rail operators<br>• Establish and oversee work zones | On-going | COO | | • Dispatch of multiple operators<br>• Communication with multiple operators<br>• Need for vehicles equipped with AVL and communications system<br>• Dispatch control of non-transit vehicles using the busway<br>• Location of dispatch center<br>• Potential decisions to update full fleet dispatch and AVL system for CT Transit Hartford and other operators. |
| Operations | Radio System | • Radio systems for operator-dispatch, supervisors, maintenance personnel | | COO | | • Design radio system to meet the communications needs of the operation.<br>• Provide recording system of all radio and phone communication. |
| Operations | Field Supervision of Operations | • Observe operations along the busway<br>• Manage busway service quality<br>• Carry out dispatch instructions "on the ground"<br>• Respond directly to incidents<br>• Respond directly to emergencies<br>• Communicate with drivers | | COO | | • Supervision of multiple operators<br>• Common operations procedures<br>• Interface of busway and roadway operations |
| Operations | Traffic Signal Priority | • Assist with development of practical and effective busway traffic signal system<br>• Train staff in its use<br>• Maintain equipment (suggest delete this bullet as it's covered in Maintenance) | | ConnDOT | Municipalities, Amtrak | • Busway grade crossing signals<br>• Busway entrance exit signals<br>• Coordination with Amtrak<br>• Interconnect with nearby intersections<br>• Standard Conn. state/local practices<br>• Pedestrian signals<br>• Roadway ownership across intersections |
| Operations | Fare Policy | • Develop fare policy for busway services<br>• Design fare collection system to implement policy | | ConnDOT | | • Cost recovery expectations<br>• Overall system fare policy integration<br>• Goals and objectives |

| Subject Area | Activity | Tasks | Schedule | Responsible Organization | Support Responsibility | Issues and Dependencies |
|---|---|---|---|---|---|---|
| Operations | Fare Collection System Operation | • Assist with system design<br>• Support procurement of and installation of equipment<br>• Perform day to day servicing such as ticket refilling and cash removal<br>• Enforcement of fare rules<br>• Vault/secure room for counting and storage of cash<br>• Monitor revenue collection vehicles | | ConnDOT, COO | Operators | • Procurement of equipment is based on the fare collection policy established for the busway. (Long lead time required.) Considerations include:<br>o System cost<br>o Impacts on operations, dwell time, etc.<br>o Impacts on revenue, yield management, fare evasion, etc.<br>o Equipment selection<br>o Enforcement issues and difficulties |
| Operations | Service Plan Integration | • Coordinate service planning for routes and schedules for all bus services using the busway | | COO | ConnDOT, CT Transit Hartford, NBT, DATTCO, CCSU | • Central service planning is required for the busway to operate at maximum efficiency. For instance various operators should schedule their services to provide consistent headways along the busway and to make connections between routes as short as possible |
| Operations | Private Operator Access Policy | • Determine practicality of allowing non-public bus services to use busway<br>• Determine desirability of allowing non-public bus services to use busway | | ConnDOT | | • Purpose and need<br>• Cost and benefits<br>• AVL requirements<br>• Communication system requirements |
| Operations | Station Operations | • Develop procedures for stopping at stations, layover, parking locations and use of driver break rooms, etc.<br>• Implement and enforce procedures through field supervision | | COO | | • Location of route terminals<br>• Operators using station<br>• Space available at each station for layover and demand fort that space<br>• Primary operator of stations<br>• Coordination with station maintenance organization |
| Operations | Performance Monitoring | • Monitor service levels<br>• Operating and capital improvements<br>• Community outreach and liaison<br>• Staffing requirements – positions and no. of personnel<br>• Special event coordination | | COO | ConnDOT, Operators | • Ensure quality service through ongoing monitoring for busway operation |
| Operations | Operations Training and Procedures Development | • Develop written operations material and standard procedures<br>• Train staff in their respective areas of responsibility | | COO | Operators | • The development of written operations material and standard procedures will occur with support from the various transit operators using the busway |
| Maintenance | Roadway Maintenance | • Roadway surface maintenance<br>• Maintenance of guiderails, curbs, signage and other physical infrastructure<br>• Maintenance of lighting<br>• Maintenance of signals, transit priority, and related equipment<br>• Snow removal | | ConnDOT | | • Busway is considered a Connecticut State Highway.<br>• Standard highway maintenance procedures including procedure for transitions between state and municipal ownership will be in effect. |

| Subject Area | Activity | Tasks | Schedule | Responsible Organization | Support Responsibility | Issues and Dependencies |
|---|---|---|---|---|---|---|
| Maintenance | Station Maintenance | • Development maintenance procedures<br>• Maintain platforms<br>• Maintain shelters<br>• Maintain lighting, communications, cameras, real time passenger information and other electrical services<br>• Maintain and update signage<br>• Snow removal from platforms<br>• Regular servicing of stations including trash removal, replacement of consumables, graffiti removal and so on. | | Busway Maintenance Organization (BMO) | | • Busway stations are generally maintained by the primary operator of the busway service. This removes any organizational barriers between the operator, who is responsible for the overall passenger experience and the maintenance of the facilities that those passengers use. |
| Maintenance | Parking Lots and Driveways | • Maintain parking lot and driveway surface<br>• Maintain lighting, signage, and landscaping | | BMO | | • Another party could be responsible for routine station maintenance of New Britain station.<br>• It must be determined if it is cost effective for BMO staff to perform maintenance duties or to contract all or portions of the duties to an outside third party. |
| Maintenance | Traffic Signal Coordination and Priority | • Develop transit signal priority protocols and design signal system for all busway interface locations with the public road system<br>• Procure compatible equipment and software<br>• Develop maintenance procedures<br>• Maintain equipment on an on-going basis | | ConnDOT and Municipalities | Amtrak | • Coordination between ConnDOT and municipalities on signal maintenance will follow standard procedures for the intersection of state and local roads.<br>• Busway grade crossing signals<br>• Busway entrance exit signals<br>• Coordination with Amtrak<br>• Interconnection with nearby intersections<br>• Pedestrian signals<br>• Roadway ownership across intersections |
| Maintenance | Parallel Busway/Railroad Crossings | • Periodic and corrective maintenance of grade crossings<br>• Coordination with Amtrak | | Amtrak | | • Should responsibility be assigned to Amtrak? |
| Maintenance | Structures | • Periodic and corrective maintenance of busway structures | | ConnDOT | | • |
| Maintenance | Ticket Vending Machines and Fare System | • Procure compatible equipment and software<br>• Develop maintenance procedures<br>• Maintain equipment on an on-going basis<br>• Perform regular services including preventive maintenance, ticket stock replenishing, and cleaning. | | BMO | | • Training on equipment maintenance and servicing can only be completed after equipment has been procured. Different types of equipment, such as paper ticket vendors, magnetic stripe vendors and readers, and smart card readers can have very different maintenance needs. |
| Maintenance | Radio System Antennas and Equipment | • Maintenance of off-site communication infrastructure | | COO | | • |
| Maintenance | Maintenance Procedures and Training | • Develop procedures and training programs for all busway maintenance functions including safety training | | ConnDOT and BMO | Municipalities | • Signal system maintenance training will be the responsibility of the organizations responsible for signals, ConnDOT and the municipalities<br>• Training for vehicle maintenance will be the responsibility of the owning operators<br>• Final development of training programs will be completed in cooperation with equipment manufacturers |

| Subject Area | Activity | Tasks | Schedule | Responsible Organization | Support Responsibility | Issues and Dependencies |
|---|---|---|---|---|---|---|
| Safety and Security | Patrol of Busway Roadway | • Provide security patrols and emergency response services along the busway roadway<br>• Enforcement of traffic laws on cross-street and in station areas, especially at grade crossings | | Connecticut State Police | Municipal Police | • As an official state highway, police jurisdiction along the busway resides with the Connecticut State Police, supported by local municipal police.<br>• Amtrak has a police force that performs security duties on Amtrak property which parallels the busway<br>• Will need active and ongoing coordination among the police agencies |
| Safety and Security | Patrol of Busway Stations and Parking Lots | • Provide security patrols and emergency response services at busway stations and parking lots | | COO | Municipal Police | • Busway station security is generally provided by the transit agency either through a transit police force or a private security firm. The same is generally true of train stations on light rail transit systems. |
| Safety and Security | Video Surveillance | • Install and monitor closed-circuit video surveillance to supplement physical patrols | | COO | | • The COO will monitor surveillance cameras and coordinate with appropriate law enforcement personnel when necessary.<br>• Since the busway will not be in continuous daily use it will be necessary to assign surveillance responsibility during off hours. |
| Safety and Security | Emergency Services Jurisdiction | • Provide emergency service (fire, ambulance, paramedics) response to busway in case of accident, fire, natural disaster, or other emergency. | | Municipal emergency service providers | | • Each municipality would respond to emergencies within their boundaries along the busway. |
| Safety and Security | Use of Busway by Emergency Vehicles | • Develop a policy for allowing emergency vehicles to use the busway under certain conditions for non-busway related travel. | | ConnDOT | | • There may be benefits to allowing emergency vehicles to use the busway for more direct travel routes in respond to emergencies not directly related to the busway. Operations and safety aspects of operating non-transit vehicles that may not be equipped with the busway's AVL and dispatch system need to be determined. |
| Safety and Security | Restricting Access to Busway | • Establish the legal basis for limiting the busway to buses only | | ConnDOT | | • The legal basis for restricting the busway to buses only and for enforcing this restriction must be established. This will likely take the form of state legislation making it illegal to operate an unauthorized vehicle on the busway and setting a specific fine for violating this regulation. |
| Safety and Security | Multi-Use Trail Security | • Provide security patrols and emergency response services along the multiuse trail. | | Municipal Police | COO | • Each municipality would provide security services within its boundaries. |
| Safety and Security | Fare Enforcement | • Establish a legal basis for fare enforcement on the busway, with penalties for violations<br>• Patrol busway buses and stations checking passengers for proper fare payment | | CT State Police Transit Division | | • Fare enforcement is provided by a wide variety of arrangements at different busways around the United States and Canada. Generally where the busway travels through a single jurisdiction only the police force of that municipality provides fare enforcement under contract to the transit agency. Where multiple jurisdictions are involved, the transit agency provides the service through its own police, security or operations personnel. In some cases, e.g., Los Angeles, fare enforcement is provided by a regional law enforcement agency under contract to the transit agency.<br>• The New Britain Hartford Busway covers multiple jurisdictions making a model where the transit agency, or in this case the central busway operator, a more efficient option for fare collection.<br>• Fare collection procedures are to some extent a matter of marketing and image, with the decision of whether to portrait an open and friendly atmosphere that might lead to less fare revenue but more ridership, or a more disciplined approach with more revenue but lower ridership. |

| Subject Area | Activity | Tasks | Schedule | Responsible Organization | Support Responsibility | Issues and Dependencies |
|---|---|---|---|---|---|---|
| Safety and Security | Security Training and Procedures | • Develop procedures and training programs for all busway security functions | | | ConnDOT, State Police, Municipal Police | • Provide training for all police, security, and emergency services organizations involved in providing services to the busway including:<br>• Familiarization with physical layout of all busway facilities<br>• Busway operations and expected usage patterns<br>• Integration with surrounding traffic patterns<br>• Issues faced by other busways |
| ITS and Communications | Central-Aided Dispatch (CAD) | • The central dispatch function must be coordinated with local street dispatch functions at all of the operators that use the busway. All dispatch and communication equipment must also be compatible across all operators. | | ConnDOT, COO | CT Transit Hartford, NBT, DATTCO | • The efficient coordination of services amongst multiple operators will require a common ITS and communications system for all operators. |
| ITS and Communications | Automated Vehicle Location (AVL) | • Install and maintain an AVL system for all vehicles that use the busway | | ConnDOT, COO | CT Transit Hartford, NBT, DATTCO | • The busway will use the latest central dispatch technology and methods to assure safe and reliable operations. For this system to work efficiently, all buses that use the busway will need to be equipped with an AVL system that allows them to be tracked by the dispatcher as they move along the busway. |
| ITS and Communications | Real-Time Passenger Information | • Install and maintain real time information displays at stations<br>• PA system for operating and emergency announcements<br>• Coordinate AVL information with publicly accessible telephone (511) and internet systems | | ConnDOT, COO | CT Transit Hartford, NBT, DATTCO | • Real time information displays require the coordination of information arriving from individual vehicles via the central dispatch system and equipment in each station. The system will also need to have access to the schedule of each vehicle trip to be able to determine which trips stop at what stations. The system requires a high level of coordination between all operating entities. |
| ITS and Communications | Emergency Phones | • Install and monitor emergency phone system to be sure it is operating properly and to track when calls are made | | COO | | • All calls will be answered by 911 operators. If an emergency is reported, the COO will coordinate with emergency services personnel to assure a prompt response. |
| ITS and Communications | Fare Collection | • Monitor equipment status and provide regular maintenance | | COO | BMO | • Fare vending machines will be equipped with alarms that sound in the central dispatch center where dispatchers can make local law enforcement aware of the problem location and send repair crews to the scene and notify drivers and fare inspectors aware of the problem. Maintenance will be provided by the station maintenance provider. |
| ITS and Communications | Safety and Security | • The busway will be equipped with a variety of security features such as video cameras and alarms. | | COO | BMO | • Busway security will be monitored at the central dispatch center where dispatchers will coordinate all incidents with the appropriate security or emergency services provider. Maintenance will be provided by the station maintenance provider. |
| ITS and Communications | Traffic Signal Systems | • The busway will include numerous intersections and grade crossing employing sophisticated traffic control systems such as transit signal priority actuated by AVL. | | ConnDOT Maintenance | Municipalities | • Provision of ITS and maintenance functions for the signal system along the busway will be the responsibility of ConnDOT and the local municipality that shares jurisdiction over the busway intersection with the state. |

Connecticut Department of Transportation

# NEW BRITAIN - HARTFORD BUSWAY
# ITS CONCEPT OF OPERATIONS

REVISED FINAL REPORT

OCTOBER 28, 2010

IBI GROUP

# DOCUMENT CONTROL

| | |
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| Project Name: | New Britain - Hartford Busway |
| Report Title: | New Britain - Hartford Busway<br>ITS Concept of Operations |
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| Originators: | James Sorensen, Martin Hull, Margot Danard, Tegin Teich |
| Reviewer: | Martin Hull, Carl-Henry Piel, Ritesh Warade |

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# TABLE OF EXHIBITS



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# 1. INTRODUCTION

## 1.1 Project Background

The New Britain-Hartford Busway was first proposed as part of a major investment study in the I-84 corridor, completed in the late 1990s. Several modes were looked at to reduce traffic congestion and improve transportation services including roadway expansion, light rail, commuter rail and high occupancy vehicle lanes, in addition to the busway. The busway was selected as the locally preferred alternative because of its relatively high ridership and relatively low cost compared to the other alternatives. The busway also provided a number of unique service advantages over other transit options including more frequent service, the ability to provide service to locations not directly on the busway, flexibility to change routes when necessary, and the ability to operate local and express services along the same right-of-way. Intelligent Transportation Systems (ITS) can play an important role in helping bus rapid transit (BRT) systems accomplish the goal of providing high quality, flexible rapid transit service.

## 1.2 Document Purpose & Structure

Consistent with standard Systems Engineering practices, the purpose of the *ITS Concept of Operations* report is to develop a high-level ITS system concept designed to meet the needs of the planned New Britain-Hartford Busway. This report provides a description of existing conditions, documents stakeholder-identified needs, describes the proposed ITS technology and systems to meet those needs, and finally proposes a system architecture showing how all of the existing and new components will function as a complete system. Some recommendations are provided as to what is required to implement, operate, and maintain the BRT system. This document will form the basis for subsequent development of ITS system requirements and detailed ITS system design.

Since its original submission in March of 2010, this *ITS Concept of Operations* report has been updated to reflect the evolving design of the New Britain-Hartford Busway. As design of the busway has progressed, various operational and technological decisions have been made that affect ITS on the busway, and therefore, the contents of this document. The information contained in this report is consistent with the final *Functional Requirements for the New Britain – Hartford Busway ITS & Communications Systems*, also submitted in October of 2011.

This document is structured as follows:

- **Chapter 2: Existing Conditions**
- **Chapter 3: Needs Analysis**
- **Chapter 4: Potential ITS Solutions**
- **Chapter 5: Proposed ITS System**
- **Chapter 6: Operational Scenarios**
- **Chapter 7: Next Steps**

## 1.3 Acronyms and Abbreviations

| | | | |
|---|---|---|---|
| ADA | Americans with Disabilities Act | IVR | Interactive Voice Response |
| AFC | Automatic Fare Collection | LAN | Local Area Network |
| APC | Automatic Passenger Counter | LCD | Liquid Crystal Display |
| APTS | Advanced Public Transportation Systems | LED | Light Emitting Diode |
| ATM | Asynchronous Transfer Mode | MDT | Mobile Data Terminal |
| AVAS | Automatic Voice Annunciation System | MOU | Memorandum of Understanding |
| AVL | Automatic Vehicle Location | MTBF | Mean Time Between Failures |
| AVM | Automatic Vehicle Monitoring | NIC | Network Interface Card |
| BMO | Busway Maintenance Organization | NTCIP | National Transportation Communications for ITS Protocol |
| BRT | Bus Rapid Transit | NTD | National Transit Database |
| CAD | Computer Aided Dispatch | OEM | Original Equipment Manufacturer |
| CCSU | Central Connecticut State University | OVM | On-board Video Monitoring |
| CCTV | Closed Circuit Television | PA | Public Address |
| CMS | Changeable Message Signs | PDA | Personal Digital Assistant |
| COO | Central Operating Organization | POP | Proof of Payment |
| CSP | Connecticut State Police | RFP | Request For Proposals |
| CTDOT | Connecticut Department of Transportation | RTPI | Real-Time Passenger Information |
| DMS | Dynamic Message Sign | SONET | Synchronous Optical Networking |
| DSL | Digital Subscriber Line | TCP | Transmission Control Protocol |
| EMS | Emergency Medical Service(s) | TCRP | Transit Cooperative Research Program |
| FCC | Federal Communications Commission | TOC | Traffic Operations Center |
| FTA | Federal Transit Administration | TSP | Traffic Signal Priority |
| GPS | Global Positioning System | TVM | Ticket Vending Machine |
| GUI | Graphical User Interface | VLU | Vehicle Logic Unit |
| HOC | Highway Operations Center | VMS | Variable Message Sign |
| HVAC | Heating, Ventilation, and Air Conditioning | VOMS | Vehicles Operated in Maximum Service |
| IEEE | Institute of Electrical and Electronics Engineers | VPN | Virtual Private Networking |
| IP | Internet Protocol | WLAN | Wireless Local Area Network |
| ITS | Intelligent Transportation System | | |

# 2. EXISTING CONDITIONS

## 2.1 Busway Overview

The New Britain-Hartford Busway is a 9.4 mile long bus-only roadway running from East Main Street in downtown New Britain to Asylum Street in downtown Hartford. Most of the roadway is two lanes wide, with three or four lane sections at stations to enable buses to pass each other. The busway is built along the former New Britain Secondary railroad between New Britain and Newington Junction and beside the active Amtrak Springfield to New Haven Line from Newington Junction to Union Station in Hartford.

The busway will include 11 stations. New Britain Station at the southwestern end of the busway will have a larger 16 berth transit center due to its location at the hub of New Britain local services. Union Station at the northeastern end of the busway in Hartford will include two shelters on street. The nine through-stations will have two side platforms of approximately 10 feet by 100 feet. Northbound platforms at stations along the Amtrak rail line will only be accessible by crosswalks from the southbound platform to avoid the construction of pedestrian crossings on the rail tracks.

Buses will enter the busway at New Britain Station, East Street Station, Cedar Street Station, at the Oakwood Avenue grade crossing, and at Sigourney Street Station. There is also additional flexibility in the busway physical design to enable buses to enter at Stanley Street, East Main Street, Smalley Street and Newington Junction.

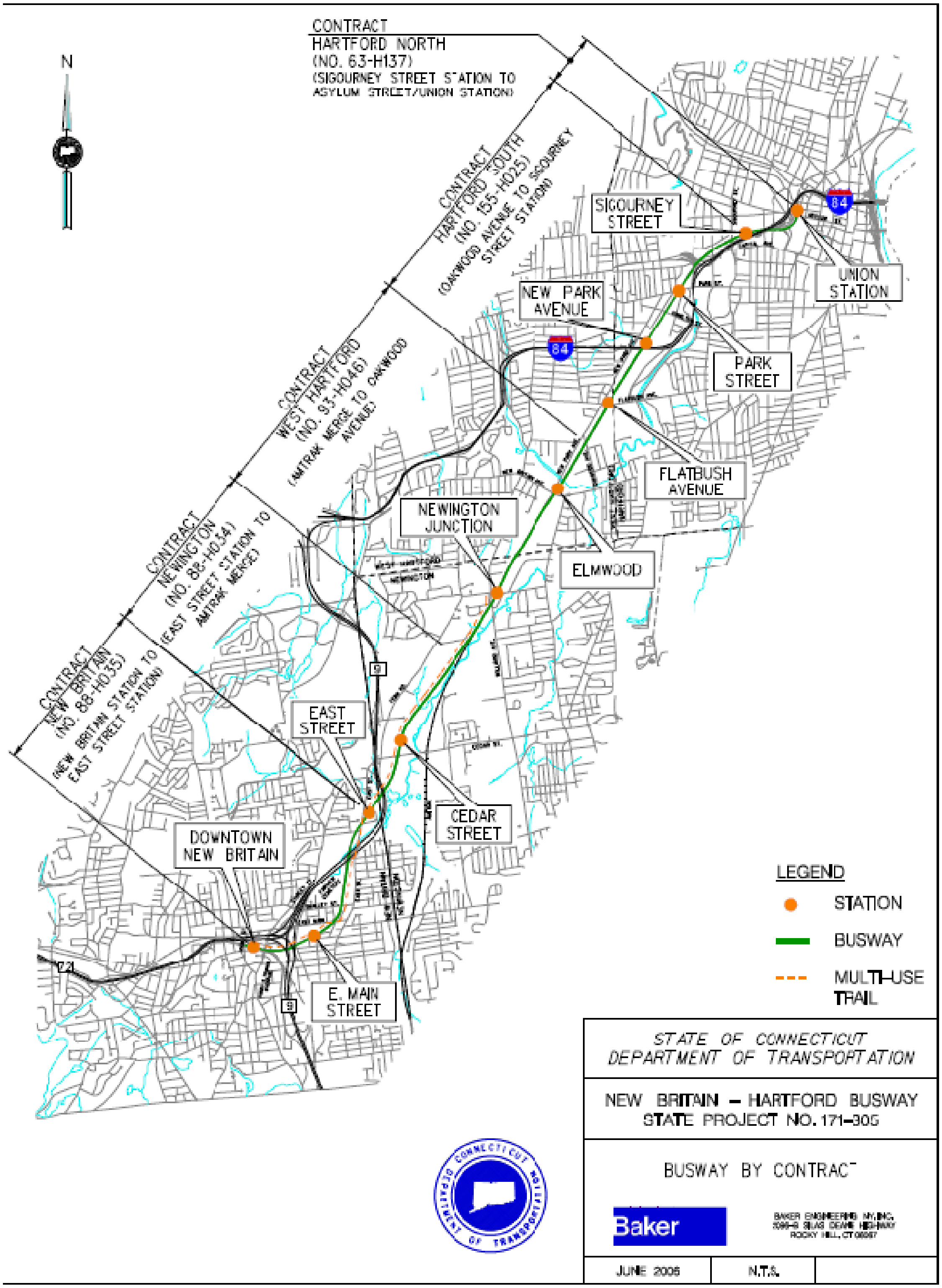
Small park-and-ride lots will be included at East Street, Cedar Street, Newington Junction, Elmwood, Flatbush Avenue, and Parkville.

Although most of the busway will be grade-separated, grade crossings will be located at Stanley Street (New Britain), East Main Street (New Britain), Smalley Street (New Britain), Oakwood Avenue (West Hartford) and Hamilton Street (Hartford). These crossings will be protected by signalized intersections interconnected with the adjacent rail grade crossing.

The busway will also have a single lane section for approximately 1,300 feet starting at Sigourney Street Station and running to Flower Street. This section is required due to space limitations under the I-84 Viaduct at this location.

A map of the overall busway is provided in Figure 1 below.

**Figure 1: Overall Busway Map**



## 2.2 Operations Plan Summary

The Operations Plan[1] sets the overall framework for the busway organizational structure, establishes the organizations that will be involved in creating the final plan, creates a forum for discussion, and sets milestones for its development.

Like the overall CTTRANSIT system, the busway plan has a diverse decentralized structure that builds on the strengths of the many organizations involved. In the case of the busway, this diversity presents operational challenges which will be coordinated through state-of-the-art ITS. The primary recommendations and elements of this organizational structure are:

- CTDOT has been and will continue to be the primary owner and manager of the New Britain-Hartford Busway. They will see the busway project through to completion and will retain ownership after it goes into operation. CTDOT will remain ultimately responsible for the level of service provided, planning of specific services, selecting and coordinating operators, facility maintenance, and community relations.

- Bus service on the busway will be operated by multiple organizations including CTTRANSIT Hartford, CTTRANSIT New Britain through New Britain Transportation, DATTCO, CCSU, and possibly other contract operators for new transit services. Private intercity bus service providers, such as Peter Pan, may also be allowed to operate on the busway at some point in the future. A Central Operations Organization (COO) will be established to dispatch and monitor the busway and coordinate between this diverse set of operators. The COO could be established as a division of CTDOT, could be contracted to one of the operators, or operations could be contracted out to a separate organization similar to the manner in which some traffic operations centers are organized in Connecticut.

- CTDOT will maintain the busway roadway and bridges directly like any other state highway. At stations, the services of a Busway Maintenance Organization (BMO) will be required. Similar to the COO, the BMO is a placeholder for an organizational responsibility that will be assigned to a specific organization (or organizations) as the design and function of the busway are developed. The BMO will be responsible for transit specific aspects of the busway like maintenance and servicing of stations, park-and-ride lots, and technology, as well as for responding to other maintenance issues as they arise. As design proceeds, CTDOT may evaluate providing maintenance services for the busway and stations separate from providing maintenance services for the ITS technology deployed along the busway.

- Safety and security will be provided along the busway roadway, at stations, and on buses by the Connecticut State Police, possibly by the establishment of a new division. Other emergency services will be provided by municipal police, fire and EMS.

The desire of CTDOT and the Operations Committee is to be aggressive with intelligent transportation systems (ITS) features on the busway to provide a high level of active management, monitoring, information provision, and incident response. ITS provides an overarching framework within which to implement many of the recommendations in this operations plan. ITS will support the operations, maintenance, and safety and security functions. The diverse matrix of operating organizations on the busway will present unique challenges to the development of the ITS plan.

Other related issues included in the Operations Plan include vehicle types, scheduling, and central dispatch operations management.

[1] Connecticut Department of Transportation. New Britain – Hartford Busway Operations Plan, Draft Report. August 2009.

## 2.3 Service Plan Summary

The New Britain-Hartford Busway Service Plan[2] describes the bus route network that will use the busway to provide fast, frequent and reliable service in the heavily-traveled New Britain to Hartford corridor. The plan includes both routes that operate on the busway and routes that connect with the busway; building on previous planning that has been completed for the project over the past 10 years.

The goal of the service plan is to create an efficient route structure that attracts the maximum number of riders and provides the highest user benefit for the minimum operating cost. This maximizes the public benefit of the project and ensures a worthwhile long-term investment, critical to securing federal and state funding for the project.

The service plan includes four types of routes: busway local routes, busway express routes, connectors and circulators, and existing local transit routes.

- Busway local routes operate between downtown Hartford and various destinations along the corridor via the busway making stops at all busway stations on their route. There are five busway local routes in the service plan which will typically operate every 12 minutes during peak periods and every 20 minutes off-peak.

- Busway express routes operate between park-and-ride stations located along I-84 and downtown Hartford, Asylum Hill and Capitol Hill, primarily serving long distance commuters to downtown Hartford, but also providing for reverse commuting. There are two busway express routes in the service plan, operating every 30 minutes during peak periods and every 60 minutes off-peak.

- Connectors and circulators are new local transit routes created to link important employers, neighborhoods, and other activity centers to the busway. These routes will serve places such as CCSU, St. Francis and Hartford hospitals, Capitol Hill, West Hartford, Bishop's Corner, and Newington, connecting them to the busway. These routes will typically operate every 15 to 30 minutes during peak periods and every 30 to 60 minutes off-peak.

- Existing transit routes in the CTTRANSIT system will be augmented to best serve the needs of riders. Many existing routes will be modified to serve busway stations. A few routes will be discontinued, shortened, or reduced in frequency where they duplicate new services provided along the busway.

A total of nine existing New Britain area routes and eight existing Hartford area routes are included in the service plan, in addition to existing express services to Bristol and Cheshire.

A new fleet of vehicles will be acquired to implement this service plan. It is expected that 74 vehicles will be required to provide service on the various routes in the busway corridor during peak periods, an increase of 26 vehicles from existing peak vehicle requirements.

The vehicles required to implement the service plan are of various models. Both new and existing vehicles will be used. Four types of vehicles will be used to implement the service plan: 30-foot low-floor buses for connectors and circulators, 40-foot low-floor buses and 60-foot low-floor articulated buses for busway locals, and 45-foot coaches for busway expresses. These provide a variety of features to suit the characteristics of various busway routes.

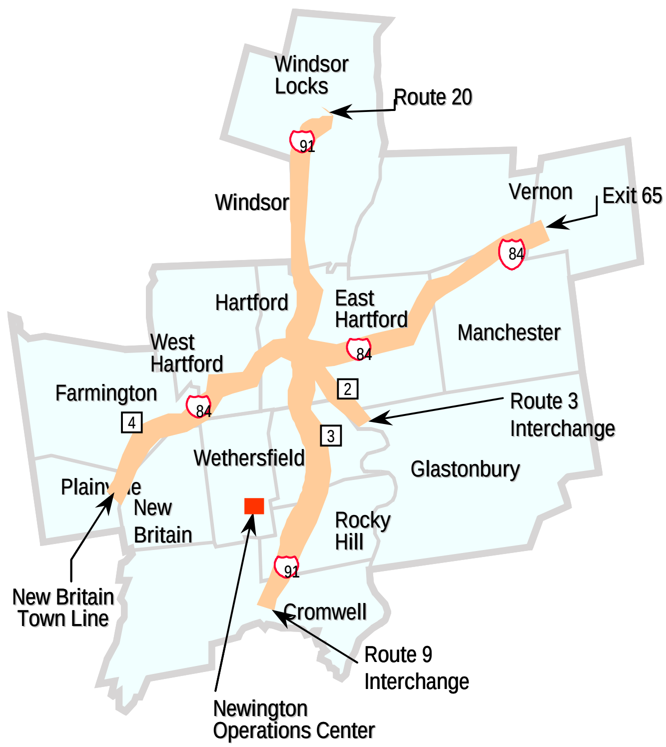
[2] Connecticut Department of Transportation. New Britain – Hartford Busway Service Plan, Draft Report. August 2009.

## 2.4 Existing ITS Infrastructure

CTDOT has deployed a variety of ITS infrastructure in the region, including CCTV (closed-circuit television) traffic cameras, roadside Variable Message Signs (VMS), and Traffic Flow Monitors (radar/microwave detectors). These ITS components are supported by the State's fiber-optic data transport network. The data transport network for the region includes a fiber-optic cable backbone along Interstates 84, 91 and Route 2 in the Hartford area. Figure 2 below shows the project area served by the State's data transport network.

**Figure 2: CTDOT Data Transport Network**

Source: Piel, Decker, Balskus. Development of a Video and Traffic Data Transport System for the Connecticut Department of Transportation. 2001.




The data transport network also connects CTDOT's Highway Operations Center in Newington with the Connecticut State Police (CSP) in Hartford, the City of Hartford's Traffic Operations Center (TOC), the State Police Communications Center in Middletown, and the CTDOT Bridgeport Highway Operations Center. This interagency connection enables the sharing of video and data with the State Police and the City of Hartford. A major fiber hub is located in downtown Hartford, at the intersection of I-91 and I-84, with another fiber access point (splice point) located on Myrtle Street providing a connection to the CSP's Hartford barracks (Troop H).

## 2.5 Related Initiatives

In addition to the busway project, there are several other important transportation initiatives being led by CTDOT that will impact the busway project. These initiatives include:

- **CTDOT Radio System Upgrade:** The current radio system in use by state-owned transit operators is outdated and in need of replacement. CTDOT, in conjunction with the Connecticut Department of Public Safety, is in the process of developing a Statewide Request for Proposals (RFP) which will include replacing this radio system for all eight divisions of state-owned transit. The bandwidth provided by this upgraded radio system should be sufficient for voice communications and some low-speed data transmission. High-speed data requirements will need to be met by other forms of communications, such as cellular communications or wireless broadband.

- **System-wide CAD/AVL System:** CTTRANSIT is in process of developing a specification for a system-wide CAD/AVL system. Moving forward, CTDOT may decide to have the busway's CAD/AVL system interface with or be incorporated into the system-wide CAD/AVL system. For now, the CAD/AVL system described in this report refers only to a stand-alone CAD/AVL system for the busway. If, in the future, CTDOT decides to incorporate the busway's CAD/AVL system into the system-wide CAD/AVL system, then it is assumed that CTTRANSIT and CTDOT will ensure that the new CAD/AVL system can provide the necessary functionality for managing and monitoring multiple operators' vehicles on the busway.

- **Scheduling Software Upgrade:** CTDOT recently upgraded the Trapeze scheduling software for all the transit operators that will be using the busway to Version 9 to assist in scheduling and run-cutting. CTDOT also plans to upgrade the transit operators to Version 11 of the Trapeze scheduling software in the not distant future.

- **Future 511 System:** Connecticut's regional ITS architecture calls for the future development of a 511 traveler information system. A Connecticut 511 system would feature an Interactive Voice Response (IVR) system allowing travelers to use their telephone to access multimodal, real-time traveler information. It is assumed that CTDOT will want the traveler information systems implemented as part of the busway project to eventually serve as one of several inputs into this larger, statewide effort. Busway ITS procurements should not preclude future integration with other CTDOT traveler information systems.

- **Future CTTRANSIT Website Enhancements:** Based on discussions with CTDOT personnel, CTDOT plans to eventually upgrade the CTTRANSIT website to include real-time bus location information. Ideally, CTDOT would like to upgrade the website to include a real-time map of bus locations that could be accessed from personal computers and personal mobile devices. CTDOT is also interested in eventually providing this information to third parties, such as the media and private software developers, in order to disseminate this travel information as widely as possible. Again, it is assumed that CTDOT will want the traveler information systems implemented as part of the busway project to eventually be used as an input into these larger, statewide traveler information efforts. Busway ITS procurements should not preclude future integration with other CTDOT traveler information systems.

- **Future Automatic Fare Collection (AFC):** Based on discussions with CTDOT personnel, CTDOT may eventually modify its fare policy, fare structure and fare media. In the future, smart cards may be used on the New Britain-Hartford Busway, which, linked with AVL and APC data, can provide a rich dataset for analysis. Therefore, when installing an off-board, Proof of Payment (POP)-based AFC system, consideration should be given to the potential integration of these cards without requiring purchase of all new equipment. The system will have to take into account the more complicated interoperability of bringing the data from these multiple sources back to a central point for analysis. CTDOT will also need to ensure that its back-office revenue management system is up-to-date and capable of handling the new AFC system transactions. Because CTDOT has not yet settled on a future fare policy, the system should be installed with adaptability in mind for expansion and redefinition of fare structures. Fare policy decisions should drive technological solutions, and not vice versa. In addition, technology continues to evolve regarding fare media. Smart cards, cell phone payment, and credit cards with smart chips may all evolve into a preferred fare media.

- **WLAN at Garages:** CTTRANSIT is in the early stages of installing a wireless local area network (WLAN) at three garages for an asset management system. CTDOT and CTTRANSIT will investigate whether or not they will be able to use this same WLAN to download bulk data from on-board bus ITS systems for vehicles that operate on the busway.

# 3. NEEDS ANALYSIS

The Federal Transit Administration (FTA) defines Bus Rapid Transit (BRT) as “a rapid mode of transportation that can provide the quality of rail transit and the flexibility of buses”. The Transit Cooperative Research Program (TCRP) paper on BRT (Paper 90)[3] has an expanded definition: “BRT is a flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways, and ITS elements into an integrated system with a strong identity.” Intelligent Transportation Systems (ITS) plays an essential role in BRT deployments. These technologies help BRT systems fulfill their goal of providing high quality, flexible, and attractive rapid transit service to the general public.

Given the ever-evolving nature of transportation technology and federal requirements for utilization of Systems Engineering practices, it is necessary that ITS planning be clearly tied to stated needs and objectives. This allows the ITS planning to adapt as technology improves or as stakeholder needs evolve and change. This section provides a preliminary needs analysis for the New Britain-Hartford Busway project. Potential ITS subsystems will then be identified in subsequent sections in order to address these stakeholder-identified project needs.

## 3.1 Stakeholder Outreach

Early on in the project development process, ITS was recognized as playing an important role in the New Britain-Hartford Busway project. The ITS Draft System Architecture Plan[4] identified the need to consider the following types of ITS components:

- Traveler Information Systems
- Transit Safety and Security Systems
- Fleet Management System
  - Busway Operations Center
  - Automatic Vehicle Location (AVL)
  - Fleet Communication
  - Transit Priority
  - Maintenance Management
  - Intelligent Vehicle System
- Fare Payment Systems
- Data Transmission Systems

In order to further define ITS components to consider and to clarify stakeholder needs, two stakeholder meetings were held on September 25, 2009 and October 22, 2009 respectively in support of this ITS Concept of Operations. These meetings were attended by representatives from CTDOT and CTTRANSIT; public transit operators; public safety officials, including police and fire; and private intercity bus operators. Following these stakeholder meetings, additional meetings and discussions with CTDOT representatives were also held. These stakeholder meetings focused on looking at busway transportation needs from a variety of perspectives and prioritizing these busway

[3] Federal Transit Administration. TCRP Report 90 – Bus Rapid Transit. 2003.
[4] Connecticut Department of Transportation. New Britain Hartford Busway Intelligent Transportation Systems Draft System Architecture Plan. June 18, 2008.

needs. Meeting notes from these stakeholder meetings are including in Appendix A of this document.

## 3.2 Summary of Needs

After a review of previous reports and stakeholder discussions, the following four (4) ITS-related needs have been identified at this time to support the implementation of busway operations:

1. **Operational Efficiency** – Given the service frequency and the multiple transit providers operating on and off the busway, there is a clear and vital need for ITS to assist in improving operational efficiency. ITS systems that can reduce dwell times, improve travel reliability, improve schedule adherence, and enhance operational awareness are desired.

2. **Enhanced Traveler Information** – In order to increase the attractiveness of the busway and encourage ease of use, enhanced traveler information isor submissiondevelop a draft Concept of Operations document.rations.posed technologiesgered after hours would be sufficient. p desired.

3. **Safety and Security** – Passenger safety and the security of transportation infrastructure is an ongoing priority. In particular, systems to monitor the station platforms and the ticket vending machines, as well as provide emergency alerts are desired.

4. **Communications Infrastructure** – Communications infrastructure to support robust and reliable real-time information is necessary to support the busway's desired technologies.

## 3.3 Additional Considerations

In addition to the four (4) general needs identified above, project stakeholders also identified several considerations that should be weighed when identifying potential ITS solutions:

- **Cost** – The cost-effectiveness of potential ITS solutions should to be prioritized to ensure maximum return on investment.

- **Ease of Maintenance** – ITS solutions should be reliable and easily maintained. Where possible, system maintenance activities should not interfere with the typical operation of the busway.

- **Interoperability and Compatibility Issues** – In order to ensure maximum benefit is derived from ITS investments, all solutions should be designed to be interoperable and compatible – allowing data to be freely exchanged among subsystems and for multi-disciplinary and interagency purposes.

- **Scalability and Expansion** – Systems should be designed to be scalable and expandable to adapt to future capacity needs. It is envisioned that the ITS components implemented as part of the busway project can serve as the foundation for additional future transit ITS investments.

- **Provisioning for Future Interfaces** – Where possible, systems should be procured with provisions in place to facilitate future, planned interfaces. Identifying these future interfaces as early as possible helps decrease the likelihood of costly future system modifications.

# 4. POTENTIAL ITS SOLUTIONS

This section describes the potential ITS solutions that may be deployed to address the stakeholders' identified busway transportation needs. It is important to note that ITS does not offer a solution to every need, but rather provides a set of tools to help address some of these transportation needs. ITS elements will need to be integrated into the larger busway and station design process to ensure the seamless provision of services and to ensure that transportation needs are being properly addressed.

## 4.1 Relationship to Needs

Based on the four (4) general needs identified by the project stakeholders, IBI Group has organized the potential ITS solutions into six (6) general categories:

- Transit Management
- Automatic Fare Collection
- Traveler Information Systems
- On-Board Technologies
- Safety and Security Systems
- Communications

Figure 2, below, illustrates the relationship between stakeholder needs and these categories of potential ITS solutions. Subsequent subsections describe these categories in greater detail.

**Figure 3: Stakeholder Needs' Relationship to Potential ITS Solutions**

| Need | Category | Technologies | Description |
|---|---|---|---|
| Improve Operational Efficiency | Transit Management | Computer-Aided Dispatch (CAD) /Automatic Vehicle Location (AVL) | A CAD system manages voice and data communications with vehicles. AVL determines the real-time location of each vehicle. These two technologies combine to improve real-time monitoring of vehicle location, on-time performance and reliability, reduce response time to incidents, and improve fleet utilization. CAD/AVL also supports several other transit ITS applications, such as APC, TSP, and Traveler Information Systems, etc. |
| | | Scheduling Software | Scheduling software assists transit agencies with route planning, restructuring, and run-cutting. As a separate initiative, CTDOT is undertaking procurement of scheduling software for all transit operators that will be using the busway. |

| Need | Category | Technologies | Description |
|---|---|---|---|
| | | Transit Signal Priority (TSP) | TSP alters signal timing to extend green time or provide an early green in order to reduce delay for BRT vehicles. |
| | Automatic Fare Collection (AFC) | Automatic Fare Collection (AFC) | AFC offers several operational benefits, including greater speed of boarding and increased service reliability. Other benefits may include customer convenience, better fare data collection, limited exchange of cash, improved security, and freeing drivers' to focus attention on operations. |
| | On-Board Technology | Automatic Passenger Counters (APC) | APCs automatically count passengers as they board and alight from vehicles. APCs provide data for planning, can improve revenue control, and reduce reporting costs. |
| | | Vehicle Diagnostics & Fleet Maintenance Monitoring | Vehicle diagnostics and fleet maintenance systems use sensors on-board vehicles to monitor vehicle components and alert transit agencies to maintenance needs. |
| Enhanced Traveler Information | Traveler Information Systems | Pre-trip Traveler Information Systems | Pre-trip traveler information systems provide general service information, trip planning, real-time service information, and multimodal travel alternatives. As a separate larger effort, CTDOT is working to enhance provision of pre-trip traveler information through a future 511 system, Google transit, and the CTTRANSIT Website. |
| | | Station Traveler Information Systems | Station traveler information systems provide passengers waiting at the stations with real-time service information. They typically include Variable Message Signs (VMS), audio announcements via PA system, and in some cases, information kiosks. |
| | On-Board Technology | In-Vehicle Traveler Information | On-board vehicles, passengers can be provided information via an Automatic Voice Annunciation System (AVAS) and VMS. |
| Safety and Security | Safety and Security Systems | Station Monitoring | Surveillance cameras are used to monitor stations, deter crime, aid investigation into an incident, and provide situational awareness during an emergency. |
| | | Emergency Alerts | Emergency call boxes at stations are positioned to allow passengers and transit agency personnel to directly contact 911 dispatch in case of emergency. |

| Need | Category | Technologies | Description |
|---|---|---|---|
| | | Intrusion Detection | Intrusion detection systems alert busway and potentially law enforcement personnel of unauthorized use of the busway. |
| | On-Board Technology | On-Board Video Monitoring | Cameras on-board vehicles monitor vehicle interior, and in some cases, exterior, in order to deter crime and investigate incidents. |
| | | On-Board Silent Alarms | In case of emergency, on-board silent alarms can be triggered discretely by bus operators to alert busway dispatch and law enforcement. |
| Necessary Communications Infrastructure | Communications | Busway Communications | Communications infrastructure along the busway will facilitate communications with ITS devices. |
| | | Fleet Communications | As part of a separate effort, radio communications on all busway vehicles are being upgraded to improve voice and data communications in support of ITS. |

Many of these potential ITS solutions offer benefits in more than one category. For example, Computer Aided Dispatch (CAD)/Automatic Vehicle Location (AVL) technology supports transit management, traveler information, and safety and security efforts. In these cases, the potential ITS solutions have been placed in the category most reflective of their primary use. Therefore, in this example, CAD/AVL has been placed in the transit management category.

## 4.2 Transit Management

The Transit Management ITS components manage vehicle fleets; coordinate with other modes and transportation services; and provide maintenance, customer information, planning, and management functions for the transit property. These components also collect operational, maintenance, and revenue data from transit vehicles, manage vehicle service histories, and assign drivers and maintenance personnel to specific vehicles and routes. These components also provide on-time performance information to dispatchers, reducing the need for radio communication and on-road monitoring by supervisors.

The main components of the Transit Management System are the CAD/AVL System, scheduling software, and Transit Signal Priority.

### 4.2.1 CAD/AVL SYSTEM

#### 4.2.1.1 Description

Computer Aided Dispatch (CAD)/Automatic Vehicle Location (AVL) is the basic building block for other ITS applications that depend on knowing vehicle location. CAD/AVL also allows for, and facilitates, informed dispatch operations. For transit, a CAD/AVL system provides the following functionality:

- Provides real-time vehicle location data needed for management of on-road transit operations by dispatchers and supervisors, and to support other ITS applications such as covert alarms, Automatic Passenger Counters (APC), real-time traveler information, in-vehicle signs and audio annunciators, Transit Signal Priority (TSP) and farebox/headsign integration.

- Acts as the primary point of interface between the dispatchers and the drivers and is used to track vehicles and to provide headway and schedule control.

- Collects and stores operational data that can be used by Service Planning personnel to improve transit services.

One major benefit of a CAD/AVL system is the dispatcher's ability to quickly send response personnel to the precise location of an incident or emergency. Having AVL-equipped vehicles also offers the possibility for transit interfaces to regional traffic management centers in order to share and receive real-time information related to congestion levels on monitored roadways.

The CAD/AVL system includes all systems and devices (hardware and software) that support the core vehicle location, computer dispatch, reporting, statistics and integration functions. Usually, the central CAD/AVL system consists of one or more software applications and data servers along with the supporting communications and linkages to external systems such as the scheduling and driver management software. The CAD/AVL system relies on schedule data generated by the Scheduling Software and vehicle location information received from vehicles to maintain headways and track schedule adherence. The system usually includes the following components/features:

- On-board GPS receiver which determine the current location of vehicles.

- On-board computers, also called Vehicle Logic Units (VLU), which connect to the GPS receiver, store data including schedule data, and perform schedule adherence comparisons based on vehicle location and schedule information.

- On-board Mobile Data Terminals (MDT) which allow drivers to log-on/log-off from a route, facilitate two-way text message communication between dispatchers and drivers, and display current route information including schedule adherence status (late or early and by how many minutes) to the driver.

- Data communications system that transfers information, including real-time vehicle location information, between the central CAD/AVL system and VLUs in vehicles.

- Graphical User Interface (GUI) which provides an interface between dispatchers and the central CAD/AVL system functions and data. This usually includes:

    - List displays of components such as routes, employees, vehicle status, statistics;

    - Real-time map display of all vehicles in the system; and

    - Route Display, which is a graphical overview of current vehicle location, and schedule adherence status.

- Dispatch system that enables the dispatcher to respond to unforeseen service interruptions by allowing them to assign a block to a vehicle, request a replacement vehicle, add trips, execute a short turn and assign traffic signal priority.

- Voice communications between dispatchers and drivers.

- Connection Protection subsystem to ensure connections between routes.

- Headway Control for managing headways by standardizing the distance between vehicles.

- Emergency Alarms which is an alarm that appears on a dispatcher's screen when an operator has pushed the Emergency button on the vehicle. The dispatcher sees a high priority message on the status screen and can then respond accordingly.

- WLAN reporting tools which are used to manage the files that are transferred between the Central CAD/AVL system and on-board VLUs over the WLAN network. This is required if data from the vehicles is downloaded regularly through a WLAN network to the central system.

- Interface to the Scheduling Software which is required whenever there is a schedule update. The CAD/AVL system should be capable of storing multiple schedules.

- Interfaces to Traveler Information applications to provide real-time arrival/departure information.

- Database and a Data Management tool to administer and edit data.

- Statistics/Reporting Software application which is used to evaluate the performance of vehicle operations by providing the capabilities for generating standard reports and ad-hoc reports on historical data.

- Playback and review of historical data for analysis of bus operations and to verify customer service comments.

- Real Time Passenger Information display subsystem which is a software module to manage the real time passenger information (RTPI) displays.

- A "Forms" feature which is used to collect information in a structured format e.g. incident forms.

#### 4.2.1.2 Best Practices

Based on experience with the implementation of CAD/AVL systems, the following best practices are presented:

- Involve all departments and any required external players in the design and implementation of the system to ensure that all aspects of the operation are taken into account when designing the system and also to ensure system acceptability. The needs assessment should include discussions with not only dispatchers, supervisors, and drivers but also Maintenance, IT, Customer Service, Transit Planning, Scheduling and Service Planning staff. Staff who have been consulted and had their input considered are much more likely to embrace, and take ownership of the system; all of which leads to a more successful implementation. This would partly entail identifying the busway Central Operating Organization (COO), as described in the Operations Plan[5], as early as possible, in order to solicit their input during system design and implementation.

- A time consuming issue is often the development of the interface between the scheduling software and the CAD/AVL system. While it may seem like a simple operation, the time to create such an interface to ensure a consistently accurate transfer of data can be significant. During procurement, potential vendors for the CAD/AVL system should be asked if they have had prior experience interfacing with the Trapeze scheduling software.

[5] Connecticut Department of Transportation. New Britain – Hartford Busway Operations Plan. Draft Report. August 26, 2009.

- It is important to ensure that the Facilities, IT and Vehicle Maintenance departments will be capable of providing the required support for the system. Preferably, assign an existing, or hire a new full time employee familiar with technology deployments and operations/maintenance to oversee the implementation and upkeep of the CAD/AVL system, and also of the other ITS technologies being implemented.

- During the procurement stage, talk to other transit operators who have implemented similar systems to discuss system performance, customer service, and support issues.

- Prior to signing the final contract with a vendor, carefully review all aspects of the proposed design to ensure that there is full agreement and also identify any options that could come up during the course of the implementation, in order to limit the number of possible change orders.

#### 4.2.1.3 Examples of Implementation

Currently, there are four major vendors in the Transit Management System market that provide CAD/AVL systems:

- INIT;

- Trapeze ITS (formerly Continental and Siemens);

- Clever Devices; and

- Affiliated Computer Services (ACS) (formerly Orbital).

One particularly relevant example is in York Region, Ontario, Canada. York Region Transit (YRT) implemented a transit management system initially in an express bus system (VIVA) then rolled the system out to include all of their conventional vehicles. This project is relevant to the Hartford situation because YRT has four (4) different independent operating companies providing the service in the Region. YRT implemented the CAD/AVL system in each operation such that all of the dispatch functions remained with the individual operators, with YRT having access to all operators' systems for monitoring purposes.

**Figure 4: VIVA Bus Station**


### 4.2.2 TRANSIT SIGNAL PRIORITY (TSP)

While the New Britain-Hartford Busway will not initially implement a TSP system, a full description and assessment of TSP is included in the following section to support possible future TSP implementation.

#### 4.2.2.1 Description

While the travelling public will not necessarily be aware of TSP, it can have a noticeable impact on the reliability and performance of bus service along the busway. TSP involves permanent (passive) or temporary (active) modifications to the operation of a traffic control signal in order to provide priority to transit vehicles at an intersection. These two techniques are described below.

*Passive Transit Priority* – is a low-tech TSP solution that does not adjust the signal timings in response to the presence of a transit vehicle. Typically, passive priority is implemented through predetermined signal timing plans developed to benefit transit vehicles (using predetermined analysis of transit routes and demands). For example, a signal phase used by transit could get a more favorable split and offset (taking into account transit speeds and dwell times at a bus stop) – than justified by mixed traffic volumes alone. In addition, treatments such as bus stop relocation, taper length modifications, parking/stoppage restrictions, and minor geometric improvements can also provide 'passive' priority to buses.

Passive transit priority strategies do not require monitoring and/or detection of transit vehicles, and can therefore be implemented anywhere – when warranted. This approach to transit priority produces consistent signal operation for vehicle traffic while increasing the efficiency of transit operations for the given traffic constraints. However, changes in regular signal timing plans can be of limited value because transit vehicles can still arrive during the red interval due to variations in travel time, while the priority based green phases can delay the cross-street vehicles regardless of the presence of a transit vehicle.

*Active Transit Priority* – can be considered as a milder variation of the more traditional pre-emption of signals by trains or emergency vehicles. Active transit priority causes regular operation of traffic signals to be altered temporarily in response to the presence, or imminent presence of a transit vehicle as determined by some form of transit vehicle detection. Signal settings may be adjusted at an individual signal or at a group of signals.

The application of active transit priority on a regular basis can be disruptive to competing traffic movements. For this reason, active priority for transit vehicles has been divided into two categories, namely unconditional or conditional. Generally,

- Signal priority is unconditional if it is granted every time a transit vehicle is detected to approach a signalized intersection;
- Signal priority is conditional if only granted when conditions, in addition to the presence of a transit vehicle, are met (e.g. specific route, specific run, schedule adherence, position of adjacent vehicles on the route, heavy passenger load, etc).

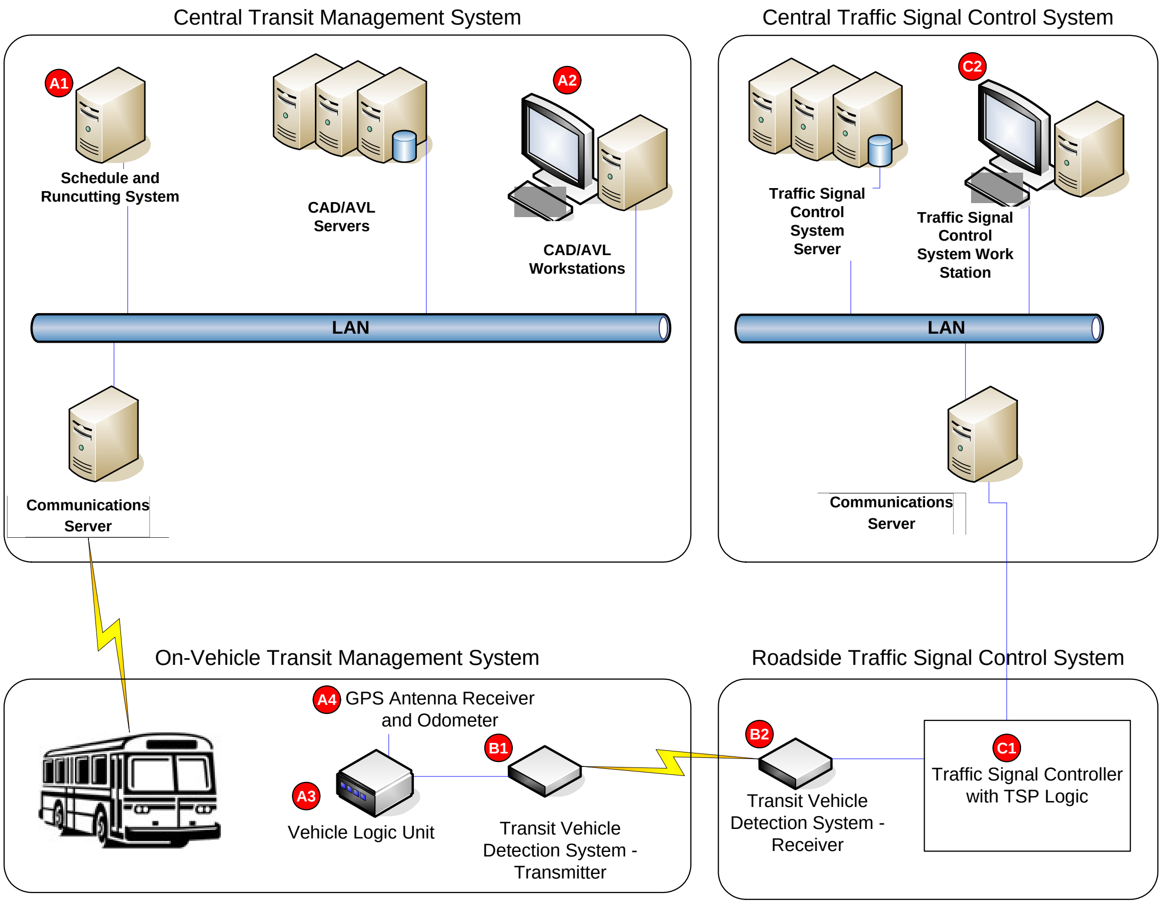
Conditional active transit priority requires increased system sophistication in order to determine whether the additional conditions have been met prior to granting priority. The system allows transit vehicles to request priority through an automated process, if proper conditions are met. Drivers are typically not allowed to manually request priority. Parameters are usually established such that the need to request priority will be calculated by the on-board Vehicle Logic Unit (VLU) based on schedule adherence thresholds and other characteristics. This is referred to as conditional priority.

A sophisticated TSP system often includes four main components:

1. Central Transit Management System;
2. On-Vehicle Transit Management System, which includes an on-board VLU;
3. Roadside Traffic Signal Control System, including local signal controller; and
4. For centrally controlled traffic signal systems, a Central Traffic Signal Control System.

Figure 5, below, provides an overview of a typical TSP system.

**Figure 5: Transit Signal Priority Overview**




The following describes the functionality of the various TSP system components shown in Figure 5.

**Central Transit Management System**

- A1 – Scheduling System/Software: This system is used for transit service planning. This system stores route data including the route schedule and timing points. These timing points are used for conditional priority, which is based on schedule adherence (e.g. request priority when vehicle is behind schedule more than one minute). The scheduling system stores the TSP assignment points (check-in/check-out) used to initiate the request for priority. With respect to the New Britain-Hartford Busway project, CTDOT is in the process of upgrading its Scheduling System/Software as part of a separate CTDOT initiative.

- A2 – Computer Aided Dispatch (CAD)/Automatic Vehicle Location System (AVL): This system is used to monitor vehicle operations in real-time, and to make strategic control decisions regarding operations (i.e., insert a bus in the route, or short-turn a bus). The CAD/AVL system interfaces with the Scheduling System/Software to acquire route information, such as TSP assignment points, etc. The CAD/AVL system often interfaces with vehicles in the garage through a wireless LAN (not shown in Figure 5.) to transfer schedule, route information and parameters to vehicles and to transfer TSP event logs from vehicles. The TSP event logs include details on the actual TSP check-in/check-out for each vehicle (date, time, GPS location, and text description of TSP assignment points).

**On-Vehicle Transit Management System**

- A3 – Vehicle Logic Unit (VLU): The VLU is an on-board computer that facilitates the CAD/AVL operations. The VLU uploads the schedule information from the CAD/AVL system in the garage. Once on route, the VLU tracks the vehicle's progress against the schedule information using a combination of Global Positioning System (GPS) and odometer readings. When the vehicle is at a check-in TSP assignment point, the VLU checks if the conditions for TSP have been met (e.g., off schedule by more than one minute). If the conditions are met, the VLU initiates the request for priority using the transit vehicle detection system (B1). When the vehicle is at a check-out TSP assignment point, the VLU cancels the request for priority. The VLU logs all TSP activity, which is uploaded to the CAD/AVL for analysis.

- B1 – On-vehicle Transit Vehicle Detection System Device: The on-vehicle transit vehicle detection system component interfaces with the VLU (A3). When the VLU initiates the request for priority, this device relays the request for priority to the signalized intersection. The communication to the roadside may be as simple as request for priority, or may be more complex including additional information, such as the specific bus number. Vehicle detection system technologies include: optical, transponder and radio frequency.

**Roadside Traffic Signal Control System**

- B2 – Roadside Transit Vehicle Detection System Components: The roadside transit vehicle detection system components include a receiver and a roadside computer. The receiver reads the request for priority from the transit vehicle and relays the priority request to the roadside computer. The roadside computer is responsible for deciphering the priority request and issuing the request for priority to the traffic signal controller. The roadside computer also records TSP event logs, and typically can identify system faults, such as when the priority request has exceeded a predetermined threshold time duration.

- C1 – Traffic Signal Controller: The traffic signal controller receives the request for priority from the transit vehicle detection system, and implements the transit priority routine (typically green extension or early phase activation). The traffic signal controller records the TSP event log (date, time, and input), and typically has some system fault capabilities.

**Central Traffic Signal Control System**

- C2 – Central Traffic Signal Control System: For centrally controlled and coordinated signal systems, the traffic signal controller can then communicate TSP information back to a central traffic signal control system. Central traffic signal control system software can typically monitor the intersection operation in real-time, and serves as a database for storing traffic signal control system data. The central traffic signal control system stores the intersection controller data, including TSP parameters such as green extension duration, and TSP event logs recorded in the traffic signal controller (C1). For the New Britain-Hartford Busway, it is intended to keep the signal intersections as simple as possible. Therefore no central traffic signal control system for transit signal priority is envisioned at this time. Instead, TSP requests will be handled locally at the local traffic signal controller.

**TSP Cycle**

In general, the TSP cycle includes the following five functions that use the transit vehicle detection system, in concert with the traffic signal control system (either local controller and/or central traffic signal control system), to progress the transit vehicle through the signalized intersection:

1. Check-In – The transit vehicle detector detects the transit vehicle and issues a request for priority to the traffic signal control system (i.e. central software or local controller).

2. TSP Delay – TSP Delay is the period of time between receipt of request for priority and TSP Sequence initiation. The TSP Delay function is used to adjust the priority input based on transit vehicle travel time requirements.

3. TSP Sequence – A TSP timing sequence is implemented that may use a host of TSP strategies depending on the capabilities of the traffic signal control system and local controller. TSP strategies used may include: Green Extension, Early Phase Activation, Phase Rotation, Lift Strategy and Special Transit Phase, etc to progress the transit vehicle through the signalized intersection.

4. Check-Out (Optional) – The transit vehicle detector issues a request to the traffic signal control system to cancel the TSP Sequence.

5. End TSP Sequence – In the event that the check-out does not occur within a predefined duration, the TSP sequence will be terminated.

**Performance Monitoring**

The performance of the TSP system can be monitored with respect to the maintenance requirements, time savings from the existing operation and the evaluation of whether TSP was granted with respect to how often it is requested. This last evaluation is done by reviewing the TSP logs from the Transit Management System with the traffic signal logs from the various agencies whose traffic signal system is involved.

**Jurisdictional Experience**

Numerous communities nationwide have implemented some form of TSP. In suburban Chicago 15 intersections along heavily traveled Cermak Road were TSP-enabled. Transit vehicle run times were reduced by 7% to 20%, schedule adherence improved, and there was no negative feedback from motorists regarding the signal priority for buses. In Bremerton, Washington, 43 of 45 signalized intersections in the City were equipped with transit priority. Transit travel times were reduced by 5% to 16% and average travel time was reduced by 10%. In Portland, Oregon signal priority was implemented at 250 traffic signals on seven routes. The transit management system requested priority on less than 40% of the trips studied but still saw a reduction in travel time of 8% to 11% during the p.m. peak hour. During the off-peak period the reduction in travel time was less significant. Travel time variability was also reduced.

**Applicability to Busway**

Given the high frequency of the New Britain-Hartford Busway service, active transit priority was considered. However, given the exclusive busway, it was determined that using a semi-actuated signal system using loop detectors could provide much of the same benefit at reduced cost. It is CTDOT's intention that at the five grade crossings on the busway itself, Stanley, East Main, Smalley, Oakwood, and Hamilton, all buses approaching these crossings will trigger loop detectors and will receive automatic green signals, except:

- In cases where granting the green would conflict with train signal pre-emption at the Oakwood and Hamilton crossings;
- In cases where granting the green would conflict with emergency vehicle pre-emption; or
- If a certain threshold of green time has already been given to the busway, e.g. when a service delay results in a platoon of buses arriving at a crossing at once.

In other words, whenever a bus operating on the busway approaches an intersection, loop detectors will trigger a green request. This request will be granted by providing a green light or by extending the signal green time, as appropriate, so long as it 1). does not interfere with railroad crossing or emergency vehicle preemption and 2). does not create unacceptable delays for traffic on the cross street.

#### 4.2.2.2 Best Practices

While TSP is not proposed for the New Britain-Hartford Busway at this time, CTDOT may consider implementing TSP at a future date. If CTDOT does decide to pursue TSP at a future date, the following best practices are presented based on experience with the implementation of TSP systems:

- Identify which intersections should be equipped with TSP and the traffic signal control system that will accommodate the priority. In particular, it is important to identify how the TSP will be integrated into the traffic signal control system and interact with emergency vehicle and railroad pre-emption. Also, an Americans with Disabilities Act (ADA) requirement is that TSP should not negatively affect the pedestrian phase; therefore the pedestrian phase must still be appropriate to pedestrian volumes and compliant with ADA requirements.
- Develop timing points and incorporate them into the scheduling data. This represents a significant effort that is often underestimated by transit properties.
- Develop Memoranda of Understanding with all agencies that have traffic signal equipment in the corridor to get permission to affect their traffic signal control systems. The institutional relationships that support TSP are inherently complex because of the involvement of multimodal transportation operations (transit management and operations of arterial streets) as well as overlapping jurisdictional boundaries. Development of an agreement of the roles and responsibilities of each of these participating jurisdictions is as crucial to a successful implementation as the selection of an appropriate technology. Once an agreement between the players has been reached, it is important to develop clear Memoranda of Understanding that are agreed to by all agencies to cement these roles and responsibilities.
- Develop signal timing patterns and parameters to optimize busway operations and minimize cross street delay. Signal timing patterns and parameters will need to be developed that take into account not just the busway intersections, but also the adjacent railroad crossing and nearby local traffic signals.
- Develop a detailed system testing plan. Given the multiple jurisdictions, and the need to accommodate the safety regulations of the parallel railroad line, testing and fine tuning of the TSP system will be important.
- Establish a policy for collecting and analyzing the following data:

- Traffic counts and analysis data both before and after TSP implementation, to determine impacts to traffic patterns.
- Data logs from the traffic signal system, which need to be compared regularly to the requests for priority data coming from the buses to evaluate if priority is being granted as required.
- Reports on TSP status and operations for monitoring purposes (not necessarily in real-time, but the reporting frequency should be configurable).
- TSP data for performance analysis, including success/failure reports, equipment diagnostics by site, etc.

#### 4.2.2.3 Examples of TSP Implementation

Most CAD/AVL suppliers in the Transit Management System market can provide TSP as a part of their product.

### 4.2.3 ISSUES AND CONSIDERATIONS

Moving forward, there exist a number of issues and considerations regarding the Transit Management ITS components that remain to be decided. These issues and considerations include:

- Currently, CTDOT has instructed IBI Group to assume that the busway operations dispatch will be located at the existing CTTRANSIT facility in Hartford. However, the Central Operating Organization (COO) has not yet been identified. The designation of the COO may affect some of the operational policies and procedures associated with transit management, which in turn may have technological implications. .
- There remains a pressing need to continue design and engineering coordination between ITS systems and signal systems. In particular, it will be important to coordinate signal control along the one-lane section of the busway in order to optimize signal timing and ensure safe and efficient operations.
- Ongoing coordination is also required with CTDOT's separate initiative to upgrade its scheduling software. The interface between the scheduling software and the CAD/AVL software is vital to the successful operation of the busway and supports several other ITS technologies.
- As a general consideration, it will be important to stress software integration and interoperability. As mentioned previously, the CAD/AVL system will need to be integrated and interfaced with several different applications. This integration needs to be as seamless as possible to ensure efficient operation of the busway. Where possible, open, non-proprietary software solutions that meet National Transportation Communications for ITS Protocol (NTCIP) standards should be pursued.

## 4.3 Automatic Fare Collection (AFC)

### 4.3.1 DESCRIPTION

Advanced revenue collection systems, such as Automatic Fare Collection (AFC), offer a variety of operational benefits, including greater speed of boarding and increased service reliability. Many

AFC deployments encourage passengers to purchase fares prior to boarding, further increasing speed of boarding. Passengers who do not pay their fare in advance may be offered an alternative, such as paying with cash on-board, though this tends to result in less time savings. Other benefits of AFC include simplification of revenue collection and greater customer convenience if the system is well-designed; better fare data collection through automated transactions; limited exchange of cash; improved security; and freeing drivers' attention from cumbersome transactions.

AFC can take place under different rubrics. However, given the need for high frequency bus service and reduced dwell times at stations, a proof-of-payment (POP) system has been identified as the preferred approach for the New Britain-Hartford Busway. In a POP system, fares are paid and validated off-board, enabling faster boarding through multiple doors. Passengers are expected to have proof of validation ready for inspectors or they are subject to warnings or fines. An effective POP system eliminates the need for barriers to entry, such as the turnstiles generally seen on metro systems or higher-volume Latin American BRT systems.

The following are the typical components of a POP-based AFC system. The selection of one component often is related to and dictates selection of other components to ensure interoperability.

*Ticket Vending Machines (TVMs):* TVMs, sometimes also referred to as Fare Vending Machines (FVMs), are vending machines that issue or replenish fare media. TVMs for the New Britain-Hartford Busway must be able to produce regular and discounted individual, 10-ride, all-day, multiple-day, and monthly passes to comply with existing fare policy. For ease of payment, the TVMs should be able to process both cash and credit card transactions. If smart card media is implemented in the future, TVMs should also allow value to be added and stored on electronic fare cards. The machines are typically placed on platforms or in designated waiting areas. TVMs should be located in such as way as to comply with ADA requirements, not impede pedestrian flow, and not pose a safety hazard. TVMs are also often sheltered or placed within enclosures for customer convenience and to avoid maintenance issues resulting from adverse weather conditions. Some transit properties have also made the decision to locate TVMs on-board vehicles, due to limited space at stops and a desire to avoid queues from use of driver-monitored fareboxes on vehicles. Most TVMs are also 'hardened' to prevent vandalism, tampering, and theft.

*Ticket Validators:* Ticket Validators, sometimes also referred to as Fare Media Validators (FMVs) or Stand Alone Validators (SAVs) are machines used to validate pre-purchased fare media in POP systems. They physically stamp, mark, or date tickets or electronically validate them for specific trips. These machines can be located on-board or off-board. Ticket Validators are simpler and less expensive than TVMs because they do not handle transactions, though fare media can also be validated through TVMs.

*Fare Media:* An AFC system must have a fare media that can be automatically processed in TVMs and Ticket Validators. The media can take many forms, including paper tickets, magnetic stripe cards, or smart cards. The media, when validated, can also function as ticket transfers.

*Fareboxes:* On-board fareboxes primarily gather fare payments from customers by collecting cash fares, and/or by validating a variety of fare media. In addition, fareboxes can issue tickets, receipts, or transfers; and also recharge stored-value cards. Though POP systems are intended to avoid the need for on-board transactions, fareboxes will still be required for when vehicles exit the busway.

*Ticket Office Machines (TOMs):* Many transit properties also feature TOMs. These are attended sale locations generally geared towards selling passes and multi-use tickets that may also be sold through TVMs and validated for specific trips through Ticket Validators.

These components are those with which passengers interact. The 2002 TCRP Report 80: A Toolkit for Self-Service, Barrier-Free Fare Collection[6] also highlights the need for station controllers, central computing, and data processing capabilities.

### 4.3.2 BEST PRACTICES

The following best practices are focused on issues most relevant to POP AFC systems. Many of these are contained in the TCRP Report 80 and the 2006 Update of "Advanced Public Transportation Systems: The State of the Art."[7]


**Figure 6: MBTA Ticket Validator**

- *TVMs and Ticket Validators:* According to the TCRP report, most North American POP systems use stand-alone Ticket Validators as well as TVMs to prevent passengers who only want to validate their fares from having to engage in the longer queues and transaction times associated with TVMs. Ticket Validators can be used instead for quick validation.

- *TVMs:* There are many considerations when planning for the number and location of TVMs. TVMs should be placed in monitored or secure locations wherever possible. They should also be installed at every stop when space and budget allows. However, an agency may wish to limit the number of TVMs installed because they are more expensive than Ticket Validators and have more security concerns related to the storage of cash. If TVMs are not installed at every stop, on-board payment options should be provided for passengers who do not have prepaid fare media. This can include on-board fareboxes at the front entrance, or a TVM at an alternative entrance.

- *Ticket Validators:* Although different Ticket Validator locations may be appropriate for different contexts, on-board Ticket Validators are used less often because they can slow down boarding if near a monitored door; if not near a monitored door, then, passengers can avoid validating a ticket unless an inspector is spotted boarding a vehicle. The format of validation should also take into consideration whether passengers can or will counterfeit time and date stamps.

- *Smart Cards:* Smart Cards can be integrated into POP systems, a common occurrence in French BRT systems. Generally, a smart card would be 'tapped' upon boarding a vehicle; however, in a POP system they must be electronically validated before boarding. This POP method requires inspectors to use portable readers for enforcement (or mobile enforcement devices) since visual checks will not be possible. The main benefits of introducing smart cards would be to reduce transaction times and to allow for more coordinated data collection. According to the APTS State of the Art update, smart cards are most beneficial when they can be used to provide a variety of payments (e.g., transit fares, parking fares, etc.).

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[6] Transportation Research Board (2002). "*Advanced Public Transportation Systems: The State of the Art*", Washington, D.C.: National Research Council.

[7] Hwang, Kemp, Lerner-Lam, Neuerburg, et al; ed. Schiavone, John. (2006) "*Advanced Public Transportation Systems: The State Of The Art Update 2006",* Washington, D.C.: USDOT and FTA.

- *Fare Policy:* Fare structure should be consistent and easily understood across the entire system through formal policy clearly communicated to the public. This helps limit non-compliance in POP systems due to confusion. Fare policy should include a regionally consistent transfer structure. If the fare structure is zone-based, the design of an AFC system must take into account how to identify both start and end stations.

- *Fare Enforcement:* A clearly-defined procedure for enforcing fare payment should be established early in order to determine the resources that will be required as well as appropriate performance measures. Enforcement often is not adequately tracked and measured leading to limited knowledge of evasion rates and cost of enforcement. These measures help determine the effectiveness of POP and guide future decisions related to AFC systems. The method of measuring performance measures should also be clearly defined to enable comparison of results over time. For example, evasion rates may or may not include consideration of warnings issued when there is no fine. Finally, there should be a pre-existing, appropriate legal framework to allow transit police or independent inspectors to issue citations, as well as a system in place to track and enforce payment of fines. Mobile enforcement devices may also be used to support enforcement efforts. These handheld devices may allow enforcement officers to quickly check to ensure fare media has been validated and may also simplify data entry for issuing violations.

- *Costs:* It is more expensive to issue single fare tickets through TVMs because of transaction costs as well as the cost of fare media. Therefore, providing deeper discounts on passes and multi-ride tickets will increase their use and may contribute to lowering the cost of operating a POP AFC system. Though it is recommended that TVMs be installed at all stations to achieve the greatest time savings, this approach may be expensive and certain stations may need to be prioritized over others. According to the TCRP Report 80, MARTA in Atlanta decided not to switch to POP system because it would have cost more to install all required TVMs than to update an existing barrier system.

### 4.3.3 EXAMPLES OF IMPLEMENTATION (POP BRT)

*Green Line and Silver Line | MBTA | Boston*

Certain sections of MBTA service are POP-based AFC to allow boarding through all doors. This occurs on the D and part of the E branch of the light rail (Green Line) and one BRT station (Silver Line). In particular, the new Silver Line station near the intermodal South Station has a Ticket Validator without a TVM. This may be more feasible in this location due to its close proximity to South Station, a major intermodal hub with many TVMs.

*Viva | YRT | York Region*

Viva is a new POP-based BRT system in York Region, Ontario. Viva's TVMs, which allow riders to purchase single and multiple tickets, have attached ticket validators. *VivaNow* machines validate tickets by printing the date and time that the fare will expire (two hours from purchase). There are no fareboxes to allow for on-board payment. Viva's system is zone-based; therefore TVMs allow upgrades to more expensive zones. Cash and credit are accepted. Security cameras monitor abuse of machines. Seamless transfers requiring no additional payment are allowed between Viva and other YRT services after presenting validated tickets. There are plans to implement use of a regional smart card called Presto in 2010.[8]

[8] "Viva (bus rapid transit)." From http://en.wikipedia.org/wiki/Viva_(bus_rapid_transit)#Fares.

*Orange Line | LACMTA | Los Angeles*

The Orange Line BRT in Los Angeles County currently uses TVMs to issue and validate tickets on a POP basis. There are no on-board fareboxes. Eventually, the system will use smart cards, integrated with the rest of the fare structure of the transit network, for AFC.[9]

**Figure 7: LA Orange Line Station**

*EmX | Lane Transit District (LTD) | Eugene*

This POP-based BRT system requires passengers to have a valid pass before boarding. Passes range from single ride to monthly passes. The EmX vehicle has doors on both sides, making off-board payment more crucial to allowing boarding through all doors. The LTD website offers an online video instructing passengers how to use the TVMs.

*Transitway BRT lines | OC Transpo | Ottawa*

This approach to AFC is a hybrid off-board on-board payment structure. The Ottawa Transitway lines allow passengers with passes to board through all doors while requiring those using cash, tickets, and transfers to board only through the forward door.

#### 4.3.4 ISSUES AND CONSIDERATIONS

There remain several issues and considerations to be addressed regarding the AFC system for the New Britain-Hartford Busway, including:

- *Interoperability:* As already suggested, interoperability both with existing systems as well as potential future systems will be a consideration in procuring any equipment. In the future, smart cards may be used on the New Britain-Hartford Busway, which, linked with AVL and APC, can provide a rich dataset for analysis. Therefore, when installing an off-board, POP-based AFC system, consideration should be given to the potential integration of these cards without requiring purchase of all new equipment. Finally, the system will have to take into account the more complicated interoperability of bringing the data from these multiple sources back to a central point for analysis. CTDOT will also need to ensure that its back-office revenue management system is upgraded to handle the new AFC system transactions.

- *Unstable Fare Policy:* Because CTDOT has not yet settled on a future fare policy, the system should be installed with adaptability in mind for expansion and redefinition of fare structures. Fare policy decisions should drive technological solutions, and not vice versa. In addition, technology continues to evolve regarding fare media. Smart cards, cell phone payment, and credit cards with smart chips may all evolve into a preferred fare media. Given this uncertainty, a flexible, modular, and upgradeable AFC system is preferred.

- *Future Rubrics:* While the current circumstances make POP a reasonable system to adapt, enforcement statistics or increased ridership may make a barrier system worth considering. This future possibility should not necessarily preclude purchase of equipment best suited to

[9] Hwang, Kemp, Lerner-Lam, Neuerburg, et al; ed. Schiavone, John. (2006) "*Advanced Public Transportation Systems: The State Of The Art Update 2006",* Washington, D.C.: USDOT and FTA.

POP; however, metrics and assessments should always consider whether the current approach is the most cost effective.

- *Enforcement:* There remains uncertainty regarding enforcement of fare policy along the busway. CTDOT will need to invest time and effort into identifying the enforcement agency, enforcement costs and logistics, and developing and enacting the necessary enabling legislation.

## 4.4 Traveler Information Systems

### 4.4.1 DESCRIPTION

Traveler information for transit passengers can be typically divided into pre-trip passenger information, en route passenger information, passenger information at the transit station, and passenger information provided on-board a transit vehicle. Pre-trip passenger information is information that passengers need before embarking on a trip. It comprises mainly of static information like schedules, fares, intermodal connections and maps. En route passenger information is provided to travelers on their way to station. Station passenger information is accessed at the transit stop and plays a significant role in keeping transit passengers up to date on the status of the transit service. On-board passenger information provides information to passengers on-board transit vehicles about transit routes and destinations, service alerts, upcoming stops/stations, and connecting services.

These different transit information services may include static information as well as real-time information about the status of transit vehicles. The inclusion of passenger information functions is known to improve passenger satisfaction, helps to reduce wait times, and can increase ridership. Some transit agencies offer a combination of real time and static information to their customers using a number of technologies. The technologies described in this section are typically used to provide both real-time and static information.

**Pre-trip Passenger Information**

Pre-trip passenger information provides travelers with general information to assist them in making informed decisions regarding time of travel, travel mode, and travel path. Pre-trip passenger information typically includes services to provide passengers with static information about routes or schedules, trip planning services, travel connections, and multimodal alternatives along specific travel corridors.

The Internet is commonly used to provide pre-trip passenger information, both real-time and static information, to passengers. For example, as part of a separate effort, CTDOT has plans to continue upgrading its CTTRANSIT website to incorporate additional trip planning functionality. Trip-planning programs typically allow the user to enter travel information such as departure dates, times, origin, destination, preferred modes and walking distance. The system then suggests an optimal route for the user along with schedule information and any other pertinent traveler information. Real-time websites also sometimes provide users with tabular or graphical representations of the current status for their route. An emerging trend in real-time bus information is to display actual vehicle locations on a map of the service area. Once CAD/AVL systems for gathering vehicle location information are in place, mapping of real-time bus locations would be made exceedingly possible in the future. Subscription services, where individuals register to receive custom information about specific routes, stations, or types of service alerts, are also becoming increasingly popular.

Transit information can also be provided to third parties, such as Google Transit or local media, in order to more broadly disseminate pre-trip passenger information. Given the broad nature of pre-trip passenger information systems, these systems are not currently envisioned as part of the New Britain-Hartford Busway project. Rather, information gathered from ITS deployed as part of the New Britain-Hartford Busway is intended to serve as one of many inputs into these larger, separate pre-trip passenger information systems development efforts.

**En-route Passenger Information**

En-route passenger information is provided to passengers on their way to transit stations. These systems provide up-to-date information on service status and alerts to travelers. Most commonly, en-route passenger information is provided to passengers via mobile phones or web-enabled personal devices.

Across the country, transit agencies are making advances in providing passenger information through 511 telephone and web applications. 511 is the federally designated phone number for traveler information. In accordance with federal 511 guidelines, static route and schedule information, along with transit service alerts are often provided as an input to regional 511 services. Passengers are then able to obtain transit information by interacting with the 511 system's Interactive Voice Response (IVR) system. Many 511 services incorporate a visual component via 511 web applications. These web applications can provide both static and real-time transit information. The 511.org website that supports the San Francisco Bay area is an example of successful integration of AVL data from various transit agencies into a regional website. Currently the website includes information on traffic conditions, transit (including access to the regional Trip Planner), ride share, bicycle, and other transportation-related information. The website links about 40 organizations, with approximately 24 transit agencies being part of the Trip Planner service.[10]

Real-time information, including 'next bus' arrival times can also be provided to web-enabled mobile phones or personal devices. Special websites designed specifically for mobile devices can display route, direction and stop information. These websites could also work in conjunction with CAD/AVL systems to display estimated arrival times for the selected route and stop. Some transit agencies have also implemented an alternative approach that involves text (SMS) messaging. A specific phone number is provided for each transit stop. When a customer sends a text message to that number, the traveler information server will send back a text message with the next bus arrival time for that location. This approach has the benefit of not requiring customers to own a web-enabled device or have a data plan with their mobile phone.

GPS-enabled mobile devices allow even more flexibility for trip planning. As mobile devices increasingly incorporate relatively accurate real-time location capability, it creates the opportunity for traveler information to be customized to the current location.

Again, given the broad nature of en-route passenger information systems, these systems are not currently envisioned as part of the New Britain-Hartford Busway project. Rather, information gathered from ITS deployed as part of the New Britain-Hartford Busway is intended to serve as one of many inputs into these larger en-route passenger information systems development efforts, such as any future Connecticut 511 system.

[10] Hwang, Kemp, Lerner-Lam, Neuerburg, et al; ed. Schiavone, John. (2006) "Advanced Public Transportation Systems: The State Of The Art Update 2006", Washington D.C.: USDOT and FTA.

**Station Passenger Information**

Station passenger information helps to significantly improve the traveling experience for transit users. Station passenger information is often provided via Variable Message Signs (VMS), Public Address (PA) Systems, and information kiosks.

*Variable Message Signs:* VMSs are a subset of a larger category of sign types called Changeable Message Signs (CMS) or Dynamic Message Signs (DMS). VMSs are electronic displays that can provide single- or multi-line information about the next scheduled arrival(s) at the station. VMSs can also provide more general information such as the date and time, as well as specialized service announcements or alerts. VMSs can also be used to display real-time information about predicted bus arrival/departure times. In most systems, this is accomplished by having the CAD/AVL system send the vehicle's real-time location information to a central system. The central system then calculates when the vehicle is expected at the bus stop, and sends this arrival/departure information to the sign at the bus stop where it is displayed.

In order to provide real-time bus information on VMS, several components are needed. There needs to be a CAD/AVL system in place to track and analyze vehicle location information. The components required to operate the VMS include the sign, sign case, environmental protection components (heating, fans, glass), driving electronics including a controller (computer), photo sensor control, mounting hardware, associated cables and wiring, communication interface between the display and the CAD/AVL system, power, and central software to manage the information shown on the display.

Currently, there are two basic options available for real-time passenger information signs in a transit environment:

- Light Emitting Diode (LED) signs are the de facto standard. These signs are available in line matrix or full matrix, one sided or two sided and can be single or multiple lines long. There are multi-colored LED signs but those suppliers to the transit industry usually have one color on black (usually amber to satisfy ADA requirements) and can show text and limited graphics. LED signs have a proven history of operating in a wide spectrum of operating conditions.

- Liquid Crystal Display (LCD) signs are a new technology in the transit field as compared to LED. These signs are used where multiple lines of text information is required and can also be used to show images and video. The signs are colorful and have a much higher resolution than LED. Currently, these signs are used mainly in indoor environments at stations and terminals. There is very limited experience of using LCD in transit operations in an external environment; however, suppliers are now indicating that they can guarantee signs at temperature ranges that make them viable to use in outdoor locations that experience extreme temperatures.

The main difference between the two signs is that LCD offers a colorful, high definition sign with the ability to provide more information to the passengers than the LED sign. However, the one major drawback is that there has been limited experience with LCD signs in transit operations in an outdoor environment with a wide temperature range. As the LCD signs become more proven in outdoor transit environments, CTDOT may want re-assess LCD sign suitability for the busway.

*Public Address (PA) Systems:* The PA system is an alternative or complementary method used for information dissemination. At stations, it is used to announce bus arrivals and schedule disruptions. Like VMS displays, PA systems are also typically operated remotely by a central system which processes real-time vehicle location information obtained from the CAD/AVL system to calculate bus arrival times or schedule disruptions. The real-time information from the central system is downloaded to intelligent announcement units at each transit stop where the updated audio with passenger information is played. Public announcements may be scheduled to play automatically at regular intervals or may be triggered by detectors or other wireless/communication links. In many cases, PA systems are also designed to be controlled and operated locally, in case of emergency or loss of communications with the central system, to issue notifications to passengers on the platform.

The most important user consideration to be taken into account during the design process for a PA system is its sound quality. Announcements should be clear and audible without creating noise pollution for neighboring concerns. Also, it is vital that the PA information be properly synched with the information being displayed on VMS displays in order to avoid passenger confusion.

*Information Kiosks:* An information kiosk is an interactive wayside device. It is a popular traveler information device due to its interactive capabilities. This feature allows users to choose and access specific information from a large pool of information in a relatively short time. When combined with real-time vehicle location information, kiosks can provide customers with real-time information, such as the on-time status of their transit vehicle. When connected to the internet, kiosks can provide boundless additional data including weather and road conditions. Interactive kiosks are a lower priority for the New Britain-Hartford Busway due to limited platform space and the growing prevalence of web-enabled mobile devices. It is helpful to know however that interactive kiosks along with other electronic forms of customer information help transit agencies to comply with the Americans with Disabilities Act by providing services to the visually and hearing impaired.

**On-board Passenger Information**

On-board passenger information provides travelers with information while on-board transit vehicles. These systems are discussed in greater detail as part of *Section 4.5: On-board Technology*.

### 4.4.2 BEST PRACTICES

Obtaining accurate, consistent, and complete data for the traveler information systems is one of the biggest challenges in implementing successful traveler information systems. Some of the key lessons learned from similar traveler information systems implemented elsewhere include:

- Allow adequate time to develop and calibrate the required data collection systems.
- Ensure that all relevant processes and resources are in place to deal with ongoing data requirements and maintenance.
- Conduct limited field demonstrations first.
- Improve the customer's experience with transit data, by having consistency between names and abbreviations used on paper timetables, bus head signs, websites and other materials. For transit websites, the user interface is important. Volpe Transportation Center has developed guidelines to assist in the user interface development.
- Ensure that trip planning and other traveler information systems receive a significant amount of refinement and maintenance.
- Have only one source map for various information systems to improve accuracy.
- Ensure clarity of audio and visual display systems after installation.

- Be aware that real-time communication lags can limit timeliness and accuracy of passenger information systems. GPS-based AVL that includes variable position reporting rates can help report bus position and speed more frequently especially when buses are not on schedule.[11]

- Locate VMS displays such that they are easily readable and are consistent with ADA legibility guidelines.

#### 4.4.3 EXAMPLES OF IMPLEMENTATION

The Tri-County Metropolitan Transportation District of Oregon (TriMet) in Portland, Oregon has provided real-time bus arrival information on LED signs at bus stops. Information that is sent to each bus driver via an MDT about their arrival time at the next stop is also sent to the signs. Each sign has the schedule loaded in it, and the sign processor applies arrival time information to the schedule, to determine the offset from the schedule. This is a distributed, decentralized system, because information that will be used to determine arrival times is sent to the sign for processing. Signs installed at MAX (light rail) stations provide only scheduled arrival time information. Bus stops serving more than one route are outfitted with multilane LED displays to list arrival information for three or four buses.[12]

**Figure 8: VMS Display at Tri-Met Bus Stop, Portland, Oregon**


Source: Schweiger, Carol L. "*Real-Time Bus Arrival Information Systems: A Synthesis of Transit Practice 48*." Transportation Research Board, National Research Council. Transit Cooperative Research Program, 2003, 61pp. [Project J-7]

London employs the largest signpost-based AVL systems to monitor all the buses in the London Buses division of Transport for London (TfL). It was also one of the first cities in the world to deploy LED signs indicating bus arrival times at each equipped stop. It employs countdown style displays which are also installed at many underground stations.

[11] Hwang, Kemp, Lerner-Lam, Neuerburg, et al; ed. Schiavone, John. (2006) "*Advanced Public Transportation Systems: The State Of The Art Update 2006",* Washington, D.C.: USDOT and FTA.

[12] Schweiger, Carol L. (2003) "Real-Time Bus Arrival Information Systems: A Synthesis of Transit Practice 48." Transportation Research Board, National Research Council. Transit Cooperative Research Program, 61pp. [Project J-7].

**Figure 9: VMS Display at a London Bus Stop**


Source: Schweiger, Carol L. "*Real-Time Bus Arrival Information Systems: A Synthesis of Transit Practice 48*." Transportation Research Board, National Research Council. Transit Cooperative Research Program, 2003, 61pp. [Project J-7]

### 4.4.4 ISSUES AND CONSIDERATIONS

This section has emphasized the importance of VMS displays due to their effectiveness in communicating essential information. However, VMS displays are capital intensive and may require significant fine-tuning to ensure accuracy of displayed information. Also, as already mentioned, the information kiosks may not be completely practical for the New Britain-Hartford corridor due to space limitations at the platforms. CTDOT may also want to re-assess the capabilities of LCD display monitors as they demonstrate more proven reliability in outdoor environments over time.

Real-time information displays depend on CAD/AVL systems being deployed in the entire New Britain-Hartford corridor as well as coordinated communications software. The compatibility and consistency of the vehicle location information collected will be a key determinant in the usefulness and accuracy of the real-time information displays. Consistency of data collected is especially important given the multiplicity of operators and vehicles that will be using the busway.

A final consideration is the need to incorporate the real-time traveler information collected by the CAD/AVL system into larger, statewide traveler information system development efforts. These efforts may include the dissemination of vehicle location information to other public agencies and to the private sector. For example, vehicle location information could be shared with third party applications such as Google Transit where users can view bus schedule information alongside traffic condition reports. Such sharing of information will also enable more flexibility for information applications for use with mobile and PDA devices. The traveler information infrastructure should also be designed to be able to fit into larger regional information systems like a potential future 511 system.

## 4.5 On-Board Technology

### 4.5.1 DESCRIPTION

A number of technologies can be installed on-board transit vehicles. These include:

- Mobile Data Terminals (MDT)
- Vehicle Logic Units (VLU)
- Public Address System (PA)
- Variable Messages Signs (VMS)
- Automatic Voice Annunciation System (AVAS)
- Automatic Vehicle Monitoring (AVM)
- Automatic Passenger Counters (APC)
- On-board Video Monitoring (OVM)
- Automatic Vehicle Location (AVL)
- Automatic Fare Collection (AFC)
- On-board Silent Alarms

The technologies and their benefits are described below (Note: some of these technologies, such as the AFC and AVL systems, have been described in earlier sections):

**Mobile Data Terminals (MDT)**

Mobile Data Terminals[13] are on-board information and communication devices that serve as an information link between control centers and vehicles. MDTs provide drivers with a limited interface to the CAD/AVL system allowing to drivers to log-on/log-off from a specific route/run, and displaying relevant information such as run, trip, route, and schedule adherence status. MDTs also communicate and display short text messages between dispatch and drivers including typical 'canned' messages and free-form text messages.

Generally, MDTs are integrated with other on-board technologies such as CAD/AVL, AFC, AVM, and APC. This allows MDTs to display information collected by these systems such as vehicle location, schedule adherence status, passenger counts, mileage, and fare data.

MDTs have the benefit of replacing voice radio communications for most situations except for atypical or emergency events, which reduces overload on the voice radio communications network and reduces costs. MDTs can virtually replace note taking and written manifests, and also becomes the entry point for data to perform system wide passenger accounting and vehicle performance analysis.

**Figure 10: Mobile Data Terminals**

http://rtcu.dk/images/MDT-200%20(Custom).jpg


http://www.trapezeits.com/images/solutions-onboard-mdt.jpg

[13] Harman, L. J., & Shama, U. (2007). *TCRP Synthesis 70 – Mobile Data Terminals*. Washington, D.C.: Transportation Research Board.

**Vehicle Logic Unit (VLU)**

Vehicle Logic Units[14] are on-board computers that are connected to, control, process, and store data collected by other on-board technologies such as CAD/AVL, AFC, MDT, VMS, AVAS, AVM, APC, and OVM. Data from VLUs can then be transmitted in real-time or uploaded later when the vehicle is at the garage.

**Figure 11: Vehicle Logic Unit**

http://www.eurotech.com/en/photo.aspx?pg=DuraCOR DC 1400

VLUs have the benefit of processing and integrating data from a variety of technologies. For example, VLUs can match passenger count data (boardings and alightings) to vehicle trip, location and stop data from the AVL system, and to fare collection data from AFC system. VLUs can also ensure that information is consistent across different technologies. For example, VLUs can ensure that the same next-stop information is displayed on VMSs and announced by the AVAS system.

**Public Address System (PA)**

The Public Address system comprises speakers and microphones, and is used to make audio announcement on-board the transit vehicle. The PA system allows the driver to make announcements such as the route name and/or number, destination, name of the next stop, emergency announcements, etc.

**Variable Message Signs (VMS)**

Variable Message Signs are LED or LCD display screens that can provide information to riders on-board transit vehicles by displaying a variety of messages. Messages displayed can include the route name and/or number, destination, name of the next stop, emergency announcements, etc.

VMS allows information to be provided to hearing-impaired passengers consistent with Americans with Disabilities Act (ADA) requirements[15].

**Automatic Voice Annunciation System (AVAS)**

The Automatic Voice Annunciation System (AVAS) automatically makes important announcements through the transit vehicle's Public Address System as it approaches a stop or an important location. Announcements typically made include the route name and/or number, the name of the next stop, major intersections, transfer point and connecting routes, etc. The AVAS system is typically integrated with the CAD/AVL systems to get schedule, and trip, and real-time vehicle location information. The AVAS system is generally connected to the on-board VMS to ensure that the same information is communicated both audibly and visually.

A key benefit of AVAS is that it provides information to visually-impaired passengers consistent with ADA requirements.

**Automatic Vehicle Monitoring System (AVM)**

The Automatic Vehicle Monitoring System[16] continuously monitors conditions of the transit vehicle components by interfacing with the vehicle's built-in computer. Data collected includes the amount

[14] Furth, P. G., Hemiliy, B., Muller, T. H., & Strathman, J. G. (2006). *TCRP Report 113 – Using Archived AVL-APC Data to Improve Transit Performance and Management*. Washington, D.C.: Transportation Research Board

[15] ADA requires that announcements be made regarding routes, major intersections, and transfer points on-board transit vehicles to allow passengers who are visually-, cognitively-, or hearing-impaired, to safely navigate on the transit system.

of time that the engine has been running, fuel and other fluid levels, engine temperature, pressure, voltages, etc. The system can also monitor mechanical components such as brakes, electrical, and heating, ventilation, and air conditioning (HVAC) and check for out-of-tolerance readings.

The collected monitoring data can either be transmitted in real-time to the control center or uploaded when the vehicle is at the garage. The driver and dispatcher can also be alerted in case of out-of-tolerance readings or component failures.

Key information collected from the engine such as engine running times are critical for ongoing maintenance and repair. The data can also be used to support trend analysis for condition-based maintenance and to predict failure of parts. When connected to the CAD/AVL system the AVM system can be used identify and schedule preventive maintenance for vehicles that are in need of repair or are underperforming.

AVM Systems are also known as Vehicle Component Monitoring, Maintenance Management Systems, and Maintenance Tracking. These systems are becoming increasingly more standard on new vehicle procurements.

**Automatic Passenger Counter System (APC)**

The Automatically Passenger Counter System[17] is an on-board data collection tool that automatically counts the number of boardings and alightings at every stop, recording the data by time and by location. Passenger counts are collected either by using pressure mats or by using overhead- or side-mounted infra-red beams. The APC system can be extended to record other stop-related activity such as door-open/door-close, wheelchair lift operation and bike rack use. APC data can be transmitted in real-time and used for real-time operational control, and/or can be uploaded at a later time and used for planning purposes. Generally, APC systems are connected to the on-board MDT, CAD/AVL, and VLU devices and systems.

The APC system directly provides counts of boarding and alightings, which can be used to develop load profiles. In addition, the APC system generally provides better estimates of travel times than the AVL system, because the APC system also records door-open and door-close times, better accounts for terminal conditions, and can differentiate between route, dead-head, and recovery times.

APC data can be used to derive a number of key route-specific measures such as maximum passenger load, as well as key system-wide measures including unlinked passenger trips, passenger miles travelled, passenger hours travelled, etc. which are very important for on-going service planning. APC data can also be used for reporting to the National Transit Database (NTD). APC data (number of boardings) can also be used to validate or reconcile AFC data (fare collected). This is especially important for a POP system, where fares will be collected prior to passenger boarding.

There are some advantages to using the APC system to collect passenger counts over other methods such as using the AFC system or ridecheckers. The AFC system is typically not able to count alighting passengers, and so is unable to generate load profiles. Also, once implemented, the APC system provides a much larger sample of trips at a lower cost than is possible by using ridecheckers.

[16] FTA. (2007, December). *Maintenance Management Systems Fact Sheet: Transit Overview*. Retrieved November 22, 2009, from The ITS Professional Capacity Building Program: http://www.pcb.its.dot.gov/factsheets/maint/mntOve_print.htm
[17] FTA. (2007, September). *Transit Technology Fact Sheets – Transit Core Technologies*. Retrieved November 20, 2009, from The ITS Professional Capacity Building Program: http://www.pcb.its.dot.gov/factsheets/core.asp

**On-board Video Monitoring (OVM)** [18]

On-board Video Monitoring consists of security cameras installed within transit vehicles to record and monitor the safety and security of passengers, employees, equipment, and materials. In some cases, the video feed is transmitted in real-time to the control center and is used to alert officials in case of incidents, accidents, crime, or violence onboard the vehicle. Video data can also be stored on the vehicle for later uploading. The uploaded video can be used for detailed analysis or investigation after the fact.

Analog or digital technology can be used. Analog technology is cheaper but records at lower quality (5 to 20 frames per second), and cannot be transmitted real-time without conversion into digital format. Digital technology records at higher quality (over 30 frames per second), and can easily be transmitted by the communications system, and stored in the VLU without conversion.

**On-board Silent Alarms**

On-board silent alarms allow a driver to discretely alert dispatch of an emergency situation. These alarms are typically located in such a way that they are not easily triggered accidentally, but can be quickly and discretely triggered during an emergency. These systems allow for quicker emergency response to dangerous situations on-board a transit vehicle. Once triggered, the alarm is typically sent to central dispatch, which can implement its standard emergency procedures. If the silent alarm is integrated with a CAD/AVL system, dispatch software can often automatically focus in on the real-time location of the bus in question. Sometimes, the silent alarm is also tied into the exterior signage of the transit vehicle to display a “Call 911” or similar message.

### 4.5.2 BEST PRACTICES

**General**

General ‘best practices’ for installing technologies on-board transit vehicles are described below:

*Planning* – At the planning stage, it is important to develop a well-structured structured procurement plan, as well as performance-oriented requirements, and specifications. Staff from various departments, including Management, Planning, Operations, and Information Technology (IT), as well as outside stakeholders such as vendors and contractors should be involved in the planning process. Visiting peers at other transit agencies should be useful in ascertaining the full functionality of various on-board ITS technologies, their costs and other issues to consider in the concept and planning stage. On the technical side, it is important to ensure the availability of adequate data storage and analysis capacity; to avoid proprietary interfaces between vehicle and control center components; to choose technologies with open standards, and develop detailed documentation; and to ensure scalability for changes in fleet size.

*Implementation* – During implementation, it will be necessary to ensure that central systems (such as the central CAD/AVL system) and communications systems are compatible with the proposed on-board technology. Human resources are also important in the success of a technology implementation. To that end, transit operators should work to develop efficient operating procedures; training drivers and dispatchers to follow procedures and to properly use the full functionality of the on-board technologies. Transit operators should also hire and train new staff as necessary to analyze data collected from vehicles. All data should be tested and validated to ensure that data is being gathered correctly.

[18] FTA. (2007, December). *Transit Technology Fact Sheets – Security Cameras/Systems Fact Sheet: Transit Overview*. Retrieved November 20, 2009, from The ITS Professional Capacity Building Program: http://www.pcb.its.dot.gov/factsheets/security/secOve_print.htm

*Integration* – At the integration stage, Information Technology (IT) staff should be involved to ensure that they have reviewed the requirements and specifications and signed off and budgeted appropriate staff to provide internal technical support.

These general 'best practices' are applicable to the installation of most on-board technologies as described earlier. However, some technologies have more specific 'best practices'. These are described below:

**Mobile Data Terminals (MDT)[19]**

Transit operators should be aware that there is a learning curve as drivers and dispatchers understand system features and functionality and develop efficient procedures, especially log-on/log-off and communications procedures.

**Automatic Voice Annunciation System (AVAS)**

During implementation, transit operators should check to make sure that the announcements made by the AVAS meet ADA requirements.

**Automatic Vehicle Monitoring System (AVM)[20]**

During planning and procurement, space constraints within the vehicle for additional wiring and equipment and discuss impacts to available passenger space should be identified. The AVM should also include the ability to interface with other ITS capabilities and functions, including the scheduling system.

**Automatic Passenger Counter System (APC)**

At the implementation and integration stages, APC data should be verified to ensure that it is properly integrated with the CAD/AVL data and gets correct location and time stamps.

### 4.5.3 EXAMPLES OF IMPLEMENTATION

Some on-board technologies are near ubiquitous in the transit industry, having been implemented on almost all transit systems. These include VLU and PA systems. Others are gradually being implemented across transit agencies, examples of which are listed below.

**Mobile Data Terminals (MDT)[21]**

Some notable examples of transit agencies that have implemented mobile data terminals across their bus fleets include:

- *Tri-County Metropolitan Transit District of Oregon (TriMet), Portland, OR* – TriMet has installed 900 MDTs from a non-traditional transit MDT manufacturer on its fixed route and demand-responsive bus fleets (fixed-route: 641 vehicles operated in maximum service (VOMS); demand-responsive: 302 VOMS). MDT functionality on the TriMet fixed-route system includes downloading the manifest to the vehicle; transmitting drivers sign-on/sign-off, start run/end run (revenue service), and covert alarms; counting and transmitting boardings and alightings; and communications between operations center and driver. All

[19] FTA. (2007, December). *Communication Technologies Fact Sheet: Fixed Route Bus Transit*. Retrieved November 22, 2009, from The ITS Professional Capacity Building Program: http://www.pcb.its.dot.gov/factsheets/comm/comFix_print.htm
[20] FTA. (2007, December). *Maintenance Management Systems Fact Sheet: Transit Overview*. Retrieved November 22, 2009, from The ITS Professional Capacity Building Program: http://www.pcb.its.dot.gov/factsheets/maint/mntOve_print.htm
[21] Harman, L. J., & Shama, U. (2007). *TCRP Synthesis 70 – Mobile Data Terminals*. Washington, D.C.: Transportation Research Board.

MDT data identification is accompanied by a GPS location stamp (latitude/longitude) and GPS date/time stamp.

- *Delaware Transit Corporation (DTC), Wilmington, DE* – DTC has installed 415 SmartMDTs using SmartTrack software from Orbital TMS on its fixed route and demand-responsive bus fleets (fixed-route: 221 VOMS; demand-responsive; 245 VOMS). MDT functionality on the fixed-route system includes downloading the manifest to the vehicle; transmitting drivers sign-on/sign-off, start run/end run (revenue service), and covert alarms; counting and transmitting boardings and alightings; transmitting video feeds; and communications between operations center and driver. On the demand-responsive system, MDTs are used for downloading the manifest to the vehicle and automatically updating any schedule changes.

**Variable Message Signs (VMS)**

Some notable examples of agencies that have installed on-board VMSs to disseminate information to the public include:

- *New York City Transit Authority (MTA), New York, NY*
- *Capital District Transportation Authority (CDTA), Albany, NY*
- *PACE, Chicago, IL*
- *Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia, PA*

**Automatic Voice Annunciation System (AVAS)**[22]

A number of transit agencies have implemented AVAS across their bus fleets. Some notable examples include:

- *The Greater Cleveland Regional Transit Authority (GCRTA), Cleveland, OH* – GCRTA has deployed AVAS on 675 vehicles across its fixed route and demand-responsive bus fleets (fixed-route: 620 VOMS; demand-responsive: 105 VOMS).
- *Los Angeles County Metropolitan Transportation Authority (LACMTA), Los Angeles, CA* – LACMTA has deployed AVAS on 2400 vehicles across its bus fleet (2681 VOMS).
- *Capital District Transit Authority (CDTA) in Albany, NY* – CDTA has installed AVAS on its entire fixed-route bus fleet (fixed-route: 238 VOMS) with software from INIT.

**Automatic Vehicle Monitoring System (AVM)**[23]

Notable examples of transit agencies that have implemented Automatic Vehicle Monitoring Systems across their bus fleets include:

- *Los Angeles County Metropolitan Transportation Authority (LACMTA)* – LACMTA has deployed an on-board AVM system on 100% of its bus fleet (2681 VOMS). Key features include integration with the maintenance and material management systems, and transmission of powertrain alarms in real time.

[22] FTA. (2006). *Advanced Public Transportation Systems: The State of the Art Update 2006*. Washington, D.C.: FTA.
[23] FTA. (2007, December). *Maintenance Management Systems Fact Sheet: Transit Overview*. Retrieved November 22, 2009, from The ITS Professional Capacity Building Program: http://www.pcb.its.dot.gov/factsheets/maint/mntOve_print.htm

- *Chicago Transit Authority (CTA), Chicago, IL* – CTA has deployed an on-board AVM system on 100% of its bus fleet. Key features include transmission of powertrain alarms in real time, and use of voice annunciation system to report health status of ITS components.

**Automatic Passenger Counter System (APC)**

A number of transit agencies have implemented APCs across their bus fleets. Some notable examples include:

- *Regional Transportation District (RTD), Denver, CO* – RTD has deployed APCs on 20% of its bus fleet (fixed-route: 1071 VOMS; demand-responsive; 376 VOMS) with hardware from INIT and software from Ridecheck Plus.

- *Tri-County Metropolitan Transit District of Oregon (TriMet), Portland, OR* – TriMet has deployed APCs on more than 75% of its bus fleet (fixed-route: 641 VOMS; demand-responsive: 302 VOMS) with hardware from Red Pine and software developed in-house.

**On-board Video Monitoring (OVM)** [24]

OVM is becoming increasingly ubiquitous on new transit vehicle procurements. Notable examples of transit agencies that have implemented OVM systems include:

- *Washington Metropolitan Area Transit Authority (WMATA), Washington, D.C.* – WMATA has deployed On-board Video Monitoring on 640 buses in their fleet (fixed-route: 641 VOMS)

- *Dallas Area RapidTransit (DART), Dallas, TX* – DART has installed security cameras on 68 buses in the its fleet (fixed-route: 740 VOMS)

#### 4.5.4 ISSUES AND CONSIDERATIONS

There are a number of issues to be considered when deploying on-board technologies. In particular, since many of these systems are procured as part of vehicle procurements and replacement purchases, the various transit operators and CTDOT should determine which of these systems are required and mandatory for operating on the busway, and which of these on-board technologies can be incrementally deployed as part of the standard vehicle replacement/retrofitting process. In addition, the transit operators should also consider the following:

- Whether or not to use the AVM system to diagnose vehicle problems remotely, because it increases costs, and adds to strain on the communications network.

- Besides planning purposes, APC data can also be used to fulfill NTD reporting requirements. However, NTD has very strict requirements for APC data accuracy and precision, which in many cases is more rigorous and cumbersome than for ridecheck data. Considering this, the transit operators should decide whether or not to use APC data for NTD reporting.

[24] FTA. (2007, December). *Transit Technology Fact Sheets – Security Cameras/Systems Fact Sheet: Transit Overview*. Retrieved November 20, 2009, from The ITS Professional Capacity Building Program: http://www.pcb.its.dot.gov/factsheets/security/secOve_print.htm

## 4.6 Safety and Security Systems

### 4.6.1 DESCRIPTION

ITS technologies can improve the safety and security of passengers and transit operators. The following are several systems that can be used to promote safety along the New Britain-Hartford Busway:

*CCTV Cameras*: Closed-circuit television cameras are commonly used by transit properties to monitor sensitive locations, deter crime and vandalism, aid in incident investigation, and provide situational awareness during an emergency. At stations, CCTV cameras are commonly located along platforms and areas where passengers tend to congregate, with maximizing the field of view being the primary consideration. Cameras are also often located to monitor fare collection points to deter fraud and aid in investigations. CCTV cameras can be fixed or Pan-Tilt-Zoom (PTZ). Cameras are usually monitored and recorded at transit station security hubs or remotely at a central dispatch location. Along the transit route, CCTV cameras can also be placed to monitor operations and increase passenger safety when not at the station.

Different transit properties have developed different procedures for recording and storing video data. These procedures are often dictated by local laws and legislation relating to liability and privacy issues. In most cases, video data is recorded for a set period of time and then overwritten. If an incident occurs during that time period, the video data is saved to a separate data storage unit. Video recordings are most commonly stored using hard disk drives in lieu of video cassette recorders. The quality of digital recordings is subject to compression ratios, images stored per second, image size and duration of image retention before being overwritten. Different vendors of digital video recorders use different compression standards and varying compression ratios.

Growing in popularity are Internet Protocol cameras (IP cameras). IP cameras are flexible and easily addressable to allow agencies to relocate cameras around on an IP network. These cameras also offer remote accessibility and cost advantages for larger deployments.

*Emergency Call Boxes:* Emergency call boxes are usually “single button” or “lift-to-talk” devices that provide passengers with direct communication to local 911 dispatch. Emergency call boxes are often placed on platforms and other areas where passengers congregate. The New Britain-Hartford Busway project may want to consider placing emergency call boxes in some of the state-owned parking lots as well, particularly in those lots that are screened from general street traffic. In order to aid the COO’s response to emergencies, it is advisable that the emergency call boxes be configured to also trigger an alert to transit dispatch. Based on this alert, transit dispatch can use the CCTV camera feeds to monitor the situation and help coordinate their response with local public safety agencies.

*On-Board Video Monitoring and Silent Alarms:* These technologies, discussed in *Section 4.5: On-board Technology*, also offer safety and security benefits.

*Intrusion Detection:* Some transit agencies have also implemented intrusion detection systems to deter and detect unauthorized access to sensitive transit facilities or infrastructure. For example, some transit agencies have implemented alarmed security doors to prevent access to sensitive equipment rooms inside transit stations. Given that the stations on the New Britain-Hartford Busway will be primarily located outdoors, there is no identified need for security doors at the stations. However, as a safety and security precaution, CTDOT may want to consider having door alarms placed on communications cabinets at the stations.

CTDOT may also want to consider implementing some form of intrusion detection along the busway to detect unauthorized vehicle access during non-operating hours. Given that there are no gates or physical barriers to entering the busway, it is possible that individuals may attempt to illegally access the busway during off hours. In such a scenario, CTDOT may want to consider an intrusion detection system; triggered by the loop detectors to be installed along the busway near the intersections as part of the signal system. This intrusion detection system may be a lower priority system, since it remains to be seen whether or not illegal off-hours usage will be an issue.

*Building and Fire Alarms:* Some of the buildings and facilities being constructed as part of the busway project may include building and fire alarms. These alarms are being designed and provided by others. While some transit agencies have integrated building and fire alarms into an integrated ITS and security system, stakeholders have not currently identified a need for an integrated system along the busway.

#### 4.6.2 BEST PRACTICES

In terms of best practices, CCTV camera deployments are fairly commonplace. It is important to consider camera locations early on in the design process to ensure adequate field of view, identify mounting locations, and provision for appropriate power and communications connections. Given CTDOT's experience with traffic cameras, it may be advisable to adopt similar standards and specifications with regard to image quality, communications, and maintenance agreements.

Many transit agencies have found it beneficial to integrate camera views and camera controls into their existing transit management software. Software integration allows busway operators to quickly identify the nearest camera to a reporting incident. Software integration also allows busway operators to view and control cameras without having to switch software applications or use a separate workstation.

From an operational perspective, CTDOT should develop standard policies and operating procedures regarding camera use. These policies and procedures should include a policy for video recording covering such issues as: typical length of recording, data storage needs, after-incident evaluation of video, and long-term data storage. Law enforcement personnel should be consulted regarding the data quality and policies necessary for the video to support their investigation and enforcement efforts. Camera policies should also be developed to address liability and privacy concerns, particularly in regards to how video is used and stored during an incident.

CTDOT may also wish to develop interagency video sharing agreements. These agreements would govern whether or not busway camera feeds would be available to other agencies or even the general public. During stakeholder meetings, stakeholders have expressed interest in a future system that would allow authorized public safety personnel to access real-time camera feeds via the Internet. While stakeholders identified this as a lower priority system, provisions should be made to allow CTDOT to easily pursue this type of web interface at a future date. If desired, such a web interface may also be expanded in the future to provide limited camera views to the general public as well.

#### 4.6.3 EXAMPLES OF IMPLEMENTATION

The use of CCTV cameras for safety and security is widespread among transit agencies and other public and private institutions.

#### 4.6.4 ISSUES AND CONSIDERATIONS

There remain several issues and considerations for CTDOT to resolve moving forward. These issues and considerations include:

- *Identification of camera mounting infrastructure.* It will be important to identify the pole locations that the cameras will be mounted to at both the stations and along the busway. Given that the shelters at the stations are centrally located, they do not offer the optimal mounting location to provide a clear field of view of the entire platform. It may be necessary to install a pole at one end of the platform to mount the camera. Along the busway, it is likely that a sufficiently rigid camera pole will need to be designed and installed. Possible locations should be identified early on in the design process to ensure that these cameras are considered as part of the pole and foundation design.

- *Placement of emergency call boxes on platforms and at stations.* Given the space constraints on the platforms, it will be important to locate emergency call boxes on platforms and at stations where they are easily visible while not impeding pedestrian flow.

- *Video recording policies.* In order to identify the short-term and long-term data storage needs for the central digital video recording system, it will be necessary for CTDOT to define its recording policies.

## 4.7 Communications

### 4.7.1 DESCRIPTION

**General**

Robust and reliable communications are essential to the proper operation and management of a BRT system. Communications networks support increased operational efficiency by communicating voice and data information between transit vehicles and central dispatch. Communications networks also support a variety of ITS located at stations or roadside.

Radio communications on all busway vehicles are being upgraded to improve voice and data communications in support of ITS as part of a separate CTDOT effort. These fleet communications support the on-board ITS equipment and are vital to the efficient operation of the busway. It is currently anticipated that voice and low-speed data communications will be handled by the separate radio procurement under development by CTTRANSIT in coordination with the Department of Public Safety. High speed and bulk data communications with the fleet will occur via the cellular data network. CTDOT will be responsible for procuring the necessary cellular data provider services.

This rest of this communications section focuses primarily on busway communications, or rather the communications infrastructure along the busway designed to communicate with ITS field devices.

These ITS field devices are described in detail in previous sections and may include closed circuit television (CCTV) cameras at station platforms and along the busway, TVMs and ticket validators at each station, VMSs and PA systems installed on station platforms, emergency call boxes at stations, etc.

**Network Architecture**

The communications network supports voice, data and video transmission required for ITS deployments. A typical communications network is comprised of three basic elements:

- Backbone: The communications backbone is capable of carrying all types of voice, data and video traffic in the system. The backbone interconnects a number of nodes, which are central locations where the information can be inserted onto or removed from the backbone.

- Distribution: The distribution portion of the network provides a connection between a communications node and a group of ITS devices or buildings. Distribution electronics are commonly co-located with the backbone node equipment in a communications hub.

- Local: The local portion of the network or “drop” that connects an end device or building to a distribution cable or directly to a communications node on a backbone.

**Physical Topology**

The devices, centers and other facilities on a communication network can be connected in a number of different physical configurations or topologies, including star, ring, and/or mesh networks.

**Physical Network - Wireline**

Physical network communication options include:

- Twister Pair Cable: Twisted pair cable was the original physical plant used for communications networks. Twisted pair networks are still used for most traffic signal systems to interconnect the traffic signals. The most significant drawback of twisted pair plant is the narrow bandwidth it can provide. Although compression techniques have greatly improved data speeds, they are still generally limited to low speed data unless costly multiplexing equipment is utilized.

- Coaxial Cables: Coaxial cables were introduced to provide increased bandwidth and are still widely used to carry broadband video services by the Cable TV industry. In ITS systems they are typically used to make video connections where the cable is 500 feet or less in length, which does not require any transmission equipment.

- Leased Lines: Another option is to simply lease a twisted pair from a third party. Although there is other equipment that is likely in place on this link, it is not visible to the user, and the link can be considered as a physical plant link between two locations. Leased links incur ongoing monthly charges, but do not require a large capital outlay to have installed. They carry the same data as a twisted pair cable. They are often used effectively to serve remote devices where it would be too costly to install a dedicated cable.

- Leased Fiber: Fiber optic cables can be leased from the utilities in the region. These fibers are contained in cables owned by the utility, but would be segregated and leased exclusively for ITS use. Although dark fibers incur monthly charges, they provide the full benefit of the fiber optic cable without the capital construction costs. Utilization of leased dark fiber may be particularly advantageous for phased network implementation, with the leased segments being replaced by new construction as network deployment proceeds.

- Fiber Optic Cable: Fiber optic cable has become the preferred choice of physical plant installations for ITS systems. Fiber optic systems can carry very large bandwidth on a single fiber, and cost effective transmission systems are available for CCTV video signals. Fiber has the advantage of low signal loss, allowing signals to be carried large distances without repeaters. In recent years the cost of fiber optic cable has decreased, and it costs far less than a twisted pair of equivalent capacity.

**Communications Technology Options – Sub-network level**

Backbone Technologies: A key aspect of the network architecture is the type of transmission system used in the backbone to interconnect network nodes. Examples include ATM, SONET and Gigabit Ethernet (GigE) technologies. In newly constructed networks generally a single backbone transmission system is selected for the entire network. The selection must consider the current needs, industry standards, and the developing standards.

Ethernet is increasingly used as the backbone in ITS networks based on Gigabit Ethernet operating at 1000 Mbps, with support for all Ethernet standards commonly available today (10 Mbps, 100 Mbps and 1000 Mbps on twisted pair and fiber optic cable). Standard TCP/IP protocols are used throughout the network, and the components are widely available and interoperable between vendors.

Gigabit Ethernet (Gig E) provides a number of advantages:

- Based on established standards.
- Provides direct TCP/IP connectivity for center to center connectivity.
- Allows a standard IP addressing scheme, and subnetting.
- Supports Virtual Private Networking (VPN).
- Maintains the simple communication configuration.
- Supported by standard Network Interface Cards (NIC) and drivers, allowing direct connection to the backbone.
- Equipment is inter-operable between a number of vendors, and compatible with the equipment and systems installed in the region’s facilities.

The extensive use of Ethernet in communications networks worldwide ensures that it will continue in the future.

Under this configuration, a serial hub or terminal server device would provide the low speed EIA/TIA 232 communication for existing ITS devices (ex. traffic signal controllers) using EIA/TIA 232 communication, but this provides flexibility by allowing each port to be addressed with an IP address. Many new ITS devices may be procured with the Ethernet protocol in place of RS-232/422/485 and no serial hub or terminal server device is required. The routers are not required to convert the Ethernet traffic to other protocols for transport. The equipment at a node is also greatly simplified.

Distribution Technologies: The options for communication in the distribution network are driven mainly by the communication protocol used by the ITS device. Most distribution networks support these protocols directly, however, some distribution systems convert signals in a number of protocols into a common channel that can be easily carried on the backbone network. There are 3 main options discussed below are:

- RS232/422/485
- Video Transmission
- Ethernet

RS232/422/485: The traditional low speed protocol used by ITS devices is RS-232. This protocol is still widely used, and is one of the two low speed protocols recognized by NTCIP as a standard. RS-422 and RS-485 are similar protocols, and are often found in the circuits used for camera control. Each of these low-speed protocols was originally designed for twisted pair communication, but are now widely supported by fiber optic components.

Communication for the ITS subsystems requires the provision of low speed links to the controllers for each device. A number of controllers can typically share each low speed channel, and with NTCIP compliant controllers, functions such as vehicle detection and VMS sign control signal can share the same channel.

Video Transmission: There are two economical methods of carrying the video signals from the field cameras to a Control Center, simple analog video transmission over fiber optic cables or digitized video carried by the backbone transmission equipment.

Analog video signals can be carried economically over relatively short distances and provide a full motion video signal. Such transmitters could also carry the camera control signal. A number of video signals can be multiplexed and transported over a single fiber. Such systems typically combine from four to twelve signals on a fiber, but systems with as many as 128 signals are available. These systems become economical when there are few fibers available or the transmission distances are greater. Individual camera signals would be carried on single channel transmission systems to a communication node location. At the node, a number of camera signals will be multiplexed into one signal that can be carried over a fiber to the Control Center.

The trend in the ITS industry is towards digital video transmission equipment that will carry digitized video signals over a TCP/IP network ("IP Video"). There is significant development occurring in this area, with improved quality using less bandwidth, and the systems are becoming more cost effective.

Ethernet: With the proliferation of Ethernet (TCP/IP) communication in most computing equipment, this protocol is now appearing as an option in many ITS devices. Ethernet is a shared network providing a much wider bandwidth link to each device.

Ethernet is the second low speed protocol standardized under NTCIP, and is gaining use in this area because the increased connection speed is needed to support the overhead required by the NTCIP protocol. Where the backbone network is Gigabit Ethernet, the use of Ethernet for the distribution can result in a very simple and flexible network. Small serial hubs can be used to convert RS-232/422/485 signals to Ethernet traffic so that the network can support all data requirements.

**Wireless Communication**

In addition to the wireline communications options discussed above, agencies may also consider wireless communications to support voice, video and data communications with BRT stations and the various ITS devices. As with wireline communications, wireless options include both agency owned and leased (commercial wireless carrier) options. Commercial carrier services usually involve leasing or buying a wireless data card or purchasing a wireless modem and in both cases, involve monthly service charges. The remainder of this section focuses on agency owned wireless communications approaches.

Many options exist for low speed systems that do not require FCC licensing to operate. These systems typically operate in the 900MHz, 2.4GHz and 5.8GHz frequency bands[25] and employ

[25] Technologies utilizing these frequencies include both vendor proprietary solutions, as well as, open standard solutions marketed as WiFi.

Frequency Hopping Spread Spectrum techniques where the transmitter and receiver rapidly switch frequencies that allow other users to occupy the same frequency band without interference.[26] While license free systems frequently offer a relatively inexpensive and simplified deployment compared to licensed frequency systems, the popularity of the license free frequency band has saturated the 900 MHz and 2.4GHz bands, and increasingly the 5.8GHz band. In the last few years significant research and development efforts have been made by telecommunication equipment manufacturers to provide wireless broadband access over licensed and license-free frequencies. This effort has intensified with the issuance of the IEEE 802.16[27], which addressed standards for manufacturing Ethernet compliant wireless metropolitan area networking devices.

Some agencies use frequencies reserved for public safety for wireless transmissions, including 4.9Ghz which has fairly recently become available and licensed for public safety usage.

Wireless communications solutions can be implemented at substantially lower capital costs when compared to the cost for installing new conduit and fiber (or other wireline) communications media. However, when a project already involves substantial roadway construction efforts, the incremental cost of including conduit and fiber is often nominal in the overall construction budget and agencies take advantage of the opportunity to install wireline communications, as is the case in this initiative.

### 4.7.1 BEST PRACTICES

General 'best practices' for communication systems are described below:

**Planning** – The planning of a communications network should consider current communications requirements and known additional requirements. These are combined with future growth and new technologies and those that should be supported in the future. There are a number of guiding principles used in the development of a communications plan. These principles must also be considered during detailed design:

- Reliability: The system should provide a high level of reliability, achieved through the use of components with a high MTBF (mean time between failures), and combined with a redundancy in the network design.
- Growth: The network should be expected to grow gracefully. This requires the incorporation of a reasonable amount of unused capacity and a design approach that allows extra capacity to be provided by upgrading the transmission equipment.
- Standards: Communications protocols and component selection should use widely accepted standards that minimize ongoing operation and maintenance costs.
- Flexibility: The network configuration should be designed to maximize flexibility to accommodate future changes, rearrangements and equipment changes.
- Decentralized: As the network supports several agencies, it should be configured around several centers of protocol, and allow the control location to be changed according to current needs.

[26] Spread Spectrum is a data transmission modulation technique by which the transmitted signal is spread over a bandwidth wider than the information bandwidth. Spread Spectrum radio communications was developed originally by the military because the radiated signals are distributed over a wider range of frequencies and then collected onto their original frequency at the receiver making them difficult to jam or intercept. Spread Spectrum frequency bands are designated by the FCC and require no user license. Currently three license free Spread Spectrum frequency bands have been assigned by the FCC – 902 MHz to 928 MHz, 2.4 GHz to 2.4835 GHz and 5.725 GHz to 5.85 GHz. There are two Spread Spectrum transmission techniques – Frequency Hopping and Direct Sequence. Frequency Hopping Spread Spectrum is a technique by which the frequency band is divided into a number of channels and the transmission hops from channel to channel in a pre-specified sequence. Direct Sequence Spread Spectrum is a technique by which the transmitted signal is spread over a particular frequency range.

[27] Technologies utilizing this standard are commonly referred to as WiMax.

**Implementation –** The detailed design of any section of the network should support all current requirements, and provide for all anticipated requirements. Provision for these future requirements may include the following:

- Installation of appropriate cable sizes, or the installation of underground conduit for future cable installation;
- Sizing of equipment enclosures, cabinets, and facility rooms to accommodate future requirements;
- Placement of pullboxes along the busway to support future connections;
- Installation of slack backbone cable in pullboxes for connection to future devices and to provide for repair of broken and/or damaged fiber optic cable;
- Sizing provisions for power to include the load for future equipment; and
- Choice of transmission systems that will allow modular expansion to support the anticipated future requirements.

### 4.7.2 EXAMPLES OF IMPLEMENTATION

A number of transit agencies are implementing Bus Rapid Transit along corridors with a variety of communication solutions. The communications solution have been dependent on the existing infrastructure and funding available as well as the implementation schedule to have the system operational. Some examples are presented below:

- *Community Transit, SWIFT BRT, Snohomish County, WA* – Community Transit has deployed a 17 mile corridor along an existing arterial road system with 14 stations. Due to the lack of existing infrastructure and the urban setting, communication to the stations utilize leased DSL lines to a communication hub located at each station. Station amenities supported on the communications include VMS, security cameras with local DVR's and fare collection devices.
- *Regional Transportation Commission (RTC) of Southern Nevada, Las Vegas, NV* – RTC is deploying bus rapid transit along the existing road network. The communication network will include the installation of a new fiber optic cable to a communication node at each station. Station amenities supported on the communications network include VMS, CCTV cameras, emergency call boxes and fare collection devices.
- *King County RapidRide, King County, WA* – King County is deploying the first 3 of 5 RapidRide stations along existing transit routes. RapidRide stations are located at approximately one mile intervals. The communications will be supported on a backbone fiber optic cable network brought to a communication hub at the nearest intersection to each station. The distribution network utilizes a wireless network between the intersection and the station, with a distribution node at each. Station amenities supported on the wireless communications network include VMS, and fare collection devices. TSP at the intersection is directly connected to the fiber optic network.

#### 4.7.3 ISSUES AND CONSIDERATIONS

In planning and designing a communications system to support the ITS devices along the busway, the following should be considered:

- The physical infrastructure to support the communications network (the physical ductbanks, conduit, splice vaults, pullboxes, etc.) will be designed and constructed separately from the actual communications equipment design. This work will need to be closely coordinated to ensure that the physical infrastructure is sufficient and includes provisions for future maintenance and expansion of the communications network.

- The Busway Operations Dispatch center has been proposed to be located at the CTTRANSIT facility in Hartford. It has been assumed that this facility is suitable for this purpose and has sufficient space to accommodate the necessary head-end computer and communications hardware. The facility will need to be modified and updated in order to house this additional communications equipment.

- Communications along the busway will be supported by new physical infrastructure, designed by others. For the connection between the busway and the Busway Operations Center, it is envisioned that CTDOT will take advantage of the State's existing fiber optic network infrastructure and pull new fiber inside existing State-owned conduit. This effort will need to be further coordinated with the Highway Operations unit and FHWA.

- While the fleet communications are being designed and implemented as part of a separate CTDOT effort, it will be important for CTDOT to ensure that the upgraded radio systems support the on-board ITS equipment proposed for the busway. In particular, CTDOT will want to ensure that the upgraded radio system has made proper provisions for current and future bandwidth requirements, including an analysis of the potential for ITS add-ons that should include but not be limited to: CAD/AVL, AVAS, VLU, APC, AFC, AVAS, AVM, OVM, MDT, remote disabling, and interoperability with other transportation service providers. CTDOT may also want to ensure that a proper field strength analysis along the busway route has been conducted, and that potential future issues with communications facilities, systems, sites or towers have been identified and will be upgraded in time to support the busway transit vehicles. For now, it is assumed that the upgraded radio system will be sufficient for handling all voice communications traffic as well as low-speed data communications. High-speed data communications and bulk data communications will be handled by separate cellular communications or wireless broadband communications.

# 5. PROPOSED ITS SYSTEM

This section summarizes and prioritizes the ITS subsystems proposed for initial deployment along the New Britain-Hartford Busway. These proposed ITS subsystems and their prioritization are subject to change in response to evolving needs and issues that arise during the system design and engineering.

## 5.1 ITS Subsystems

Based on stakeholder needs and the applicability of ITS solutions to the New Britain-Hartford Busway context, the following ITS subsystems are proposed:

- **Central Systems:** It is proposed that the initial ITS deployment include Central Systems, consisting of workstations, servers, communications hardware, video display, DVR and data storage located at the Busway Operations Center. These Central Systems will include a Computer-Aided Dispatch/Automatic Vehicle Location (CAD/AVL) Central Software, Automatic Passenger Counter (APC) Management Software, Traveler Information Software, Fare Management Central Software, CCTV Camera Management Software, Emergency Call Box Central Software, and Network Management Central Software. It is understood that all transit operators operating on the busway will utilize the same scheduling software, which is being upgraded as part of a separate effort.

- **Transit Management:** It is proposed that the initial ITS deployment include a CAD/AVL System. The CAD/AVL System shall include all systems and devices (hardware and software) to support the dispatch, management, and monitoring of all busway vehicles operating on busway routes, including the CAD/AVL Central Software (part of the Central Systems), and Mobile Data Computers (MDCs) and other on-board equipment installed on transit vehicles.

- **Automatic Fare Collection (AFC):** It is proposed that the initial ITS deployment include TVMs located at every station along the busway. In order to serve passenger demand and provide redundancy it is recommended that at least two TVMs be installed at each station. Ticket Validators are proposed for installation at each station, with at least one ticket validator per platform. A small quantity of handheld devices to support ticket enforcement personnel in the field is also proposed. It is assumed that upgraded fareboxes for the busway transit vehicles will be handled by others. The fare collection system will be managed through the Fare Management Central Software (part of the Central Systems). However, it is assumed that the payment and transaction processing functions will be provided by others.

- **Traveler Information Systems:** It is proposed that the initial ITS deployment include VMSs and PA systems installed on each station platform. These VMS and PA systems would be capable of being coordinated and controlled automatically from a central location or controlled locally during an emergency or if communications to the central location is temporarily lost. The central traveler information system software would be interfaced with the central CAD/AVL software to provide real-time bus arrival information. Information kiosks were identified as a lower priority technology and therefore are not proposed as part of the initial ITS deployment. Likewise, future interfaces with statewide web services and 511 telephone services are not proposed as part of the initial deployment, but rather are envisioned as potential future expansions of the busway ITS system.

- **On-board Technology:** It is proposed that MDTs, with built-in VLUs and GPS receivers, be installed on all busway transit vehicles, as well as on a limited number of supervisor vehicles. It is also proposed that all busway transit vehicles be equipped with APC sensors. The APC software will be integrated into the central CAD/AVL software (both part of the Central Systems). Additionally, to facilitate communications to transit vehicles and provide future communications flexibility, a mobile communications gateway and router is also proposed for installation on all busway transit vehicles. Other on-board technologies, such as PA, VMS, AVAS, OVM, on-board silent alarms, and AVM, are considered important future technologies. Since these technologies are typically provided by the original equipment manufacturer (OEM), it is assumed that these additional on-board technologies will be implemented as part of the vehicle procurement and retrofitting process and are therefore not included as part of this project.

- **Safety and Security Systems:** It is proposed that the initial ITS deployment include CCTV cameras to monitor the platforms, TVM transactions, and provide some coverage of station plazas and pedestrian pathways. CCTV cameras are also proposed at strategic locations along the busway. These camera feeds will be sent back to a central location for viewing and recording. The video management and recording software will be included as part of the Central Systems. Emergency call boxes are also proposed for each station platform. A future interagency video sharing website is not proposed for the initial ITS deployment, but rather is envisioned as a potential future expansion of the busway ITS system. An intrusion detection system that would alert CTDOT of unauthorized vehicle use of the busway during off hours was identified as a lower priority technology, and therefore is not proposed as part of the initial ITS deployment.

- **Communications:** It is proposed that a fiber optic cable-based communications infrastructure be included to support both the initial ITS deployment and future ITS deployments along the busway. It is anticipated that fleet and vehicle voice communications will be handled by the upgraded radio communications system that is currently under development.

  As discussed above, wireless communications solutions for equipment located in the field can often be implemented at substantially lower capital costs when compared to the cost for installing new conduit and fiber (or other wireline) communications media. However, when a project already involves substantial roadway construction efforts, the incremental cost of including conduit and fiber is often nominal in the overall construction budget and agencies take advantage of the opportunity to install wireline communications, as is the case in this initiative.

  The communications system along the busway will provide a secure, high speed and reliable platform for transmission of voice, data and video to support monitoring and management of the bus operations and security functions at stations. It is proposed that a dedicated fiber optic backbone be installed along the length of the busway connecting to stations, intersections and busway cameras.

  Communications hubs are proposed at each of the stations, with 2 hubs located at Union and East Main stations (due to the physical separation of their platforms) for a total of 13 hubs. The fiber optic backbone will interconnect each of the communications hubs. Distribution fiber will be utilized from the communications hubs to the ITS subsystems.

  A connection to the central Busway Operations Dispatch located at the CTTRANSIT facility in Hartford from the fiber optic backbone is required to allow for monitoring and management of the operations and security functions. Communications to and from central dispatch shall support direct access to control and monitor the ITS and security subsystems at each of the stations. Local access to these systems is supported by the placement of communications hubs at each station with the ability to limit access and control at stations.

Splice vaults should be located to support proposed busway camera locations, at-grade intersections, and at additional locations along the busway where future ITS devices are anticipated or connections to other systems are planned. This will provide for access to connect these devices to the fiber optic backbone. Additional splice vaults can be placed along the busway at increments to be determined for future access.

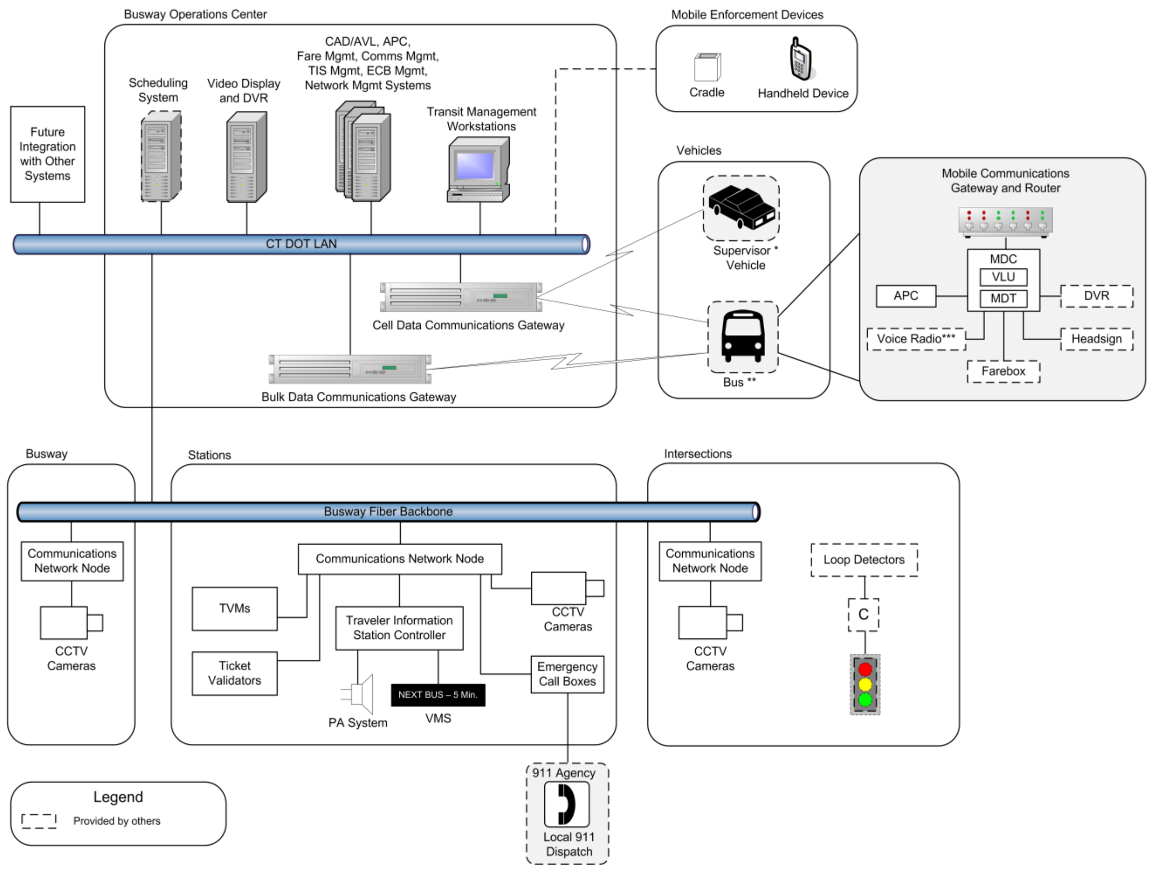
It is proposed that the communications network architecture utilize Ethernet (IP) technology for backbone and distribution to provide a flexible, expandable and reliable network for both initial and future ITS requirements. Station and platform ITS components, security/surveillance cameras, and other equipment shall connect to the network using standard Ethernet/IP interfaces.

Although radio communications on vehicles is being handled separately, communications will be required to transmit data between the vehicles and the central system. It is proposed that a bulk data communications system and a cell data communications system be included to facilitate communications between the central system and the vehicles. The cell data communications system will support the exchange of information in real-time. The bulk data communications system will support the exchange of information such as schedules and firmware updates.

## 5.2 ITS System Architecture

The diagram below (Figure 12) illustrates the proposed ITS System Architecture for the New Britain-Hartford Busway. Dashed items indicate ITS components that it is assumed will be provided by others.

## Figure 12: Proposed ITS System Architecture



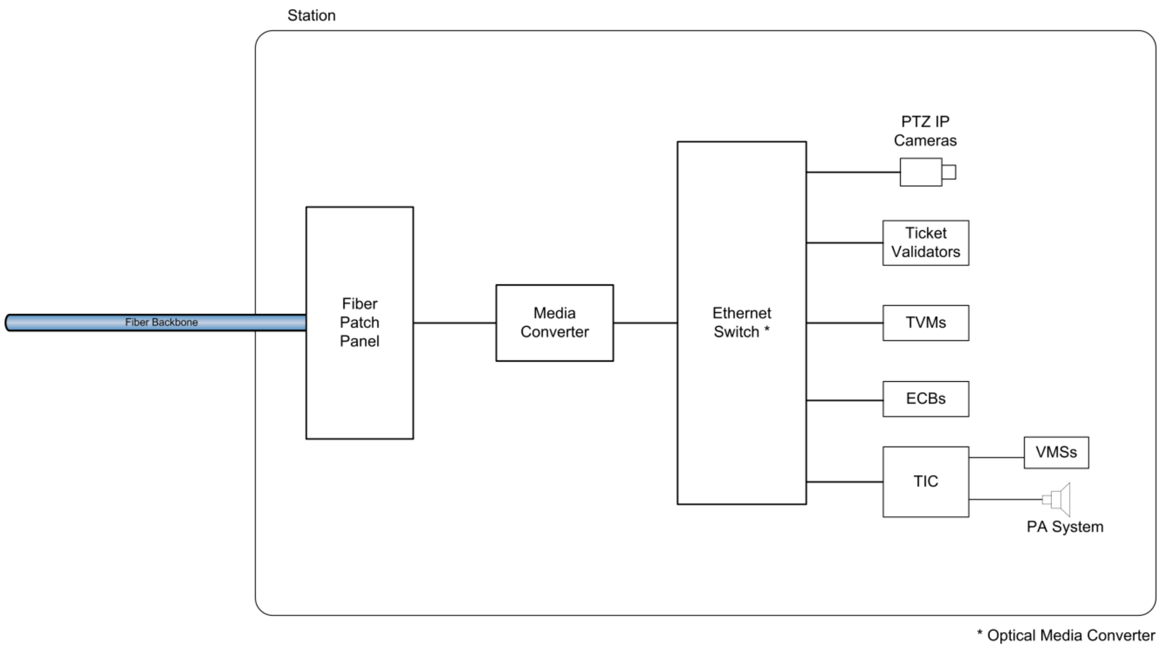

* Supervisor vehicles on-board technologies include: laptop, GPS receiver, and mobile radio system (voice/data) (radio provided by others).

** Bus on-board technologies include: MDT, VLU, APC, and mobile communications gateway and router. Additional on-board technology, to be provided by others and integrated with the VLU, may include on-board silent alarms, on-board speakers, passenger information displays, AVAS, fareboxes, on-board cameras, DVR, and headsigns.

*** Provided as part of a separate CTDOT project in coordination with DPS.

The diagram below (Figure 13) illustrates typical station communications for a fiber Ethernet network.

**Figure 13: Typical Station Communications – Fiber Ethernet Network**



## 5.3 Roles and Responsibilities

As described in *Section 2.2: Operations Plan Summary,* the recommended roles and responsibilities of project stakeholders are as follows:

- CTDOT has been and will continue to be the primary owner and manager of the New Britain-Hartford Busway. They will see the busway project through to completion and will retain ownership after it goes into operation. CTDOT will remain ultimately responsible for the level of service provided, planning of specific services, selecting and coordinating operators, facility maintenance, and community relations.

- Bus service on the busway will be operated by multiple organizations including CTTRANSIT Hartford, CTTRANSIT New Britain through New Britain Transportation, DATTCO, CCSU, and possibly other contract operators for new transit services. Private intercity bus service providers, such as Peter Pan, may also be allowed to operate on the busway at some point in the future. A Central Operations Organization (COO) will be established to dispatch and monitor the busway and coordinate between this diverse set of operators. The COO could be established as a division of CTDOT, could be contracted to one of the operators, or operations could be set up as an independent organization like some traffic operations centers are organized in Connecticut. The COO will be responsible for operating the transit management ITS components of the busway ITS system. The COO will operate and manage the busway from a central Busway Operations Dispatch center, currently planned to be located at the CTTRANSIT facility in Hartford.

- CTDOT will maintain the busway roadway and bridges directly like any other state highway. CTDOT will be responsible for the maintenance of the loop detectors and signal systems with which the busway ITS system will interact with. CTDOT will also be responsible for maintaining the CCTV cameras installed at strategic locations along the busway. CTDOT will also be responsible for implementing and maintaining future interfaces between the busway traveler information system and larger statewide traveler information system efforts.

- At stations, the services of a Busway Maintenance Organization (BMO) will be required. Similar to the COO, the BMO is a placeholder for an organizational responsibility that will be assigned to a specific organization as the design and function of the busway are developed. The BMO will be responsible for transit specific aspects of the busway like maintenance and servicing of stations, park-and-ride lots, and technology, as well as for responding to other maintenance issues as they arise. It may make sense to provide maintenance services for the busway's physical infrastructure and provide maintenance services for the busway's ITS technology components separately.

- Safety and security will be provided along the busway roadway, at stations, and on buses by the Connecticut State Police, possibly by the establishment of a new division. Other emergency services will be provided by municipal police, fire and EMS.

As the COO and BMO organizations are established, it may be necessary to revisit these roles and responsibilities.

# 6. OPERATIONAL SCENARIOS

This section provides two scenarios to illustrate the day-to-day operations of busway ITS. These scenarios were chosen to describe the intended interaction of the different ITS components and to demonstrate the benefits of coordinated ITS.

## 6.1 Busway Operations Scenario

A new 60-foot, low floor, articulated bus arrives at the New Britain Station. The vehicle is a busway shuttle, serving all 11 stations along the busway. Although the bus is operated by an individual bus service operator (e.g., CTTRANSIT New Britain, CTTRANSIT Hartford, DATTCO, or CCSU), it has been under control of the busway dispatch at the BOC, operated by the COO, since it left its garage. The farebox on the vehicle is covered to ensure that passengers do not attempt to pay for fares onboard.

At New Britain Station, travelers pay for fares using the station TVMs or use the ticket validators to validate previously purchased fare media. The station VMS and PA system announce that the next bus to leave the station is a busway shuttle, with a departure time of three minutes. The VMS displays departure information for the next three buses as well.

Passengers board quickly, having already purchased their fares, and the bus soon leaves the New Britain station. As the bus enters the busway, the COO operators monitor its progress in real-time, thanks to the CAD/AVL system. Due to the CAD/AVL system interface with the automatic scheduling software, on-time performance and schedule adherence is closely monitored. The COO also use cameras located strategically along the busway route to monitor busway conditions.

Passengers at the next station, East Main Station, are informed of the bus's estimated arrival time via VMS on the platform. These passengers have also taken advantage of the TVMs and ticket validators to pre-purchase their fares. As the bus arrives, its arrival is announced via the PA system on the platform. Passengers board and alight quickly through all vehicle doors, and the bus departs. This is repeated at all subsequent busway stations.

As the transit vehicle approaches a signalized intersection, an advance loop detector is triggered. In response, the local signal controller then alters the signal timing to provide a green to allow the bus to more quickly navigate the intersection. Another bus, immediately following, also triggers the advance loop detector. Signal timing parameters have been established at the intersection regarding maximum green times. In this instance, extending the green will not exceed the maximum green time allowed, so the signal controller extends the green time to allow this second bus to also pass.

At a downstream station, a ticket enforcement officer boards the bus. The officer visually inspects magnetic stripe tickets to make sure that passengers have indeed purchased and/or validated their fares. For those that have not, the officer uses a handheld device to enter information and compare the violators' identity or fare media to a 'badlist' to identify repeat offenders. The handheld device then prints citations in accordance with passed legislation and stores the information for later transmission to central systems.

Once the bus finishes its route, the bus leaves the busway.

## 6.2 Incident Response Scenario

A passenger experiences a medical emergency at Sigourney Station on the northbound platform. A concerned bystander uses the nearby emergency call box to directly contact 911 to request an ambulance. The COO is automatically alerted that an emergency call box has been activated at Sigourney Station on the northbound platform and a staff person is able to select the appropriate station CCTV cameras to find out what is going on. From the camera feeds, the COO staff can see that someone is lying on the ground. The COO staff contacts any supervisors/inspectors located at Sigourney Station to alert them to the situation and to gather additional information.

Local 911 dispatch has been trained to contact the COO when incidents are reported on the busway. Upon the local 911 dispatch establishing contact, the COO staff provides 911 dispatch with information about the best way to access the northbound platform at Sigourney Station.

The COO staff also immediately uses the CAD/AVL system display map to identify the vehicles that will be entering Sigourney Station soon. These vehicles are selected and messages are sent to their MDTs alerting their drivers to an emergency situation at Sigourney Station. Drivers are then able to convey that information to their passengers and let them know to expect delays and the reason for the delays. At other stations along the busway, a service alert is issued via VMS and PA system alerting passengers to potential delay due to a medical emergency.

Given the estimated amount of delay and the real-time passenger loading information from the APCs, the COO staff is able to calculate the total passenger delay expected. Based on this total passenger delay, the COO staff decides to hold buses upstream from Sigourney Station. In addition, the COO staff decides to change one bus from a local shuttle service to an additional express bus. These changes are communicated to the affected buses using the CAD/AVL system.

The COO staff continues to monitor the emergency situation via station CCTV cameras and provide updated passenger information until the situation is resolved and normal operations resume.

# 7. NEXT STEPS

Consistent with standard Systems Engineering practices, this ITS Concept of Operations report presents a high-level ITS system concept designed to meet the needs of the planned New Britain-Hartford Busway. This report provides a description of existing conditions, documents stakeholder-identified needs, describes the proposed ITS technology and systems to meet those needs, and finally proposes a system architecture showing how all of the existing and new components will function as a complete system. Some recommendations are provided as to what is required to implement, operate, and maintain the BRT system. This document will form the basis for subsequent development of ITS functional requirements and detailed ITS system design.

A number of issues and considerations were identified in this report that will need to be addressed by CTDOT. These issues are summarized below:

- The COO remains to be established. Once established, the ITS Concept of Operations should be revisited to ensure that the role and responsibilities of the COO are properly captured.
- The BMO remains to be established. Once established, the ITS Concept of Operations should be revisited to ensure that the role and responsibilities of the BMO are properly captured.
- There has been discussion of establishing a new division of the Connecticut State Police to handle enforcement along the busway. Once this, or other public safety agency, is established, the ITS Concept of Operations should be revisited to ensure that the role and responsibilities of the enforcement agency are properly captured. In particular, there should be additional discussion of enforcement legislation, practices, policies, as well as technology such as mobile enforcement devices.
- The current radio systems in use by the transit operators is outdated and in need of replacement. CTDOT, in conjunction with the Department of Public Safety, is in the process of developing a Statewide Request for Proposals (RFP) to replace this radio system for all eight divisions of state-owned transit. Coordination with this radio upgrade project will be important to the proper operation of the busway. The bandwidth provided by this upgraded radio system should be sufficient for voice communications and some low-speed data transmission. High-speed data requirements will be met by other forms of communications, such as cellular communications or wireless broadband. As one possible option, CTTRANSIT can investigate whether or not they will be able to use this WLAN installed at garages to download bulk data from on-board bus ITS systems on the busway.
- CTDOT recently upgraded the Trapeze scheduling software for all the transit operators that will be using the busway to Version 9 to assist in scheduling and run-cutting. CTDOT currently plans to upgrade the transit operators to Version 11 of the Trapeze scheduling software. Coordination with this schedule software upgrade will be important especially with regards to the CAD/AVL system design and procurement.
- CTTRANSIT is in process of developing its own specification for a system-wide CAD/AVL system. Further discussion is necessary regarding how the busway CAD/AVL system and the system-wide CAD/AVL system will be integrated/interfaced. Care should be taken to ensure that the necessary functionality for managing and monitoring multiple operators' vehicles on the busway can be provided.
- Connecticut's Statewide ITS Architecture calls for the future development of a 511 traveler information system, as well as future enhanced traveler information websites. While

outside the scope of the busway project, CTDOT should ensure that ITS and communications systems design do not preclude future interfaces with these proposed traveler information systems.

- Currently, CTDOT has instructed IBI Group to assume that the Busway Operations Center (central dispatch) will be located at the existing CTTRANSIT facility at 100 Leibert Road, Hartford, CT. This location should be assessed with regards to its suitability to house ITS and communications head-end equipment and the Busway Operations Center staff.

- There remains a pressing need to continue design and engineering coordination between the ITS systems and the signal systems. In particular, it will be important to coordinate signal control along the one-lane section of the busway to optimize signal timing and ensure safe and efficient operations.

- As a general consideration, it will be important to stress software integration and interoperability. As mentioned previously, the central CAD/AVL software will need to be integrated and interfaced with several different applications. This integration needs to be as seamless as possible to ensure efficient operation of the busway. Where possible, open, non-proprietary software solutions that meet NTCIP standards should be pursued.

- CTTRANSIT will be replacing their fareboxes in the near future. This effort should be coordinated with plans for the busway AFC system. Also, in the future, smart cards may be used on the New Britain-Hartford Busway, which, linked with AVL and APC data, can provide a rich dataset for analysis. Therefore, when installing an off-board, POP-based AFC system, consideration should be given to the potential integration of these cards without requiring purchase of all new equipment. Finally, the system will have to take into account the more complicated interoperability of bringing the data from these multiple sources back to a central point for analysis. CTDOT will also need to ensure that its back-office revenue management system is up-to-date and capable of handling the new AFC system transactions.

- Because CTDOT has not yet settled on a future fare policy, the system should be installed with adaptability in mind for expansion and redefinition of fare structures. Fare policy decisions should drive technological solutions, and not vice versa. In addition, technology continues to evolve regarding fare media. Smart cards, cell phone payment, and credit cards with smart chips may all evolve into a preferred fare media.

- While the current circumstances make POP a reasonable system to adopt, enforcement statistics or increased ridership may make a barrier system worth considering. This future possibility should not necessarily preclude purchase of equipment best suited to POP; however, metrics and assessments should always consider whether the current approach is the most cost effective.

- The importance of VMS displays was emphasized due to their effectiveness in communicating essential information. However, VMS displays are capital intensive and may require significant fine-tuning to ensure accuracy of displayed information. CTDOT may also want to re-assess the capabilities of LCD display monitors as they demonstrate more proven reliability in outdoor conditions over time.

- Real-time information displays depend on CAD/AVL system being deployed in the entire New Britain-Hartford corridor as well as coordinated communications software. The compatibility and consistency of the vehicle location information collected will be a key determinant in the usefulness and accuracy of the real-time information displays.

- In deploying on-board technologies, it will be important to coordinate with transit operators' vehicle procurement/retrofitting staff. In particular, since many of these on-board systems will be procured as part of vehicle procurements and retrofitting purchases, the transit operators and the COO will need to determine which of these systems are required and mandatory for operating on the busway, and which of these on-board technologies can be incrementally deployed as part of the standard vehicle replacement/retrofitting process.

- Transit operators will need to consider whether to use an AVM system to diagnose vehicle problems remotely, because it increases costs, and adds to strain on the communications network.

- Besides planning purposes, APC data can also be used to fulfill NTD reporting requirements. However, NTD has very strict requirements for APC data accuracy and precision, which in many cases are more rigorous and cumbersome than for ridecheck data. Considering this, transit operators will need to decide whether or not to use APC data for NTD reporting.

- It will be important to carefully locate the cameras that will be mounted at stations and along the busway. Given that the shelters at the stations are centrally located, they do not offer the optimal mounting location to provide a clear field of view of the entire platform. It may be necessary to install poles at ends of platforms to mount cameras. Along the busway, it is likely that a sufficiently rigid camera pole will need to be designed and installed. Possible locations should be identified early on in the design process to ensure that these cameras are considered as part of the pole and foundation design.

- Given the space constraints on the platforms, it will be important to locate emergency call boxes on platforms and at stations where they are easily visible while not impeding pedestrian flow.

- In order to identify the short-term and long-term data storage needs for the central digital video recording system, it will be necessary for CTDOT to define its recording policies.

- The physical infrastructure to support the communications network (the physical ductbanks, conduit, splice vaults, pullboxes, etc.) is being designed and constructed separately from the actual communications equipment design. This work will need to be closely coordinated to ensure that the physical infrastructure is sufficient and includes provisions for future maintenance and expansion of the communications network.

- Communications along the busway will be supported by new physical infrastructure, designed by others. However, it will also be necessary to identify exactly how the busway and the Busway Operations Center (proposed for the CTTRANSIT facility in Hartford) will be connected to the State's existing fiber optic network. These physical connections will need to be designed and included as part of the busway communications implementation efforts.

As a separate but related effort, a Preliminary Quantity and Cost Estimate Memorandum was prepared based on the ITS system architecture described in the March 2010 version of this ITS Concept of Operations report. This memorandum has been attached as Appendix B of this report. When this ITS Concept of Operations report was updated, a separate but related effort was made to update the Preliminary Quantity and Cost Estimate Memorandum as well. The updated version is attached as Appendix C. This Preliminary Quantity and Cost Estimate will need to be further refined and updated as part of the ITS and communications system design process.

Moving forward, IBI Group has recommended that CTDOT pursue a single systems integrator procurement for the busway ITS and communications systems. This systems integrator approach is intended to ensure interoperability and compatibility of all ITS and communications systems, as well as consolidate accountability for proper system operation and performance. IBI Group has also recommended that CTDOT use a competitive best-value procurement process to ensure that CTDOT receives the highest quality systems at the most competitive cost. In proceeding with a best-value procurement, developing transparent and traceable evaluation criteria will be an important consideration.

In accordance with standard Systems Engineering practices, the next step in the development of the ITS and communications systems after the initial submission of the ITS Concept of Operations report was the development of functional requirements for each of the systems identified in this document. A draft of the Functional Requirements for the New Britain-Hartford Busway ITS & Communications Systems report was submitted in August 2011. This document represents an updated version of the ITS Concept of Operations report to reflect the evolving design of the busway and to be consistent with the final functional requirements. These final functional requirements were submitted in October 2011 and will form the basis for the development of more detailed system requirements.

# APPENDIX A

ITS Concept of Operations Stakeholder Meeting Notes

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# Meeting Notes

| | | | |
|---|---|---|---|
| **To/Attention** | Notes to File | **Date** | September 30, 2009 |
| **From** | James Sorensen | **Project No** | B2-20848.4 |
| | | **Steno** | msoffice |

**Subject** New Britain-Hartford Busway ITS Concept of Operations Meeting
Conference Room 3130
Newington, CT
September 25, 2009
9:30AM

**Present** See Attached Sign-In Sheet

**Distribution** IBI Group - Internal

| **Item Discussed** | **Action By** |
|---|---|

## 1 Introductions

Brian Cunningham welcomed meeting attendees and facilitated introductions around the room.

## 2 Discussion of Systems Engineering Process

Martin Hull and James Sorensen gave a brief overview of the Systems Engineering process, emphasizing its role in ITS design and relevant FHWA/FTA rules and policies.

## 3 Review of Scope and Schedule

James Sorensen quickly reviewed the project scope, explaining the purpose of an ITS Concept of Operations document. The ITS Concept of Operations document will present a high-level overview of system needs, identify potential ITS solutions, describe ITS subsystems, how they will interact, and roles and responsibilities. It forms the basis for subsequent development of system requirements and system design. It will also continue to evolve throughout the project development process. The project schedule was also reviewed, with a focus on submitting a draft document – with placeholders for ongoing ITS research – to ConnDOT in late November. In order to meet this schedule, stakeholder meetings will need to take place as soon as they can be arranged.

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## 4 Discussion of ITS Concept of Operations – Draft Outline

James Sorensen quickly reviewed the draft outline for the ITS Concept of Operations document. There was general agreement regarding the outline and what the document will entail. Refer to attached draft outline.

## 5 Discussion of Existing Conditions

It was recognized that IBI Group will need to meet separately with Hal Decker and the TMC operations group to discuss a centralized transportation operations center, the Regional ITS Architecture, and existing communications infrastructure.

*Action By:* IBI Group to arrange separate meeting with Hal Decker's group.

ConnDOT is approaching 90% design for the Busway and 30% design for the Stations. Currently, the design calls for the installation of a bank of 4 ducts installed along the length of the busway. IBI Group was asked to estimate what will be needed in terms of power and communications and whether these 4 ducts will be sufficient. They want us to be sure to provide sufficient capacity not to preclude future additions to the ITS technology as well.

The current radio systems in use by the transit operators is outdated and in need of replacement. ConnDOT is preparing to hire a consultant to write the Statewide RFP to replace this radio system for all eight divisions of state-owned transit. IBI Group should provide input to ConnDOT about what should be included in this radio RFP in order to support voice and data communications for ITS applications. The funding for the radio system upgrade is separate from the $4.2 million ITS budget for the busway.

There is currently a separate fare policy and fare media in use for express and local fares. ConnDOT is interested in advanced fare media for BRT that will support existing and future fare policies. Fare policy is far from determined at this point and IBI Group should assume a worst case scenario in terms of what may be required to support AFC. IBI Group should propose a system that meets current fare needs, but can be upgraded to support future fare policies and media.

There are no GPS on snow plows, but there is GPS on police and some emergency vehicles. We will need to find out from police and fire what types of AVL they have and how it might be integrated with the busway dispatch.

ConnDOT has a preference to keep signals and signalized intersections simple, with very little specialized equipment, if possible. In ConnDOT's experience, loop detectors work well and they do not have many issues in terms of maintenance or reliability.

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The busway runs parallel to a High Speed Rail Corridor, and avoiding cross-talk frequencies and designing safe rail-street-busway intersections will be important.

Existing transit vehicles have ~7 cameras on board which store video data on board. All of the transit operators using the busway will operate the Trapeze software for automatic scheduling. They plan on upgrading to version 9 of Trapeze.

# 6 Assessment of Needs

## 6.1 Customer Services

The transit providers are moving to provide all their schedule information to Google Transit. It is also in use by Trips123. ConnDOT is planning to have their own trip planner based on schedule data as well. They are interested in the future having more real-time schedule information provided to the public, personalized alerts for service disruptions, and links to telephone services like 877-CTRIDES and possibly 511. These larger efforts are outside this busway project, but future interfaces should be provisioned for.

There are some state-owned parking facilities along the busway, but parking management and parking information is not currently seen as high priority.

On the platform, they are interested in VMS with real-time next bus arrival information, possibly for the next few buses. A PA system that can be controlled locally at the station and from a remote central location is desired. PA system should be automated to announce bus arrival information and service announcements. An emergency phone should be installed on the platform as well. An information kiosk or telephone would be lower priority at this point.

In vehicles, ConnDOT wants VMS and AAS eventually. APC is also an option, but real-time integration of APC for operations management is seen as a low priority.

## 6.2 Operations & Maintenance

There will need to be CAD/AVL on all vehicles using the busway to allow for highly efficient and reliable operations and real-time passenger information. It is envisioned that all vehicles on the busway will need to be report to a separate central dispatch that operates the busway. All vehicles will need to be able to communicate with central dispatch.

At lane access locations and intersections, ConnDOT does not see the need for gates. Instead signals and static signing are envisioned. In most cases, signals will not be timed, but rather dynamic - vehicles will arrive on red, call for the signal, and then progress through the intersection when safe. During peak periods, vehicles may arrive on green in peak direction due to TSP.

| **Item Discussed** | **Action By** |
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Proof-of-payment system is preferred, allowing all doors to open at once and minimize dwell times. IBI Group will need to consider what technology this will entail and how it may affect APC and paper transfers to local transit service.

Local police and fire utilize infrared or siren detection for signal preemption. There is also preemption in place for parallel railway. The busway intersections will need to be compatible with police and railroad preemption.

For maintenance, IBI Group will need to speak with Hal Decker's group about current ITS maintenance agreements. ConnDOT envisions having ITS providers maintain ITS systems initially, and provide maintenance training to ConnDOT in case ConnDOT decides to take it on themselves in the future. Transit operators handle their own fleet maintenance and ConnDOT does not envision any fleet maintenance interfaces with the busway ITS.

### 6.3 Safety & Security

Emergency phones on platforms and emergency call buttons on buses for bus drivers. Listen-in microphone, exterior emergency signing are also possibilities. ConnDOT would also like 100% security camera coverage on platforms. Camera feeds would be sent back to a central dispatch location. Video may also be shared in the future with state police and other agencies via secure website. Surveillance cameras are also required along the busway between the stations to monitor operations and detect incidents. Cameras and emergency buttons may also be needed at state-owned parking facilities, e.g. Cedar Street.

### 6.4 Planning & Reporting

Would appreciate some management tools that will aggregate ITS real-time information into usable reports. Particularly in terms of ridership, reliability, etc.

## 7 Challenges and Opportunities

Several challenges were identified:

- Budget restriction of $4.2 million for ITS. Radio, conduit, ducts, are being procured separately.
- Governance and maintenance of the system since multiple operators using the system, including public safety.
- Coordination with other projects being developed concurrently, especially fare policy, radio, station and busway design.
- Signal design and coordination given the parallel HSR corridor and the one-lane section.
- Travel in the viaduct may pose GPS problems.

| Item Discussed | Action By |
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## 8 Next Steps

IBI Group will coordinate with ConnDOT to arrange for additional stakeholder meetings. IBI Group will also initiate ITS research to address specific challenges

ITS
CONCEPT OF OPERATIONS
NEW BRITAIN - HARTFORD
BUSWAY

171-305 9-25-09

| | |
|---|---|
| BRIAN CUNNINGHAM | 594-3198 |
| Kevin Mahoney | 3197 |
| TONY MORELLI | 257-2402 |
| Michael Sanders | 594-2829 |
| James Nesci | 258-0347 |
| Charles Harlow | 594-2788 |
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# Meeting Notes

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|---|---|---|---|
| **To/Attention** | Notes to File | **Date** | October 28, 2009 |
| **From** | James Sorensen | **Project No** | B2-20848.4 |
| | | **Steno** | msoffice |

**Subject** New Britain-Hartford Busway ITS Concept of Operations Meeting
ConnDOT Conference Room
Newington, CT
October 22, 2009
9:30AM

**Present** See Attached Sign-In Sheet

**Distribution** IBI Group - Internal

**Item Discussed** **Action By**

## 1 Introductions

Brief introductions by meeting attendees.

## 2 Purpose of ITS Concept of Operations

James Sorensen gave a brief overview of the Systems Engineering process, and explained the purpose of the Stakeholder meeting – to gather information on system needs to assess what ITS solutions, if any, can be applied to improve the efficiency, safety, and utility of the busway. The ITS Concept of Operations document will provide a high-level description of stakeholder-identified needs, potential ITS solutions, a proposed ITS concept, high-level interfaces, and roles and responsibilities related to operating and maintaining ITS for the busway. This document will form the basis for subsequent development of system requirements and system design. It will continue to evolve throughout the project development process.

| Item Discussed | Action By |
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# 3 Assessment of Needs

There is a broader need, beyond the scope of the busway project, to expand the state's traveler information services. They are working to get the bus schedules on Google Transit for trip planning, as well as offer trip planning and static schedule information on the CT Transit website. ConnDOT hopes to be able to eventually have a real-time bus location map on the CT Transit website as well. An interface to provide traveler information via cell-phone is also a future potentiality.

On the platforms, stakeholders are looking for VMS with real-time next bus arrival information. Given the frequency of buses during peak periods, information for the next 4 buses should be displayed. It is possible that information for fewer buses may be needed at specific locations associated with service plan. For example, south of Flatbush there are fewer buses, so they might not need as many lines on their sign. However, consistency of VMS equipment for station identity and ease of maintenance, makes it desirable to have one type of VMS.

There should be a requirement for interoperable radio and data communications for all buses operating on busway. All buses operating on the busway need to be tied into the same CAD/AVL and scheduling system also.

Other on-vehicle enhancements, such as onboard VMS, automated announcements, cameras, etc., should be interoperable with other systems, but can be implemented incrementally as part of vehicle procurements. APC is a second order priority. Stakeholders see issues with regards to APC reliability and are concerned that the data provided by the APC is not sufficient for the types of reporting they want/need.

There is a need for Ticket Vending Machines (TVM) at each station. ConnDOT has not decided upon a specific fare policy or fare medium at this point. It will be important to have policy drive the technology decisions, and not vice-versa. Therefore a flexible AFC system is desirable. A proof-of-payment system is desired to reduce dwell times at stations. It was discussed that there will likely need to be TVMs at and ticket validators. These will need to located carefully to ensure ease of use, redundancy, do not impede pedestrian flow or safety.

Currently, the TVM should be able to sell one trip tickets and a variety of other types of passes, activate passes bought elsewhere, provide transfers, and have real-time communications with operations and maintenance for when a fault is detected, communications are lost, money vaults are full, etc.

| **Item Discussed** | **Action By** |
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| A system to help enforcement write up tickets and track ticket information was discussed. There is still legislation and decisions to be made regarding enforcement, but technology to assist the eventual enforcement personnel is desired.<br><br>VMS to inform passengers of bus arrival times and other service alerts is necessary. Static signing, outside the scope of the ITS, will be needed to direct passengers to other local bus stop locations.<br><br>Automatic connection protection, using technology to ensure that local connections wait for late busway buses, was discussed. There wasn't a strong need identified for this service at this time. However it will be important to include static signing to direct passengers to nearby local bus stops for connecting service. Connection protection should be examined in the future, particularly for off-peak trips with large headways and for connections to local buses with large headways.<br><br>Stakeholders again expressed their desire to keep the signal systems as simple as possible. ConnDOT wants to use loop detectors to trigger the system, (semi-actuated signals) along with TSP for bus priority.<br><br>Signals will include pre-emption for emergency vehicles. While many emergency vehicles in the region have GPS, due to privacy and security concerns, it is unlikely that there will be any interface or integration of these GPS with the transit AVL system. There will likely be a need for police dispatch to be trained to contact and coordinate with busway dispatch during emergencies/incidents, but that is viewed as sufficient for coordination needs, especially given the likely infrequency of emergencies on the busway. The busway dispatch will also be able to monitor busway via live camera feed which should help them keep track of emergency vehicles operating on the busway during an incident/emergency.<br><br>Stakeholders indicated that AVL should be installed on supervisors vehicles to help track where they are along the busway.<br><br>There is a need for emergency call buttons at stations and perhaps at some parking lots. These would directly call 911. The busway dispatch would be notified that a call had been made so they can use cameras to investigate and inform supervisors/drivers as appropriate. 911 dispatch may need to be trained to call and coordinate their response with busway dispatch during incidents/emergencies. | |

| Item Discussed | Action By |
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| Institutionally, outside the scope of the busway ITS Concept of Operations, stakeholders indentified a need for mutual aid agreements with local towns for fire and police response, a need for legislation regarding fare policy and enforcement, and a need for joint training of busway and public safety dispatch. Future consideration of allowing private bus operators to utilize the busway was also mentioned.<br><br>Unrelated to ITS, public safety stakeholders also discussed a need for a water supply along the busway, not just at stations.<br><br>Stakeholders also expressed a need for some type of off-hours intrusion notification to alert ConnDOT of vehicles driving on the busway illegally. It was thought that simply having the loop detectors alert ConnDOT personnel when triggered after hours would be sufficient. | |
| **4 Discussion of Challenges and Opportunities**<br><br>In general, stakeholders expressed the desire to include flexibility, interoperability, scalability and expansion into all ITS subsystems. | IBI Group will develop a draft Concept of Operations document for submission. |

| **Item Discussed** | **Action By** |
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## 5 Action Items and Next Steps

IBI Group will develop a draft version of the ITS Concept of Operations, summarizing stakeholder needs and proposing suitable ITS subsystems. This draft will be presented to ConnDOT for review. Upon completion of ConnDOT review, this draft will be further refined, additional information on the proposed technologies will be added, and a final version issued.

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# Meeting Notes

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|---|---|---|---|
| **To/Attention** | Notes to File | **Date** | Rev. January 21, 2010 |
| **From** | James Sorensen, IBI Group | **Project No** | B2-20848.4 |
| | | **Steno** | msoffice |

**Subject** New Britain-Hartford Busway
ITS Concept of Operations Review Meeting
ConnDOT Conference Room
Newington, CT
January 11, 2010
10:00 AM

**Present** See Attached Sign-In Sheet

**Distribution** Notes to File

**Item Discussed** **Action By**

## 1 Discussion of Station Design

The meeting began with a brief discussion of ongoing station design. There have apparently been some modifications to the New Britain Station, including relocating the building and moving the canopy. It will be important to revisit that station in terms of ITS equipment quantities and locations, as well as impacts on the service and operations plans. In general, as design progresses, it will be important to continue an iterative, coordinated design strategy to ensure that everyone is still on the same page.

## 2 Overview of Draft ITS Concept of Operations

James Sorensen gave a brief overview of Draft ITS Concept of Operations document, dated December 8, 2009. The general system needs identified by project stakeholders were discussed. The needs were also mapped to potential ITS technologies for consideration. The various ITS technologies were briefly identified, along with some key issues and considerations that remain to be addressed that may affect the Concept of Operations and future system design. The proposed ITS System Architecture was also reviewed.

| Item Discussed | Action By |
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Specifically, the following issues were identified as potentially impacting the ITS Concept of Operations and future system design:

- The need to identify the Central Operating Organization (COO) and the physical location of the busway central dispatch.
- The need for ongoing, iterative coordination of the ITS design with the signals design.
- The need for ongoing coordination between the ITS design and the separate initiatives to upgrade the State's radio communications system and to upgrade the State's transit scheduling software.
- The need for State decisions regarding fare policy, fare structure, and fare media to guide the technology utilized for Automatic Fare Collection.
- The need for significant testing and "fine-tuning" of the real-time passenger information systems to ensure that information is accurate and presented in an easy-to-understand format.
- The need for robust and reliable communications to support the proposed ITS applications.
- The need to clearly delineate which onboard ITS systems will be included as part of the ITS system budget and procurement process and which systems will be budgeted and procured through the vehicle procurement process.
- The need to identify the mounting infrastructure for cameras at the stations and along the busway, and clear delineation of how these mounting structures are accounted for and budgeted.
- The need for State decisions regarding video recording policies. In order to identify long-term and short-term data storage requirements, as well as camera control requirements, the State will need to provide guidance regarding video recording policies along the busway and at stations.

*Action By:* The State will continue to consider the issues identified and provide guidance as it becomes available.

## 3 Comments and Discussion

In general, there was general consensus regarding the style and format of the document. Baker had a list of comments that were provided to both ConnDOT and IBI Group. ConnDOT will endeavor to provide additional formal comments within the next two weeks. Additionally, there were a few items that were discussed that may need to be modified in the document.

- ConnDOT is interested in perhaps doing away with Transit Signal Priority (TSP) entirely and just optimizing the signal intersections based on the loop detectors. In other words, they propose having a presence detector at the intersection and an advance detector upstream, and just use the bus triggering the advance detector to extend the green time. This may lead to the introduction of some delay as compared to the TSP solution, particularly at either end of the one-lane section, but IBI Group will look into the cost and operational impacts of eliminating TSP from the ITS Concept of Operations.

*Action By:* IBI Group will examine the impacts of eliminating TSP from the ITS Concept of Operaions.

| Item Discussed | Action By |
|---|---|
| • The proposed CCTV cameras along the busway, in between stations and at intersections, will also need to be examined further. ConnDOT will provide additional guidance on the type of coverage they would like to have. The future design will need to clearly identify the camera quantities, supporting infrastructure, camera pole locations, cost estimates, and clearly identify how the various components will be budgeted and designed. | ConnDOT will provide guidance regarding preferred camera coverage along the busway. |
| • There is a need to identify the location of the busway dispatch center and identify the facility and communications requirements associated with that location. Currently, there is discussion of establishing the busway dispatch center at the CT Transit Facility in Hartford. Once that decision is made, ConnDOT will need to evaluate the facility with regards to the hardware to be installed there (servers, workstations, etc.), as well as how to establish a communications connection to that location. IBI Group was asked to look into the nearest communications node to link the CT Transit facility to the State's existing fiber network. | IBI Group will identify the nearest communications connection from the CT Transit facility to the State's fiber network. |
| • As IBI Group develops its communications recommendations for the ITS Concept of Operations document, IBI Group was asked to provide general guidelines regarding physical infrastructure to support the fiber system, such as typical fiber conduit sizing, spacing of pull boxes and vaults, types of vaults and splice enclosures, etc. There was discussion regarding whether or not the cost of this physical infrastructure was to be included as part of the ITS budget or separately. Baker Engineering provided clarification immediately following the meeting. | IBI Group will include general guidelines for physical infrastructure as part of its communications section of the ITS Concept of Operations. |
| • There was discussion regarding quantities of TVMs at stations and weather protection for TVMs. In general, it was agreed that the quantity of TVMs need to be sufficient to handle the anticipated passenger volume and provide redundancy. The quantities identified in the IBI Group Preliminary Quantity and Cost Estimates Memorandum, dated December 22, 2009 will need to be reviewed and discussed with the station design team as the project progresses. | |
| • There was also a brief discussion regarding alternative procurement approaches for ITS systems. ConnDOT will make some internal decisions regarding their preferred procurement approach since this may influence the ITS system design and procurement documentation. | |

| Item Discussed | Action By |
|---|---|
| **4 Next Steps**<br><br>ConnDOT will provide formal comments on the Draft ITS Concept of Operations document. IBI Group will respond to and incorporate ConnDOT comments and Baker comments into the final ITS Concept of Operations document. IBI Group will also develop a technical memorandum with recommendations regarding the proposed busway ITS systems' consistency with the Connecticut Statewide Regional ITS Architecture. | ConnDOT will provide formal comments on the Draft ITS Concept of Operations.<br><br>IBI Group will incorporate comments into a final version.<br><br>IBI Group will develop a memorandum on Regional ITS Architecture consistency for submittal. |

| IBI GROUP | PROJECT: | PROJECT NO.: | SHEET: OF: |
|---|---|---|---|
| | CLIENT: | PREPARED BY: | DATE: |
| | DESCRIPTION: | CHECKED BY: | OTHER: |

## SIGN-IN SHEET

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# APPENDIX B

Preliminary Quantity and Cost Estimate Memorandum, Revised March 17, 2010

**IBI Group**
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# Memorandum

| | | | |
|---|---|---|---|
| **To/Attention** | Tony Morelli, Baker Engineering | **Date** | Rev. March 17, 2010 |
| **From** | James Sorensen, IBI Group | **Project No** | B2-20848.4 |
| **cc** | Martin Hull, IBI Group | **Steno** | msoffice |
| **Subject** | New Britain-Hartford Busway: Preliminary Quantity and Cost Estimates | | |

## Background

The New Britain–Hartford Busway is a 9.4 mile long bus-only roadway running from Main Street in downtown New Britain to Asylum Street in downtown Hartford. The busway will be built along the former New Britain Secondary railroad between New Britain and Newington Junction and beside the active Amtrak Springfield to New Haven Line from Newington Junction to Union Station in Hartford. The busway will include 11 stations in total. Small park-and-ride lots will be located at East Street, Cedar Street, Newington Junction, Elmwood, Flatbush Avenue, and Parkville. The busway was selected as the locally preferred public transportation alternative because of its relatively high ridership and relatively low cost compared to other transit options. The busway will also provide a number of unique service advantages including frequent service, the ability to provide service to locations not directly on the busway, flexibility to change routes when necessary, and the ability to operate local and express services along the same right-of-way. Intelligent Transportation Systems (ITS) will play an important role in helping this Bus Rapid Transit (BRT) system accomplish its goal of providing high quality, flexible rapid transit service.

IBI Group has been tasked with the development of an ITS Concept of Operations report for the New Britain-Hartford Busway. Consistent with standard Systems Engineering practices, the purpose of the report is to develop a high-level ITS system concept designed to meet the needs of the planned New Britain-Hartford Busway. Concurrent with the development of this ITS Concept of Operations, Baker Engineering and CTDOT have requested that IBI Group provide additional services, not included in its original scope of work. These services included, specifically:

1. Identify, at a preliminary level, the types of equipment that may be installed at typical BRT stations. IBI Group agreed to meet with SEA Consultants to learn more about their current proposed station design and discuss typical ITS equipment installed at BRT stations. This meeting occurred on November 18, 2009.

2. Identify, at a preliminary level, where ITS equipment may be located at the stations as well as installation considerations. IBI Group agreed to meet with SEA Consultants to discuss potential equipment locations and installation considerations. It was recognized that locating this ITS equipment is essential to station design and is part of an iterative process that will need further refinement and engineering as the project proceeds. These discussions also occurred at the November 18, 2009 meeting.

3. Develop a preliminary station quantity and cost estimate for ITS elements consistent with the development of the ITS Concept of Operations document.

This memorandum summarizes IBI Group's discussion with SEA Consultants regarding general ITS equipment at the stations, as well as installation considerations. This memorandum also provides a preliminary quantity and cost estimate for busway ITS elements. It should be noted that these are preliminary estimates only, and these estimates will need to be refined and adjusted as busway design and engineering progress.

## BRT Station ITS Equipment

CTDOT and busway stakeholders have identified the following types of equipment as potential ITS systems to be deployed at the New Britain-Hartford Busway Stations:

- **Ticket Vending Machines (TVM):** These devices allow passengers to purchase a variety of fare types. It is typical to locate these devices in an easy-to-see location. These machines can be field-hardened to withstand temperature extremes; however, it is important to try and shelter these devices from wind and rain, both for customer convenience and to avoid the buildup of ice and sleet on the machine interface. TVMs should be located in accordance with ADA requirements and should not impede the safe and efficient flow of pedestrian traffic. Given that these machines deal with revenue collection, redundancy is an important consideration. It is recommended that at least two TVMs be installed at each station. Since at many stations, the northbound platform can only be accessed from the southbound platform, it may be possible to locate these two TVMs in one station location. Additional TVMs may be necessary and/or desirable at some stations due to high passenger volumes or due to passengers being able to access the platform from multiple directions. Power and communications will need to be provided to all TVM locations.
- **Ticket Validators:** These devices allow passengers to validate previously purchased fare media. These devices are often much smaller than the TVMs and are typically located on station platforms. It is recommended that at least one ticket validator be installed on each station platform. Additional ticket validators may be necessary and/or desirable at stations with high passenger volumes. Ticket validators should be located in accordance with ADA requirements and should not impede the safe and efficient flow of pedestrian traffic. Power and communications will need to be provided to all ticket validator locations.
- **Variable Message Signs (VMS):** VMSs are electronic displays, that at BRT stations, generally provide single- or multi-line information about: scheduled bus arrival(s), general information about date and time, and specialized service announcements or alerts. Given the high frequency service planned, CTDOT has identified the need for a 4-line VMS at each station platform to inform passengers of the next several bus arrivals. The VMS will need to meet ADA visibility and legibility standards. These sizable VMSs will need to be located so that it can be easily viewed by all passengers along a platform. In most cases, the VMS is mounted to an existing structure or on a stand-alone pole or pad. For safety considerations, the mounting of the VMS should not pose a physical danger to passengers, nor should it occlude a clear view of the busway. Power and communications will need to be provided to all VMS locations.
- **Public Address (PA) Speakers:** PA Speakers, at BRT Stations, generally provide audio announcements to passengers concerning scheduled bus arrivals, general travel

information, and special service announcements or alerts. PA Speakers are usually mounted to an existing structure. A general installation consideration is the need for PA Speakers to be clearly audible to station passengers without posing a noise nuisance to nearby residents and businesses. Power and communications will need to be provided to all PA Speakers.

- **Traveler Information System Controllers:** These devices interface with a central traveler information software to synchronize and control real-time messages displayed on VMSs and announced over the PA Speakers. These devices also allow authorized personnel to control station traveler information systems locally during an emergency situation or when connection to the central system is lost. These devices are often located at a supervisor's booth or communication hub. Power and communications will need to be provided to all traveler information system controllers.
- **Closed-Circuit Television (CCTV) Cameras:** These cameras monitor BRT stations to deter crime, aid in incident investigation, and provide real-time situational awareness during incidents and emergencies. CTDOT has specified that they would prefer 100% camera coverage on all station platforms. For safety and security purposes, it is recommended that cameras also be located to be able to monitor TVM locations. CTDOT may also want to consider installing additional cameras at stations that feature large pedestrian plazas and at stations with parking lots that are not clearly visible from the street. Cameras are typically mounted on existing structures or stand-alone poles. They should be mounted in locations that offer a clear field of view and are not easily tampered with or vandalized. Dome cameras with pan-tilt-zoom (PTZ) functionality are recommended. Power and communications will need to be provided to all CCTV cameras.
- **Emergency Call Boxes:** Emergency call boxes are usually "single button" or "lift-to-talk" devices that provide passengers with direct communication to local 911 dispatch. At BRT stations, emergency call boxes are often placed on platforms and other areas where passengers congregate. It is recommended that at least one emergency call box be located on every station platform. CTDOT may also want to consider locating additional emergency call boxes at stations that feature large pedestrian plazas and at stations with parking lots that are not clearly visible from the street. Power and communications will need to be provided to all emergency call boxes.
- **Communications Hubs:** Communications hubs, or nodes, are locations that support the connection of the specific ITS devices installed at a BRT Station to the communications backbone. They typically consist of a field cabinet or closet containing communications hardware (such as switches, media converters, etc.) as well ancillary equipment (such as encoders, etc.). These communications hubs are typically placed in a location that is easily accessed by station supervisors and maintenance personnel. Power and communications connections will need to be provided to all Communications Hubs.

For all ITS equipment, it is important that the devices be properly installed and integrated into the station design. Given that the ITS equipment serves as an interface with the general public, poorly integrated ITS equipment will reflect poorly on CTDOT and the busway operator, in terms of aesthetics, functionality, and ease-of-use.

Tony Morelli, Baker Engineering – Rev. March 17, 2010

## Preliminary Station Quantity Estimates

The following table provides a preliminary estimate of the types and quantities of ITS equipment that may be required at the busway stations. This estimate is preliminary and is intended as a high-level estimate for planning purposes only. This estimate is based on the assumptions listed below and in the ITS Concept of Operations document. This estimate will need to be further refined and adjusted as busway design and engineering proceeds.

| | Stations | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Equipment** | **New Britain** | **East Main** | **East Street** | **Cedar Station** | **Newington Junction** | **Elmwood** | **Flatbush** | **Kane** | **Parkville** | **Sigourney** | **Union Station** | **Totals** | **Equipment Notes** |
| Ticket Vending Machines (TVM) | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 28 | Assumed 2 per station. |
| Ticket Validators | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 26 | Assumed 1 per platform. |
| VMS | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 22 | Assumed 1 per platform. |
| PA Speakers | 40 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 140 | Assumed 1 speaker per 20' of platform |
| Traveler Information System Controller | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 13 | Assumed 1 controller at communication hub for local control of VMS and PA messages. |
| CCTV Cameras | 6 | 4 | 3 | 4 | 3 | 3 | 4 | 3 | 4 | 4 | 4 | 42 | Assumed 3 per station. 1 per platform and 1 to monitor TVM. |
| Emergency Call Boxes | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 23 | Assumed 1 per platform. |
| Communications Hubs | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 13 | Assumed 1 per station. |

**Station Notes:**

| | |
|---|---|
| New Britain | 2 TVM, 2 ticket validators, and 3 cameras were added due to platform size and passenger volume. |
| East Main | 2 TVM, 1 communications hub, 1 camera, and 1 TIS Controller were added due to physically separated NB and SB platforms. |
| East Street | CTDOT may want to consider additional camera(s) and Emergency Call Boxes for plaza and parking lot areas. |
| Cedar Station | 1 camera and 1 Emergency Call Box were added due to large parking area. |
| Newington Junction | |
| Elmwood | |
| Flatbush | One camera was added due to large canopy/plaza area. |
| Kane | CTDOT may want to consider additional camera(s) and Emergency Call Boxes for walkway and parking lot areas. |
| Parkville | One camera was added due to large canopy/plaza area. |
| Sigourney | One camera was added due to large canopy/plaza area. |
| Union Station | 2 TVM, 2 ticket validators, and 2 cameras were added due to passenger volume and physical separation of Union Station shelters. Further information on this station location is required. Equipment location will need to be integrated into existing shelter infrastructure. |

## Preliminary Cost Estimates

The following table provides a preliminary cost estimate for busway ITS equipment. This estimate is preliminary and is intended as a high-level estimate for planning purposes only. This estimate is based on the assumptions listed below and in the ITS Concept of Operations document. This estimate will need to be further refined and adjusted as busway design and engineering progresses. The costs provided in this estimate are installed unit costs only. This estimate does not include costs related to system design, integration, testing, or training. Maintenance equipment and equipment spares are not included in this estimate. This estimate also does not include any allowance for contingency. It is strongly recommended that these costs be considered as part of the overall busway system costs.

| Item | Qty. | Unit Cost | Total Cost | Notes |
|---|---|---|---|---|
| Transit Management/Operations | | | | |
| Busway Central Dispatch Hardware | 1 | $125,000.00 | $ 125,000.00 | Includes workstations, servers for operations software, communications hardware, video display, DVR, and data storage for the busway only. Located at the busway dispatch center. Does not include hardware for individual transit operators or non-busway functions. Assumes facilities and furnishings provided by others. |
| CAD/AVL Software | 1 | $200,000.00 | $ 200,000.00 | Software to manage CAD/AVL on buses, including integration with scheduling software - Web interfaces not included, but important to ensure interoperability and rights to data for future interfaces to 511, CT Transit website, etc. |
| Automatic Scheduling Software | 1 | | $ - | Assumed provided separately by others. |
| Signal System Coordination | | | | |
| Signal Equipment | | | | Assumed included as part of signals costs. Includes controllers, phase selectors, conflict monitors, cabinets, signal heads, poles, conduit, etc. |
| Signal Coordination and Timing | | | | Assumed included as part of signals costs. |
| Loop Detectors | | | | Assumed included as part of signals costs. |
| Emergency and Railroad Pre-emption | | | | Assumed included as part of signals costs. |
| AFC Equipment | | | | |
| TVM | 28 | $ 30,000.00 | $ 840,000.00 | See quantity table. Assumes medium grade functionality. |
| Ticket Validators | 26 | $ 3,500.00 | $ 91,000.00 | See quantity table. |
| Enforcement Support | 10 | $ 5,000.00 | $ 50,000.00 | Handheld devices to support ticket enforcement efforts. |

| Item | Qty. | Unit Cost | Total Cost | Notes |
|---|---|---|---|---|
| Fareboxes (on vehicles) | 46 | $ 3,500.00 | $ 161,000.00 | Assumed that new fareboxes installed on all new and retrofit vehicles using CAD/AVL on busway. |
| Traveler Information | | | | |
| VMS | 22 | $ 10,000.00 | $ 220,000.00 | See quantity table. Assumes a 4-Line VMS on Platform. Mounting infrastructure or pole to be provided by others. |
| PA Speakers | 140 | $ 150.00 | $ 21,000.00 | See quantity table. |
| Traveler Information Station Controllers | 13 | $ 5,000.00 | $ 65,000.00 | See quantity table. |
| Traveler Information System Software | 1 | $150,000.00 | $ 150,000.00 | Bus arrival prediction software with interface to AVL. Allows central control of VMS and PA Systems |
| Information Kiosk | 0 | $ 8,000.00 | $ - | Lower Priority |
| Onboard Technology | | | | |
| MDTs | 46 | $ 9,000.00 | $ 414,000.00 | Includes VLU, GPS. Assumes that MDTs will be installed on new and retrofitted transit vehicles operating on the busway. |
| APC (onboard) | 46 | $ 6,000.00 | $ 276,000.00 | Assumed that APC will be installed on new and retrofitted transit vehicles operating on busway. |
| APC Software with AVL integration. | 1 | $ 80,000.00 | $ 80,000.00 | |
| Supervisor Vehicle Equipment | 4 | $ 4,000.00 | $ 16,000.00 | Includes laptop and GPS receiver. |
| VMS (onboard) | 31 | $ - | $ - | Assumed that this will be provided by OEM as part of new vehicle procurements. Will need to be interoperable with existing ITS systems. |
| Cameras (onboard) | 31 | $ - | $ - | Assumed that this will be provided by OEM as part of new vehicle procurements. Will need to be interoperable with existing ITS systems. |
| Silent Alarms (onboard) | 31 | $ - | $ - | Assumed that this will be provided by OEM as part of new vehicle procurements. Will need to be interoperable with existing ITS systems. |
| Automatic Voice Annunciation System (onboard) | 31 | $ - | $ - | Assumed that this will be provided by OEM as part of new vehicle procurements. Will need to be interoperable with existing ITS systems. |
| Fleet Maintenance (onboard) | 31 | $ - | $ - | Assumed that this will be provided by OEM as part of new vehicle procurements. Will need to be interoperable with existing ITS systems. |

| Item | Qty. | Unit Cost | Total Cost | Notes |
|---|---|---|---|---|
| Vehicle Diagnostics (onboard) | 31 | $ - | $ - | Assumed that this will be provided by OEM as part of new vehicle procurements. Will need to be interoperable with existing ITS systems. |
| Safety/Security | | | | |
| CCTV Cameras (Stations) | 42 | $ 12,000.00 | $ 504,000.00 | See quantity table. Cost includes some allowance for mounting structures. Additional clarification of mounting and support structure is required. |
| CCTV Cameras (Busway) | 15 | $ 6,000.00 | $ 90,000.00 | At strategic locations along busway, in between stations, and at intersections. Assumed that sufficiently rigid poles provided by others. Additional clarification of camera locations and support structures along the busway is required. |
| Encoders/Decoders | 114 | $ 1,500.00 | $ 171,000.00 | One encoder and one decoder for each camera. |
| CCTV Software and Integration | 1 | $ 80,000.00 | $ 80,000.00 | Includes viewer and control software and integration into transit management software. |
| Emergency Call Boxes | 23 | $ 5,000.00 | $ 115,000.00 | One per platform (each direction) and additional for parking lots. |
| After Hours Intrusion Detection System | 0 | $100,000.00 | $ - | System tied to loop detectors to issue alert if triggered during off hours. Lower priority. |
| Interagency Video Web Interface | 0 | $150,000.00 | $ - | Lower priority. Requires interagency video sharing agreements. |
| Communications | | | | |
| Radio System Upgrade | 1 | $ - | $ - | Assumed that radio system upgrade is provided separately by others. |
| Vehicle Communications Upgrade | 31 | $ 2,000.00 | $ 62,000.00 | Assumed that radio communications equipment on vehicles is only provided for newly acquired vehicles. Assumed that existing vehicles would be upgraded by others as part of separate radio project. Assumed that supervisor vehicles' radios would also be upgraded by others as part of separate project. |
| Busway Fiber Backbone | 50000 | $ 5.00 | $ 250,000.00 | Assumes an installed cost per foot. Assumes 96 ct. fiber backbone. Assumes conduit and physical infrastructure provided by others. |
| Communications Hubs | 13 | $ 25,000.00 | $ 325,000.00 | Includes communications cabinet, communications hardware, switches, media converters, ancillary equipment, etc. |

| Item | Qty. | Unit Cost | Total Cost | Notes |
|---|---|---|---|---|
| Splice Enclosures | 15 | $ 1,500.00 | $ 22,500.00 | Splice enclosures for cameras along busway. Assumes conduit, vaults, and physical infrastructure provided by others. |
| Connection to Existing State Fiber Network | 2 | $100,000.00 | $ 200,000.00 | Assumes conduit and physical infrastructure along entire length of busway provided by others. Assumes that a connection to State FON at Myrtle Street hub is possible for Union Station connection. Assumes a connection to fiber on I-91 is possible for CTTransit facility connection. Includes cost of physical connection, switches, and communications hardware. Cost is a placeholder until additional engineering analysis of communications connections can be completed. |
| Misc. Communications Equipment | 1 | $ 50,000.00 | $ 50,000.00 | Provides for additional communications equipment along busway and at busway dispatch center. |

**Total** **$4,578,500.00**

# APPENDIX C

Preliminary Quantity and Cost Estimate Memorandum, Revised October 28, 2011

**IBI Group**
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Boston MA 02110 USA

**tel** 617 450 0701
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# Memorandum

| | | | |
|---|---|---|---|
| **To/Attention** | Tony Morelli, Baker Engineering | **Date** | Rev. October 28, 2011 |
| **From** | James Sorensen, IBI Group | **Project No** | B2-27914 |
| **cc** | Carl-Henry Piel | **Steno** | tt |
| **Subject** | New Britain-Hartford Busway: Revised Preliminary Quantity and Cost Estimates | | |

## Background

The New Britain–Hartford Busway is a 9.4 mile long bus-only roadway running from Main Street in downtown New Britain to Asylum Street in downtown Hartford. The busway will be built along the former New Britain Secondary railroad between New Britain and Newington Junction and beside the active Amtrak Springfield to New Haven Line from Newington Junction to Union Station in Hartford. The busway will include 11 stations in total. Small park-and-ride lots will be located at East Street, Cedar Street, Newington Junction, Elmwood, Flatbush Avenue, and Parkville. The busway was selected as the locally preferred public transportation alternative because of its relatively high ridership and relatively low cost compared to other transit options. The busway will also provide a number of unique service advantages including frequent service, the ability to provide service to locations not directly on the busway, flexibility to change routes when necessary, and the ability to operate local and express services along the same right-of-way. Intelligent Transportation Systems (ITS) will play an important role in helping this Bus Rapid Transit (BRT) system accomplish its goal of providing high quality, flexible rapid transit service.

IBI Group has been tasked with the development of an ITS Concept of Operations report for the New Britain-Hartford Busway. Consistent with standard Systems Engineering practices, the purpose of the report is to develop a high-level ITS system concept designed to meet the needs of the planned New Britain-Hartford Busway. Concurrent with the development of this ITS Concept of Operations, Baker Engineering and CTDOT requested that IBI Group develop a preliminary equipment quantity and cost estimate. It is recognized that this preliminary quantity and cost estimate is part of an iterative process to design and locate ITS equipment at stations and along the busway. As the design of the ITS and communications systems progresses and evolves, the underlying assumptions used to develop this preliminary quantity and cost estimate will need to be revisited and further refined.

This memorandum is an update to the one submitted in March 2010, reflecting the evolving design of the busway and maintaining consistency with the ITS Concept of Operations document as well as the functional requirements document. It summarizes IBI Group's discussions with the station and busway design consultants and further decisions made by CTDOT regarding general ITS equipment at the stations, as well as installation considerations. The main focus of this update is the preliminary quantity and cost estimate for busway ITS elements. Unit costs have been updated. The equipment quantities have also been updated based on the latest design drawings provided by Baker Engineering on October 26, 2011 and IBI Group's separate review of camera locations on earlier drawings, dated September 22, 2011. It should be noted that these still are preliminary estimates only, and these estimates will need to continue to be refined and adjusted as busway design and engineering progress.

## BRT ITS Equipment

CTDOT and busway stakeholders have identified the following types of equipment as ITS systems to be deployed on the New Britain-Hartford Busway Stations:

- **Ticket Vending Machines (TVM):** These devices allow passengers to purchase a variety of fare types. It is typical to locate these devices in an easy-to-see location. These machines can be field-hardened to withstand temperature extremes; however, it is important to try and shelter these devices from wind and rain, both for customer convenience and to avoid the buildup of ice and sleet on the machine interface. TVMs should be located in accordance with ADA requirements and should not impede the safe and efficient flow of pedestrian traffic. Given that these machines deal with revenue collection, redundancy is an important consideration. IBI Group has recommended that at least two TVMs be installed at each station. Since at many stations, the northbound platform can only be accessed from the southbound platform, it may be possible to locate these two TVMs in one station location. Additional TVMs may be necessary and/or desirable at some stations due to high passenger volumes or due to passengers being able to access the platform from multiple directions. Power and communications will need to be provided to all TVM locations.
- **Ticket Validators:** These devices allow passengers to validate previously purchased fare media. These devices are often much smaller than the TVMs and are typically located on station platforms. It is recommended that at least one ticket validator be installed on each station platform. Additional ticket validators may be necessary and/or desirable at stations with high passenger volumes. Ticket validators should be located in accordance with ADA requirements and should not impede the safe and efficient flow of pedestrian traffic. Power and communications will need to be provided to all ticket validator locations.
- **Variable Message Signs (VMS):** VMS are electronic displays, that at BRT stations, generally provide single- or multi-line information about: scheduled bus arrival(s), general information about date and time, and specialized service announcements or alerts. Given the high frequency service planned, CTDOT has identified the need for at least two 4-line VMS at each station platform to inform passengers of the next several bus arrivals. The VMS will need to meet ADA visibility and legibility standards. To meet these standards, the VMS will have integrated speakers and include a push button located near the VMS to prompt the announcement of the sign contents through the speaker. These sizable VMS will need to be located so that they can be easily viewed by all passengers along a platform, and in some cases, CTDOT has determined that this requires double-sided VMS. In most cases, the VMS will be mounted to a stand-alone pole or pad, and in some cases, VMS will be mounted to station canopies. For safety considerations, the mounting of the VMS should not pose a physical danger to passengers, nor should it occlude a clear view of the busway. Power and communications will need to be provided to all VMS locations.
- **Public Address (PA) Speakers:** PA Speakers, at BRT Stations, generally provide audio announcements to passengers concerning scheduled bus arrivals, general travel information, and special service announcements or alerts. PA Speakers are usually mounted to an existing structure. A general installation consideration is the need for PA Speakers to be clearly audible to station passengers without posing a noise nuisance to

nearby residents and businesses. Power and communications will need to be provided to all PA Speakers.

- **Traveler Information System Controllers:** These devices interface with a central traveler information software to synchronize and control real-time messages displayed on VMS and announced over the PA Speakers. These devices also allow authorized personnel to control station traveler information systems locally during an emergency situation or when connection to the central system is lost. These devices are often located at a supervisor's booth or communication hub. Power and communications will need to be provided to all traveler information system controllers.
- **Closed-Circuit Television (CCTV) Cameras:** These cameras monitor BRT stations to deter crime, aid in incident investigation, and provide real-time situational awareness during incidents and emergencies. CTDOT has specified that they require camera coverage on all station platforms. For safety and security purposes, it is recommended that cameras also be located to be able to monitor TVM locations. CTDOT has also identified the need to install additional cameras at stations that feature large pedestrian plazas and at stations with parking lots that are not clearly visible from the street. Cameras will be mounted on existing structures or stand-alone poles. They should be mounted in locations that offer a clear field of view and are not easily tampered with or vandalized. Dome cameras with pan-tilt-zoom (PTZ) functionality are recommended. Power and communications will need to be provided to all CCTV cameras.
- **Emergency Call Boxes:** Emergency call boxes are usually "single button" or "lift-to-talk" devices that provide passengers with direct communication to local 911 dispatch. At BRT stations, emergency call boxes are often placed on platforms and other areas where passengers congregate. It is recommended that at least one emergency call box be located on every station platform. CTDOT has also identified the need to locate additional emergency call boxes at stations that feature large pedestrian plazas and at stations with parking lots that are not clearly visible from the street. Power and communications will need to be provided to all emergency call boxes.
- **Communications Hubs:** Communications hubs, or nodes, are locations that support the connection of the specific ITS devices installed at a BRT Station to the communications backbone. They typically consist of a field cabinet or closet containing communications hardware (such as switches, media converters, patch panels, etc.) as well ancillary equipment (such as patch cords, connectors, etc.). These communications hubs are typically placed in a location that is easily accessed by station supervisors and maintenance personnel. Power and communications connections will need to be provided to all communications hubs.

For all ITS equipment, it is important that the devices be properly installed and integrated into the station design. Given that the ITS equipment serves as an interface with the general public, poorly integrated ITS equipment will reflect poorly on CTDOT and the busway operator, in terms of aesthetics, functionality, and ease-of-use.

## Preliminary Station Quantity Estimates

The following table provides a preliminary estimate of the types and quantities of ITS equipment that may be required at the busway stations. This estimate is preliminary and is intended as a high-level estimate for planning purposes only. This estimate is based on design drawings provided by Baker Engineering on October 26, 2011. The quantities of station cameras have been derived from IBI Group's separate review, dated September 22, 2011, of camera locations on earlier drawings. This estimate will need to be further refined and adjusted as busway design and engineering proceeds.

| Equipment | New Britain | East Main | East Street | Cedar Station | Newing-ton Junc-tion | Elm-wood | Flat-bush | Kane | Park-ville | Sigour-ney | Union Station | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ticket Vending Machines (TVM) | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | **26** |
| Ticket Validators | 6 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | **26** |
| VMS (1-sided) | 2 | 4 | 4 | 4 | 4 | 5 | 0 | 4 | 4 | 4 | 2 | **37** |
| VMS (2-sided) | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | **6** |
| PA Speakers | 24 | 4 | 6 | 8 | 4 | 6 | 6 | 8 | 6 | 10 | 2 | **84** |
| Traveler Information System Controller | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **12** |
| CCTV Cameras | 22 | 14 | 8 | 9 | 12 | 9 | 10 | 10 | 10 | 10 | 2 | **116** |
| Emergency Call Boxes | 6 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 1 | **35** |
| Communications Hubs | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **12** |

## Preliminary Cost Estimates

The following table provides a preliminary cost estimate for all busway ITS equipment. This estimate is preliminary and is intended as a high-level estimate for planning purposes only. This estimate is based on the assumptions listed below, in the ITS Concept of Operations document, and in the Functional Requirements document. This estimate will need to be further refined and adjusted as busway design and engineering progresses.

The following table contains current, 2011 cost estimates of the equipment as well as updated installation costs. In addition, a variety of updates have been made to reflect decisions made during the progression of the busway design process. Major changes from the 2010 Preliminary Quantity and Cost Estimates memorandum include the following:

- Based on CTDOT's decision to expand camera coverage at stations, the number of CCTV Cameras has significantly increased, from an estimated 43 in 2010 to 116 in 2011. This change affects not only the cost of procuring the cameras themselves, but also the cost of central hardware needed to manage, display, and store camera data.
- Based on CTDOT's revised equipment functionality and additional installation costs, the unit cost of the TVMs has increased.
- Based on CTDOT's decision to provide additional VMS, this cost estimate includes an additional 15 one-sided VMS as well as six double-sided VMS. The VMS unit cost also now includes PA speakers as well as a push button to enable announcement of the contents displayed on the VMS. This new unit cost also incorporates the associated increase in installation costs.
- Based on the current design to connect the fiber backbone to the proposed Busway Operations Center (BOC) location, the fiber quantities and costs have been refined.
- Vehicle fareboxes were confirmed to be outside the scope of this project and have been removed from the cost estimate.

The updated costs still include a busway CAD/AVL system as well as on-board equipment. CTTRANSIT is in process of developing a specification for a system-wide CAD/AVL system and may decide to have the busway's CAD/AVL system interface with or be incorporated into the system-wide CAD/AVL system. On-board systems may also be procured as part of a separate bus procurement process. If so, these costs will be removed from future estimates.

The costs provided in this estimate are installed unit costs only. This estimate does not include costs related to system design, integration, testing, or training. Maintenance equipment is also not included in this estimate. It is strongly recommended that these costs be considered when programming the overall busway system costs. This estimate does include a 15% allowance for contingency and the provision of spares.

| Item | Notes | Unit Type | Estimated Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|---|
| **Transit Management/Operations** | | | | | |
| **Busway Central Dispatch Hardware** | Includes all hardware (i.e. servers, workstations, switches, monitors and UPS) required to control and manage central software. Does not include hardware for other transit operators or non-busway functions. Does not include radio hardware. | ea. | 1 | $250,000 | $250,000 |
| **CAD/AVL Software** | Software to manage CAD/AVL on buses, including integration with scheduling software - Web interfaces not included, but important to ensure interoperability and rights to data for future interfaces to 511, CT Transit website, etc. | ea. | 1 | $200,000 | $200,000 |
| **Automatic Scheduling Software** | To be procured separately. | | | | |
| **Signal Scheduling Software** | | | | | |
| **Signal Equipment** | Assumes that this equipment is included as part of signals costs. Includes controllers, phase selectors, conflict monitors, cabinets, signal heads, poles and conduit. To be procured separately. | | | | |
| **AFC Equipment** | | | | | |
| **TVM (Ticket Vending Machine)** | Functionality includes reading magnetic stripe tickets, with ability to later upgrade to smart cards. Assumes printed vouchers will be provided | ea. | 26 | $35,000 | $910,000 |

| Item | Notes | Unit Type | Estimated Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|---|
| | instead of dispensing change. Assumes medium grade functionality. Assumes it includes concrete pad foundation and paving. See quantity table. | | | | |
| **Ticket Validators** | Machines used to validate pre-purchased fare media in POP systems. Assumes functionality to validate magnetic stripe tickets and accommodate future smart card reader. Includes post and foundation. See quantity table. | ea. | 26 | $4,000 | $104,000 |
| **Mobile Enforcement Devices** | Handheld devices to support ticket enforcement efforts. Includes ability to enter offender information and print citations. Includes docking cradle and extended battery. | ea. | 12 | $1,500 | $18,000 |
| **Fareboxes** | To be procured separately. | | | | |
| **Traveler Information** | | | | | |
| **VMS (one sided, Variable Message Signs)** | 4-line VMS at platforms. Adheres to ADA visibility and legibility standards, and includes a speaker and push-button. Includes costs for posts, foundation, and paving. See quantity table. | ea. | 37 | $12,000 | $444,000 |
| **VMS (two-sided)** | 4-line VMS at platforms. Adheres to ADA visibility and legibility standards, and includes a speaker and push-button. See quantity table. | ea. | 6 | $17,000 | $102,000 |
| **PA Speakers** | See quantity table. | ea. | 84 | $150 | $12,600 |
| **Traveler Information System Controllers** | See quantity table. | ea. | 12 | $5,000 | $60,000 |

| Item | Notes | Unit Type | Estimated Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|---|
| **Traveler Information System Software** | Bus arrival prediction software with interface to AVL. Allows central control of VMS and PA Systems. | ea. | 1 | $150,000 | $150,000 |
| **Onboard Technology** | | | | | |
| **MDCs (Mobile Data Computers)** | Includes Mobile Data Terminal (MDT), Vehicle Logic Unit (VLU), and GPS. Allows drivers to log-on/log-off from a route. Assumes that MDCs will be installed only on transit vehicles operating on the busway. | ea. | 46 | $9,000 | $414,000 |
| **APC (onboard)** | Assumes that APC will be installed only on transit vehicles operating on busway. | ea. | 46 | $6,000 | $276,000 |
| **APC Software with AVL integration** | | ea. | 1 | $80,000 | $80,000 |
| **Supervisor Vehicle Equipment** | Includes a field-hardened/rugged laptop with a built-in GPS receiver. Includes integration with CAD/AVL software. | ea. | 4 | $2,000 | $8,000 |
| **Onboard Equipment (to be provided by others): VMS, Cameras, Silent Alarms, Automatic Voice Annunciation System, Fleet Maintenance, Vehicle Diagnostics** | Assumes that this will be provided by original equipment manufacturer as part of new vehicle procurements or procured separately as part of system-wide retrofits. | ea. | 31 | | |
| **Safety/Security** | | | | | |
| **CCTV PTZ Cameras (Stations)** | Cost includes mounting equipment and installation. See quantity table. | ea. | 116 | $10,000 | $1,160,000 |
| **CCTV PTZ Cameras (Busway)** | Assumes camera pole, camera lowering system, pole-mounted cabinet, all procured separately. See quantity table. | ea. | 10 | $6,500 | $65,000 |

| Item | Notes | Unit Type | Estimated Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|---|
| **Decoding Software** | Video management software decodes IP camera and delivers to users. | variable | 1 | $4000 + $250/cam | $35,500 |
| **CCTV Software and integration** | | ea. | 1 | $80,000 | $80,000 |
| **Emergency Call Boxes** | One per platform (each direction) and additional for parking lots. Includes installation. | ea. | 35 | $7,000 | $245,000 |
| **Communications** | | | | | |
| **Radio System Upgrade** | To be procured separately. | | | | |
| **Vehicle Communications Upgrade** | To be procured separately. | | | | |
| **Busway Fiber Backbone** | Includes fiber and installation costs per foot. Assumes that conduit and physical infrastructure is procured separately. | ft. | 70,000 | $6 | $420,000 |
| **Communications Hubs** | Includes communications cabinet, communications hardware, switches, media converters, ancillary equipment, etc. | ea. | 14 | $25,000 | $350,000 |
| **Splice Enclosures** | Assumes that conduit, vaults, and physical infrastructure are procured separately. | ea. | 50 | $1,500 | $75,000 |
| **Misc. Communications Equipment** | Provides for additional communications equipment along busway and at busway dispatch center. | ea. | 1 | $50,000 | $50,000 |
| Subtotal | | | | | $5,509,100 |
| Contingency + Spares | 15% of subtotal | | | | $826,365 |
| **Total** | | | | | **$6,335,465** |

Connecticut Department of Transportation

# FUNCTIONAL REQUIREMENTS FOR THE NEW BRITAIN - HARTFORD BUSWAY ITS & COMMUNICATIONS SYSTEMS

FINAL REPORT

OCTOBER 2011

IBI GROUP

# DOCUMENT CONTROL

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| History: | |
| | |

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# 1. INTRODUCTION

## 1.1 Project Background

The New Britain-Hartford Busway was first proposed as part of a major investment study in the I-84 corridor, completed in the late 1990s. Several modes were looked at to reduce traffic congestion and improve transportation services including roadway expansion, light rail, commuter rail and high occupancy vehicle lanes, in addition to the busway. The busway was selected as the locally preferred alternative because of its relatively high ridership and relatively low cost compared to the other alternatives. The busway also provided a number of unique service advantages over other transit options including more frequent service, the ability to provide service to locations not directly on the busway, flexibility to change routes when necessary, and the ability to operate local and express services along the same right-of-way. Intelligent Transportation Systems (ITS) can play an important role in helping bus rapid transit (BRT) systems accomplish the goal of providing high quality, flexible rapid transit service.

## 1.2 Document Purpose & Structure

This document specifies the Functional Requirements for the Intelligent Transportation Systems (ITS) and Communications systems for the New Britain-Hartford Busway project. The overall goal of this Connecticut Department of Transportation (CTDOT) project is to provide reliable and efficient BRT service along the New Britain-Hartford corridor. ITS and communications systems will play an important role in ensuring the reliability and efficiency of these BRT services. In accordance with standard Systems Engineering practice, this Functional Requirements document builds upon and refines the high-level system description presented in the ITS Concept of Operations for the New Britain-Hartford Busway, submitted in March 2010 and revised in October 2011. Whereas the ITS Concept of Operations identified “what the system will do”, these Functional Requirements identify “what the system will do”, “how well”, and “under what conditions”. These Functional Requirements will help guide the development of detailed system design. This document will also be used following system implementation to verify that the system requirements have been met. This document is consistent with the standard Systems Engineering approach for ITS projects as required by FHWA rule and FTA policy.

This document is structured as follows:

- **Chapter 2: Overall System Architecture**
- **Chapter 3: Mobile Data Computer Requirements**
- **Chapter 4: Automatic Passenger Counter (APC) System Requirements**
- **Chapter 5: Mobile Communications Gateway and Router Requirements**
- **Chapter 6: Busway Operations Center Equipment Requirements**
- **Chapter 7: CAD/AVL Central Software Requirements**
- **Chapter 8: Cellular Data Communications Gateway Requirements**
- **Chapter 9: Bulk Data Gateway Requirements**

- **Chapter 10: APC Management Software Requirements**
- **Chapter 11: Traveler Information Software Requirements**
- **Chapter 12: Traveler Information System Controller Requirements**
- **Chapter 13: Variable Message Sign Requirements**
- **Chapter 14: Public Announcement System Requirements**
- **Chapter 15: Fare Management Central Software Requirements**
- **Chapter 16: Ticket Vending Machine Requirements**
- **Chapter 17: Ticket Validator Requirements**
- **Chapter 18: Mobile Enforcement Device Requirements**
- **Chapter 19: CCTV Camera Field Equipment Requirements**
- **Chapter 20: DVR System Requirements**
- **Chapter 21: CCTV Camera Management Software Requirements**
- **Chapter 22: Emergency Call Box Management Software Requirements**
- **Chapter 23: Emergency Call Box Requirements**
- **Chapter 24: Network Management System Requirements**
- **Chapter 25: Busway Communications System Requirements**
- **Chapter 26: Summary and Next Steps**

## 1.3 Acronyms and Abbreviations

| | | | |
|---|---|---|---|
| ACP | Audio Command Point | ITS | Intelligent Transportation System |
| ADA | Americans with Disabilities Act | JSON | JavaScript Object Notation |
| AFC | Automatic Fare Collection | LCD | Liquid Crystal Display |
| ALC | Automatic Level Control | LED | Light-Emitting Diode |
| ALS | Assistive Listening System | MCGR | Mobile Communications Gateway and Router |
| APC | Automatic Passenger Counters | MDC | Mobile Data Computer |
| AVAS | Automatic Voice Annunciation System | MDT | Mobile Data Terminal |
| AVL | Automatic Vehicle Location | MED | Mobile Enforcement Device |
| BOC | Busway Operations Center | NTCIP | National Transportation Communications for ITS Protocol |
| BRT | Bus Rapid Transit | NTD | National Transit Database |
| CAD | Computer Aided Dispatch | OEM | Original Equipment Manufacturer |
| CCD | Charge-Coupled Device | OFTPP | Optical Fiber Termination Patch Panel |
| CCSU | Central Connecticut State University | OVM | On-board Video Monitoring |
| CCTV | Closed Circuit Television | PA | Public Address |
| CLS | Camera Lowering System | PTZ | Pan- Tilt- Zoom |
| CTDOT | Connecticut Department of Transportation | SPL | Sound Pressure Level |
| DPS | Department of Public Safety | SSID | Service Set Identifier |
| DSS | Digital Slow Shutter | STI | Speech Transmission Index |
| DVR | Digital Video Recorder | TCP | Transmission Control Protocol |
| ECB | Emergency Call Box | TIS | Traveler Information System |
| EIS | Electronic Image Stabilization | TVM | Ticket Vending Machine |
| FHWA | Federal Highway Administration | UPS | Uninterruptable Power Supply |
| FTA | Federal Transit Administration | USB | Universal Serial Bus |
| Gbps | Gigabit per second | VLU | Vehicle Logic Unit |
| GIS | Geographic Information Systems | VMS | Variable Message Sign |
| GPS | Global Positioning System | WAAS | Wide Area Augmentation System |
| GUI | Graphical User Interface | WDR | Wide Dynamic Range |
| HVAC | Heating, Ventilation, and Air Conditioning | WLAN | Wireless Local Area Network |
| IP | Internet Protocol | XML | Extensible Markup Language |

# 2. OVERALL SYSTEM ARCHITECTURE

## 2.1 Busway Overview

The New Britain-Hartford Busway is a 9.4 mile long bus-only roadway running from East Main Street in downtown New Britain to Asylum Street in downtown Hartford. Most of the roadway is two lanes wide, with three or four lane sections at stations to enable buses to pass each other. The busway is built along the former New Britain Secondary railroad between New Britain and Newington Junction and beside the active Amtrak Springfield to New Haven Line from Newington Junction to Union Station in Hartford.

The busway will include 11 stations. New Britain Station at the southwestern end of the busway will have a larger multiple berth transit center due to its location at the hub of New Britain local services. Union Station at the northeastern end of the busway in Hartford will include two shelters on street. The nine through-stations will have two side platforms of approximately 10 feet by 100 feet. Northbound platforms at stations along the Amtrak rail line will only be accessible by crosswalks from the southbound platform to avoid the construction of pedestrian crossings on the rail tracks. Small park-and-ride lots will be included at East Street, Cedar Street, Newington Junction, Elmwood, Flatbush Avenue, and Parkville.

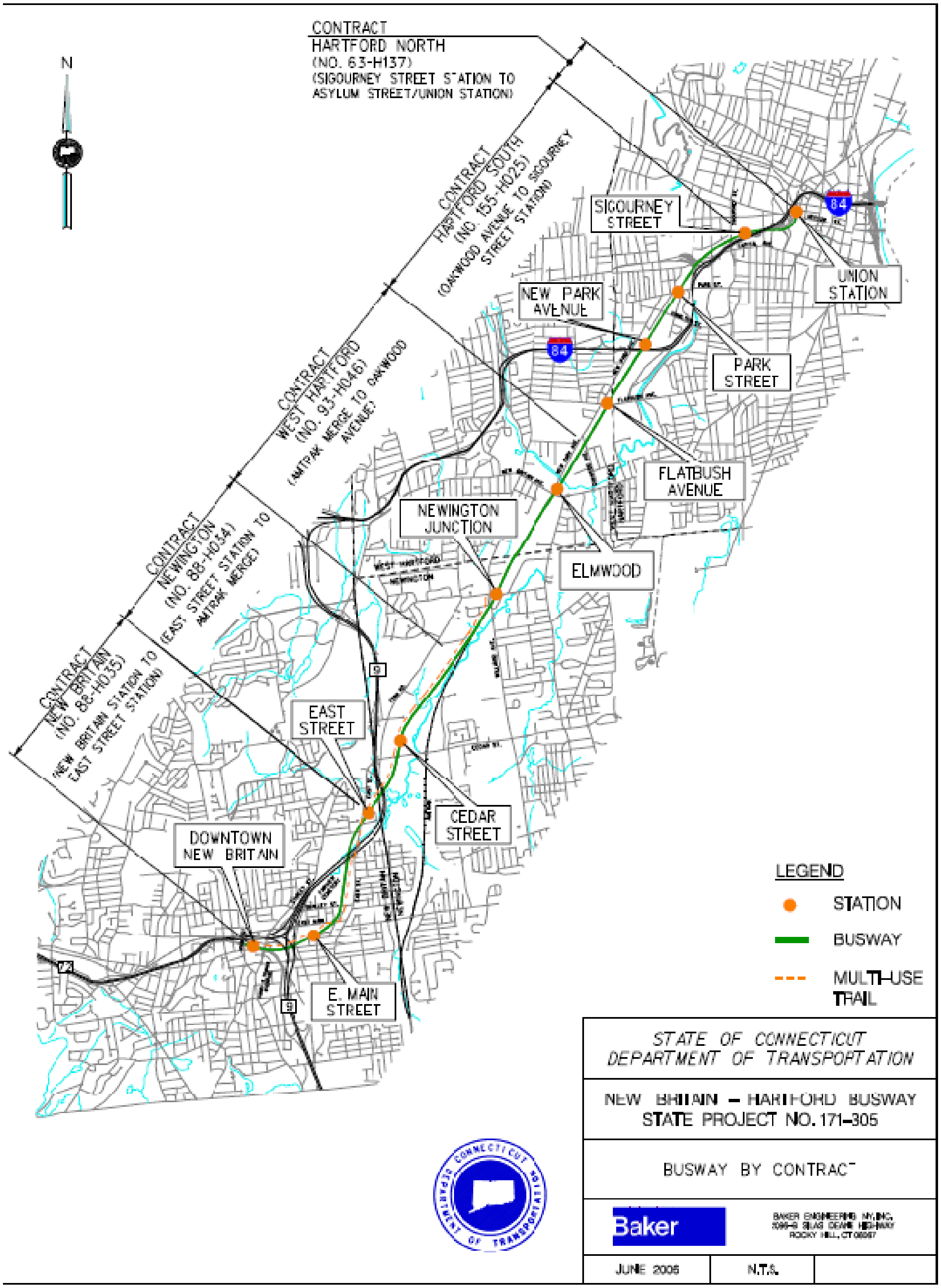
Buses will enter the busway at New Britain Station, East Street Station, Cedar Street Station, at the Oakwood Avenue grade crossing, and at Sigourney Street Station. There is also additional flexibility in the busway physical design to enable buses to enter at Stanley Street, East Main Street, Smalley Street and Newington Junction. Bus service on the busway will be operated by multiple organizations including CTTRANSIT Hartford, CTTRANSIT New Britain through New Britain Transportation, DATTCO, Central Connecticut State University (CCSU), and possibly other contract operators for new transit services in the future. All transit vehicles that will eventually operate a portion of their trip on the busway will be dispatched by operations staff located in the Busway Operations Center (BOC). ‘Home’ operating agencies (CTTRANSIT New Britain through New Britain Transportation, DATTCO, CCSU, etc.) will be responsible for operating and maintaining the equipment installed on the busway transit vehicles. The BOC is planned to be located at the CTTRANSIT facility in Hartford.

Although most of the busway will be grade-separated, grade crossings will be located at Stanley Street (New Britain), East Main Street (New Britain), Smalley Street (New Britain), Oakwood Avenue (West Hartford) and Hamilton Street (Hartford). These crossings will be protected by signalized intersections interconnected with the adjacent rail grade crossing.

The busway will also have a single lane section for approximately 1,300 feet starting at Sigourney Street Station and running to Flower Street. This section is required due to space limitations under the I-84 Viaduct at this location.

A map of the overall busway is provided in Figure 1.

**Figure 1: Overall Busway Map**



## 2.2 ITS Subsystems

The following set of ITS subsystems intended for initial deployment along the busway builds upon an initial list presented in the ITS Concept of Operations for the New Britain-Hartford Busway, submitted in March 2010 and updated in October 2011.

- **Central Systems:** It is proposed that the initial ITS deployment include Central Systems, consisting of workstations, servers, communications hardware, video display, DVR and data storage located at the BOC. These Central Systems will include a Computer-Aided Dispatch/Automatic Vehicle Location (CAD/AVL) Central Software, APC (Automatic Passenger Counters) Management Software, Traveler Information Software, Fare Management Central Software, CCTV Camera Management Software, Emergency Call Box Central Software, and Network Management Central Software. Central Systems will be integrated with CTTRANSIT's scheduling software, which is being upgraded as part of a separate effort. It is understood that all transit operators operating on the busway will utilize the same scheduling software, which is being upgraded as part of a separate effort.

- **Transit Management:** It is proposed that the initial ITS deployment include a CAD/AVL System. The CAD/AVL System shall include all systems and devices (hardware and software) to support the dispatch, management, and monitoring of all busway vehicles operating on busway routes, including the CAD/AVL Central Software (part of the Central Systems), and Mobile Data Computers (MDCs) and other on-board equipment installed on transit vehicles. It is understood that all transit operators operating on the busway will utilize the same scheduling software, which is being upgraded as part of a separate effort.

- **Automatic Fare Collection (AFC):** It is proposed that the initial ITS deployment include TVMs (Ticket Vending Machines) located at every station along the busway. In order to serve passenger demand and provide redundancy it is recommended that at least two TVMs be installed at each station. Ticket Validators are proposed for installation at each station, with at least one validator per platform. A small quantity of Mobile Enforcement Devices (MEDs) to support ticket enforcement personnel in the field is also proposed. It is assumed that upgraded fareboxes for the busway transit vehicles will be handled by others. The fare collection system will be managed through the Fare Management Central Software (part of the Central Systems), which will monitor status data and manage relevant information. Credit and debit card processing will be handled by other systems, to be determined by CTDOT as part of a separate effort.

- **Traveler Information Systems:** It is proposed that the initial ITS deployment include VMSs (Variable Message Signs) and PA (Public Address) systems installed on each station platform. These VMS and PA systems would be capable of being coordinated and controlled automatically from a central location or controlled locally during an emergency or if communications to the central location is temporarily lost. The central traveler information system software would be interfaced with the central CAD/AVL software to provide real-time bus arrival prediction information.

- **On-board Technology:** It is proposed that Mobile Data Computers (MDCs), with built-in Mobile Data Terminals (MDTs), Vehicle Logic Units (VLUs) and GPS receivers, be installed on all busway transit vehicles, as well as on a limited number of supervisor vehicles. It is also proposed that all busway transit vehicles be equipped with Automatic Passenger Counters (APC) sensors. The APC software will be integrated with the CAD/AVL Central Software (both part of the Central Systems). Additionally, to facilitate communications to transit vehicles, a Mobile Communications Gateway and Router (MGCR) is also proposed for installation on all busway transit vehicles. Other on-board technologies, such as on-board PA, VMS, Automatic Voice Annunciation Systems (AVAS), On-board Video Monitoring (OVM), and on-board silent alarms are considered important future technologies that will not be provided in this project. Since these technologies are typically provided by the Original Equipment Manufacturer (OEM), it is assumed that these additional on-board technologies will be implemented as part of the vehicle procurement and/or future retrofitting processes and are included as part of this project. In addition, CTTRANSIT is in the process of procuring a system-wide CAD/AVL system as a separate effort. If this procurement is successful, CAD/AVL systems and software do not need to be included in the technical specifications for this project. It is assumed that CTTRANSIT will ensure that the procurement results in the full functionality necessary for the busway ITS.

- **Busway Safety and Security Systems:** It is proposed that the initial ITS deployment include CCTV cameras to monitor the platforms, TVM transactions, and provide some coverage of station plazas and pedestrian pathways. CCTV cameras are also proposed at strategic locations along the busway in between stations. These camera feeds will be sent back to a central location for viewing and recording. The video management and recording software will be included as part of the Central Systems. Emergency call boxes are also proposed for each station platform.

- **Busway Communications System:** It is proposed that a fiber optic cable-based communications infrastructure be included to support both the initial ITS deployment and future ITS deployments along the busway. Fleet and vehicle voice communications will be handled by the upgraded radio communications system that is currently under development as part of a separate effort.

  The fiber optic communications system along the busway will provide a secure, high speed and reliable platform for transmission of voice, data and video to support monitoring and management of the bus operations and security functions at stations. It is proposed that a dedicated fiber optic backbone be installed along the length of the busway connecting to stations, intersections and busway cameras. The fiber optic backbone will also extend from the northern terminus of the busway to the central BOC, currently proposed at the CTTRANSIT facility in Hartford.

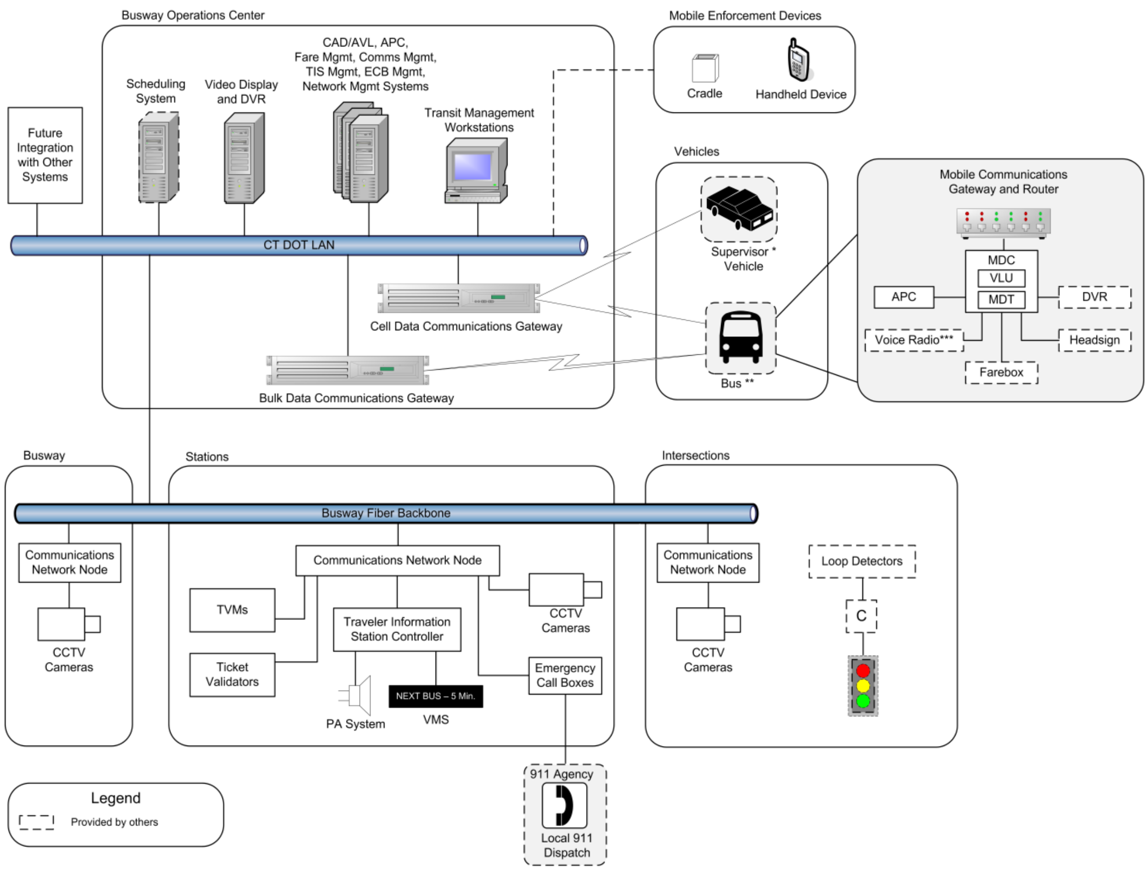
  Communications hubs are proposed at each of the stations, with two hubs located at the East Main station (due to the physical separation of its platforms). The fiber optic backbone will interconnect each of the communications hubs. Distribution fiber will be utilized to connect the communications hubs to the ITS field equipment at each station. It is proposed that the communications network architecture utilize Ethernet (IP) technology for backbone and distribution to provide a flexible, expandable and reliable network for both initial and future ITS requirements. Station and platform ITS components, security/surveillance cameras, and other equipment shall connect to the network using standard Ethernet/IP interfaces.

  It is also proposed that a bulk data communications system and a cell data communications system be included to facilitate communications between the central system and vehicles. The cell data communications system will support the exchange of information in real-time. The bulk data communications system will support the exchange of information such as schedules and firmware updates.

## 2.3 ITS System Architecture

The diagram below (Figure 2) illustrates the proposed ITS System Architecture for the New Britain-Hartford Busway. Dashed items indicate proposed ITS components to be provided by others.

**Figure 2: Proposed ITS System Architecture**



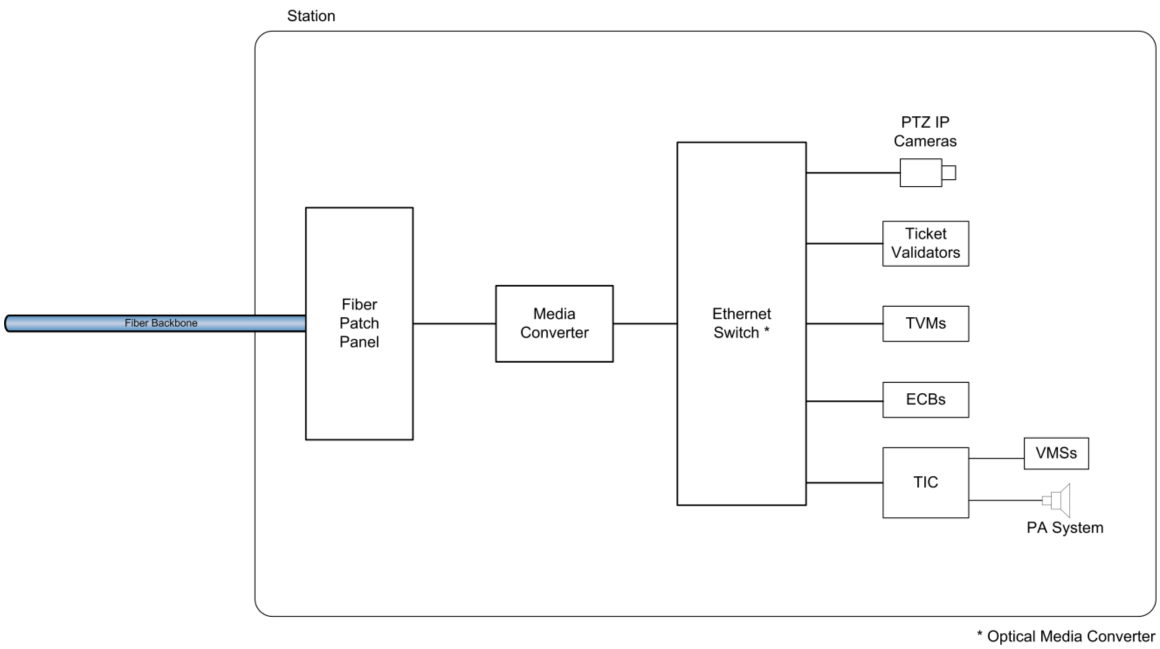

* Supervisor vehicles on-board technologies include: laptop, GPS receiver, and mobile radio system (voice/data) (radio provided by others).

** Bus on-board technologies include: MDT, VLU, APC, and mobile communications gateway and router. Additional on-board technology, to be provided by others and integrated with the VLU, may include on-board silent alarms, on-board speakers, passenger information displays, AVAS, fareboxes, on-board cameras, DVR, and headsigns.

***Provided as part of a separate CTDOT project in coordination with DPS.

The diagram below (Figure 3) illustrates typical station communications for a fiber Ethernet network.

**Figure 3: Typical Station Communications – Fiber Ethernet Network**




The following sections describe specific functional requirements for the ITS equipment identified as part of the initial ITS deployment for the busway. These functional requirements will form the basis for future equipment specifications.

# 3. MOBILE DATA COMPUTER (MDC) REQUIREMENTS

| **3.** | **Mobile Data Computer (MDC) Requirements** |
|---|---|
| **3.1.** | **General** |
| 3.1.1. | The Mobile Data Terminal (MDT) shall be connected to or integrated with the Vehicle Logic Unit (VLU) and the combination will be subsequently referred to as the Mobile Data Computer (MDC). |
| 3.1.2. | MDCs shall turn on automatically when the vehicle power is turned on, and shall shut down at an agency configurable time after the vehicle power is turned off. |
| 3.1.3. | MDCs shall be configured to allow for deferred shutdown, allowing all active sessions and connections to be closed before shutting down. |
| **3.2.** | **Interfaces** |
| 3.2.1. | The MDC shall be interfaced with the P25-compatible subscriber radio unit to automatically switch the voice radio to the 'Busway' talk group when vehicle operators logon to the 'Busway' route and for the radio to accept a notification that the overt or covert alarm (on the subscriber radio unit) have been activated. |
| 3.2.2. | The MDC shall be interfaced with the farebox to enable log on to the farebox via the MDT. The farebox will be provided by others. While on the busway, the farebox will be covered and not in operation. |
| 3.2.3. | The MDC shall be interfaced with the headsign to control the destination text to be displayed on the headsign, and to implement message programming and firmware updates on the headsign. |
| 3.2.4. | The MDC shall be interfaced with the Digital Video Recorder (DVR) for Security Cameras to provide to the DVR the run ID, operator ID, vehicle ID, and vehicle location. The Security Cameras and DVR will be provided by others. |
| 3.2.5. | The MDC shall be interfaced with the Automatic Passenger Counter (APC) system to provide run, block, route, and trip data to the APC system, to receive APC data for transfer to the central software, and to implement firmware updates on the APC system. |
| 3.2.6. | The MDC shall be interfaced with the on-board Mobile Communications Gateway and Router (MCGR) to exchange real-time information such as location updates and text messages, and bulk-data such as run/block schedule data with the CAD/AVL central software, and to implement firmware updates on the MCGR. |
| **3.3.** | **Mobile Data Terminal (MDT)** |
| 3.3.1. | The MDT shall be capable of displaying information to vehicle operators, providing audible feedback, and accepting user input. |
| 3.3.2. | The MDT shall incorporate a touch screen with a color backlit display, readable by the vehicle operator from the seated position under the full range of ambient illumination conditions. |
| 3.3.3. | The MDT shall incorporate a speaker and allow the user to adjust the volume any time while the MDT is on. |
| 3.3.4. | The MDT shall be operated using touch screen programmable buttons with visual and audible feedback. The MDT speaker shall provide audible feedback when a touch screen button is pressed. |

| | |
|---|---|
| 3.3.5. | The vehicle operator shall not be able to manually shut off or disconnect the MDT power. |
| **3.4.** | **Vehicle Logic Unit (VLU)** |
| 3.4.1. | The VLU shall serve as the controlling computing device for the overall MDC. |
| 3.4.2. | The VLU shall be capable of storing data including schedule data, and perform schedule adherence comparisons based on vehicle location and schedule data for the run selected at login. |
| 3.4.3. | The VLU shall be capable of being locally configured, diagnosed and maintained using a portable programming device (e.g., via an RS-232 console port or the operator terminal). |
| 3.4.4. | The VLU shall be able to implement firmware updates for itself and connected devices, including:<br>- Headsigns<br>- Automatic Passenger Counter<br>- Mobile Communications Gateway and Router |
| **3.5.** | **Integrated Global Positioning System (GPS) Receiver and Antenna** |
| 3.5.1. | The MDC shall incorporate an integrated GPS receiver. |
| 3.5.2. | GPS receivers shall report latitude, longitude, speed, time, direction of travel (heading) and whether the receiver has a GPS position lock. |
| 3.5.3. | The GPS receivers shall be parallel tracking receivers, capable of simultaneously tracking at least four GPS satellites in the best available geometry, while also tracking at least the four next best and/or upcoming (rising) satellites. |
| 3.5.4. | On-board GPS receivers shall be Wide Area Augmentation System (WAAS)-capable. |
| **3.6.** | **Logon and Logoff** |
| 3.6.1. | The MDC shall allow the vehicle operator to logon by entering their operator ID and run ID on the MDT. |
| 3.6.2. | The MDC shall check with the central software to confirm that the operator ID and run ID are valid and that another vehicle has not already logged on using either of these IDs. |
| 3.6.3. | Once the operator ID and run ID have been validated, the MDC shall complete the logon by selecting the trip/block schedule data stored in the MDC that corresponds with that run. |
| 3.6.4. | After logon, the MDT shall display the current block, run, route, trip, next timepoint, and operator ID. |
| 3.6.5. | Once the MDC logon has been completed, the MDC shall use the logon data to:<br>- switch the voice radio to the ‘Busway’ talk group when vehicle operators log onto the ‘Busway’ route,<br>- log onto the farebox (even if currently logged on to ensure consistency),<br>- begin the process of automatically sending display commands to the headsign based on vehicle location. |
| 3.6.6. | Upon successful logon, the MDC shall display an agency configurable pre-trip inspection screen that shall be filled in by the vehicle operator after conducting their pre-trip inspection of the vehicle. |

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| 3.6.7. | The MDC shall allow the vehicle operator to logoff by selecting the logoff key. |
| 3.6.8. | The MDC shall send a message to the dispatcher as a confirmation of the vehicle operator logoff. |
| 3.6.9. | Before completing the logoff, the MDC shall display an agency configurable post-trip inspection screen which shall be filled in by the vehicle operator after conducting a post-trip inspection of the vehicle. |
| 3.6.10. | Both pre-trip and post-trip inspection reports shall be sent to the central software and saved for use by dispatch and maintenance personnel. |
| 3.6.11. | The MDC shall periodically attempt to send a logon or logoff message until it receives an acknowledgement message from the central software. If no response is received from the central software within an agency configurable time, then the MDC shall provide the operator with a message that no logon response or no logoff response has been received. |
| **3.7.** | **Location Reporting** |
| 3.7.1. | The MDC shall store the most recent location received from the GPS receiver. |
| 3.7.2. | The MDC shall send the most recent location report to the central software once an agency configurable number of minutes have passed since the previous location report. |
| 3.7.3. | All location reports shall include: date and time stamp, “GPS lock” status, GPS location latitude and longitude, heading, vehicle number, operator ID, run ID, trip ID, block ID, and schedule adherence. |
| 3.7.4. | All data transmissions from the MDC to the central software shall include a location report. |
| **3.8.** | **Schedule Adherence** |
| 3.8.1. | When a vehicle operator is logged in to a run, the MDC shall continuously calculate the current schedule adherence defined as the difference between the estimated on-schedule time for the current location (not just the schedule adherence as of the previous timepoint) and the current time to the nearest second. The estimated on-schedule time between timepoints shall be based on the typical link operating speeds. |
| 3.8.2. | The MDC shall continuously display the current schedule adherence, updated every second on the MDT. |
| 3.8.3. | The MDC shall send the most recent schedule adherence information as part of each location report. |
| **3.9.** | **Route Adherence** |
| 3.9.1. | The MDC shall compute and determine whether the vehicle is running off-route based on agency configurable thresholds. |
| 3.9.2. | The MDC shall send a message to the central software when a vehicle has been determined to have gone off-route or have come back on-route. |
| 3.9.3. | The MDC shall periodically attempt to send an off-route message until it receives an acknowledgement message from dispatch. |
| 3.9.4. | The MDC shall display on the MDT whether the vehicle is on-route or off-route. |

| **3.10.** | **Text Messaging** |
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| 3.10.1. | The MDC shall allow the vehicle operator to send a text message to the central software by selecting from a set of agency configurable predefined messages. The MDC shall allow the vehicle operator to ask for an acknowledgement of receipt or Yes/No response to certain text messages. |
| 3.10.2. | All text messages to the central software shall include a location report. |
| 3.10.3. | The MDC shall signal with a distinct audible alert tone when a text message is received from the central software and available for viewing on the MDT. |
| 3.10.4. | The MDC shall store an agency configurable number of text messages received from the central software, indicate to vehicle operators when there are unread text messages, allow stored text messages to be viewed, and allow read messages to be deleted. The MDC shall allow the vehicle operator to view received text messages that are longer than that can fit on one line of the display. |
| 3.10.5. | The MDC shall also allow the vehicle operator to send an acknowledgement of receipt or Yes/No response to certain text messages received from the central software. |
| 3.10.6. | The MDC shall periodically attempt to send a text message or response until it receives an acknowledgement message from the central software. |
| **3.11.** | **Overt Alarm** |
| 3.11.1. | When the MDC receives a notification that the overt alarm has been activated, the MDC shall send the overt alarm message to the central software and place the MDC into the overt alarm mode. |
| 3.11.2. | When in overt alarm mode, the MDC shall send the most recent location report to the central software automatically whenever an agency configurable number of minutes have passed since the previous location report. |
| 3.11.3. | The MDC shall terminate the overt alarm mode only when it receives a message from the central software that the overt alarm has been cancelled. |
| **3.12.** | **Covert Alarm** |
| 3.12.1. | When the MDC receives a notification that the covert alarm has been activated, the MDC shall send the covert alarm message to the central software and place the MDC into the covert alarm mode. |
| 3.12.2. | When in covert alarm mode, the MDC shall send the most recent location report to the central software automatically whenever an agency configurable number of minutes have passed since the previous location report. |
| 3.12.3. | The MDC shall terminate the covert alarm mode only when it receives a message from the central software that the covert alarm has been cancelled. |
| 3.12.4. | When in covert alarm mode, there shall be no indication on the MDT other than subtle symbols or icons approved by the agency, signifying that the covert alarm mode has been activated. |
| **3.13.** | **Schedule Data** |
| 3.13.1. | The MDC shall periodically download bulk data files containing run/block data from the central software. The frequency of download shall be agency configurable. |

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| 3.13.2. | Run/block data shall be stored on the MDC, with sufficient on-board memory capacity to allow for storage of agency configurable quantities of data. |
| 3.13.3. | When an operator logs on with a run ID, the MDC shall be able to access and pull up the relevant schedule data for that run ID on the MDT. |
| **3.14.** | **P25-compatible Radio Subscriber Unit Integration** |
| 3.14.1. | The MDC shall automatically switch the voice radio on the P25-compatible Radio Subscriber Unit to the ‘Busway’ talk group when vehicle operators logon to the ‘Busway’ route. |
| 3.14.2. | The MDC shall accept a notification from the P25-compatible Radio Subscriber Unit when the overt or covert alarms (on the subscriber radio unit) have been activated. |
| **3.15.** | **Headsign Integration** |
| 3.15.1. | When the vehicle is logged into a run using the MDC and operating a trip of the run, the MDC shall automatically command the headsign to display an agency configurable message for that trip. This message could be the route number and/or route name. |
| 3.15.2. | When the vehicle is logged into a run using the MDC but operating on deadhead from the garage to the first trip of the run, the MDC shall automatically command the headsign to display an agency configurable message. This message could be “OUT OF SERVICE”, “FROM GARAGE” or the message that will be displayed during the first trip. |
| 3.15.3. | When the vehicle is logged into a run using the MDC but operating on deadhead to the garage from the final trip of the run, the MDC shall automatically command the headsign to display an agency configurable message. This message could be “OUT OF SERVICE”, “TO GARAGE” or the message that will be displayed during the final trip. |
| 3.15.4. | When the vehicle is logged into a run using the MDC but operating on deadhead for interlining between trips in the course of a run, the MDC shall automatically command the headsign to display an agency configurable message. This message could be “OUT OF SERVICE” or the message displayed during either the previous or upcoming trip. |
| 3.15.5. | When the vehicle is logged into a “special” run using the MDC, the MDC shall automatically command the headsign to display an agency configurable message for that run. This message could be “OUT OF SERVICE”, or “IN TRAINING”. |
| 3.15.6. | When the vehicle is logged into a run using the MDC, the operator shall be able to manually command the headsign to display from a set of agency configurable pre-defined messages. This message could be “OUT OF SERVICE”, or “IN TRAINING”. |
| 3.15.7. | The operator shall continue to be able to use all features of the existing headsign controller, regardless of whether or not the operator has logged into a run using the MDC or whether the MDC is operational. |
| **3.16.** | **Digital Video Recorder (DVR) for Security Camera Integration** |
| 3.16.1. | When the vehicle is logged into a run using the MDC, the MDC shall provide the run ID, operator ID, vehicle ID, route ID, trip ID and vehicle location to the DVR. |

| **3.17.** | **Automatic Passenger Counter (APC) System Integration** |
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| 3.17.1. | The MDC shall receive data records containing raw passenger counts from the APC controller when door closings are detected and immediately append stop data, location data and run/block/route/trip information to the data record. |
| 3.17.2. | The MDC shall associate each data record with the correct nearest stop, based on an algorithm that uses the recorded GPS latitude and longitude, the route, and the stops assigned to preceding and following data records. |
| 3.17.3. | The MDC shall not add a stop ID to the data record if the GPS latitude and longitude recorded for the stop are not within an agency configurable distance from a stop on the current route/trip. |
| 3.17.4. | Each data record shall also include the current GPS location latitude and longitude, as well as the current date/time, vehicle number, vehicle operator ID number, block ID, run ID, route ID, and trip ID. |
| 3.17.5. | APC data records shall be stored in the MDC, with sufficient on-board memory capacity to allow for storage for a minimum of 10 days of APC data. |
| 3.17.6. | The number of days that APC data will be stored shall be agency configurable. |
| 3.17.7. | On-board memory shall use non-volatile storage so that a power supply is not required to retain the stored APC data records. |
| 3.17.8. | The MDC shall be able to prepare an APC data package to periodically send to the central software via the MCGR. |
| 3.17.9. | The MDC shall be able to request an acknowledgment receipt from the central software when the APC data package is received. The MDC shall automatically delete the data package from its memory for which acknowledgement has been received from the central software. |
| 3.17.10. | The MDC shall allow a user to manually access and download data directly (as a redundant back-up option), using a laptop connected to a USB port. |
| **3.18.** | **Mobile Communications Gateway and Router Integration** |
| 3.18.1. | The MDC shall receive bulk data such as schedule run/block data, and real-time information such as text messages and operator login verification information from the CAD/AVL central software via the MCGR. |
| 3.18.2. | The MDC shall send via the MCGR both bulk data such as APC data records, and real-time information such as text messages, alarms, and location reports to the CAD/AVL central software. |
| 3.18.3. | The MDC shall automatically initiate data transfer when the vehicle is in range of a cellular network or WLAN, requiring no operator interaction. |
| 3.18.4. | When a WLAN connection is available, the MDC shall download configuration data and software updates, and upload diagnostics and on-board system performance data. |
| 3.18.5. | The MDC shall be able to keep account of incomplete transfers of data files between the vehicle and the central software and initiate a continuation or restart of the transfer via the MCGR whenever possible. |
| 3.18.6. | The MDC shall provide a versioning mechanism for files to be immediately downloaded to the vehicle, but delay implementation of the file until some later date. |

# 4. AUTOMATIC PASSENGER COUNTER (APC) SYSTEM REQUIREMENTS

| **4.** | **Automatic Passenger Counter (APC) System Requirements** |
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| **4.1.** | **General** |
| 4.1.1. | The APC System shall consist of APC sensors to count passenger boardings and alightings and an APC Controller to process information received from the APC sensors and prepare them to send to the APC data management software at the BOC. |
| **4.2.** | **Interfaces** |
| 4.2.1. | The APC system shall be interfaced with the MDC to send APC data for transfer to the central software and to accept firmware updates from the MDC. |
| **4.3.** | **APC Sensors** |
| 4.3.1. | All doorways on the vehicle shall be equipped with APC doorway sensors. |
| 4.3.2. | The doorway sensors shall be able to detect door openings, count and differentiate between boarding and alighting passengers. |
| 4.3.3. | The doorway sensors for all doorways shall be connected to a single APC controller. |
| 4.3.4. | The doorway sensors shall be able to separately count successive passengers that are walking as close together as is practicable, either one behind the other or side by side. |
| 4.3.5. | The doorway sensors shall be able to count moving passengers with heights between one meter in height and the maximum height of the doorway. |
| 4.3.6. | The doorway sensors shall be able to separately count a small child being carried by another passenger. |
| 4.3.7. | The doorway sensors shall not register as multiple passengers the passage of a single passenger that reaches into or out of the doorway passage, or is swinging their arms, while passing through the sensors. |
| 4.3.8. | The doorway sensors shall not separately count objects carried by passengers, such as shopping bags or umbrellas. |
| 4.3.9. | Boarding and alighting counts shall only be recorded when the doorway is open. This will avoid any counting of passengers moving in the vicinity of the doorway passages between stops. |
| 4.3.10. | Boarding and alighting counts shall only be recorded when the vehicle MDC is logged in. If there is a breakdown and passengers need to transfer to a replacement vehicle, this will allow the passenger transfer to be done with both vehicles logged out so that the transferring passengers are not double-counted. |
| **4.4.** | **APC Controller** |
| 4.4.1. | The APC controller shall be able to receive, process, and record the information received from the sensors |
| 4.4.2. | For each stop, i.e. for the time between a detected door opening and door closing, a data record shall be created to store the number of accumulated boarding and alighting passengers for each doorway. |

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| 4.4.3. | As soon as a door closing is detected by the APC sensors, the MDC shall request a data record from the APC controller and append stop data, location data, and run/block/route/trip information to the data record. |
| 4.4.4. | The APC Controller shall automatically record and log errors. |
| 4.4.5. | Utility software shall be provided, for use on a laptop computer connected via a serial communications connection to either the APC controller or the MDC, which supports calibration of the doorway sensors and review of stored data records. |
| **4.5.** | **MDC Integration** |
| 4.5.1. | The APC controller shall send APC records to the MDC for storage and transmission to the central software. |

# 5. MOBILE COMMUNICATIONS GATEWAY AND ROUTER REQUIREMENTS

| **5.** | **Mobile Communications Gateway and Router (MCGR)** |
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| **5.1.** | **General** |
| 5.1.1. | The contractor shall provide an on-board Mobile Communications Gateway and Router (MCGR) with both wireless and wired Ethernet functionality. |
| 5.1.2. | The MCGR shall support the following wireless services for external data communications between the vehicle and the central system:<br>1) Cellular data communications from common carriers including AT&T, Verizon, Sprint through a compatible cellular modem or card;<br>2) “WiFi” supporting 802.11 b, g, and n standards through an internal card. |
| 5.1.3. | The wireless modem or communications device shall be easily replaceable to accommodate changes in technology and wireless standards. A PCMCIA device or other types of acceptable standard slot devices may be used. |
| 5.1.4. | The MCGR shall have two (2) additional PCMCIA or other acceptable standard card slots for expandability. |
| 5.1.5. | The MCGR shall have at least four (4) Ethernet ports for communications with on-board equipment, expandable to eight (8) Ethernet ports either on the MCGR or a connected switch. |
| 5.1.6. | The MCGR shall include a minimum of two (2) USB 2.0 connections for communications with on-board equipment. |
| **5.2.** | **Interfaces** |
| 5.2.1. | The MCGR shall interface with the MDC via an on-board Ethernet connection to facilitate transmission of data to and from the MDC. |
| 5.2.2. | The MCGR shall interface with the cellular data communications gateway in the BOC over a cellular network to enable exchange of data to and from the central software. |
| 5.2.3. | The MCGR shall interface with the bulk data gateway in the BOC over a WLAN network to enable exchange of data to and from the central software. It is anticipated that the WLAN network may not be available at the start of service. For the period that the WLAN network is not available, the cellular network shall be used for exchange of bulk data. |
| **5.3.** | **Network Connectivity and Communications** |
| 5.3.1. | The MCGR shall be configurable to control which on-board systems can perform outbound communication, based upon the speed of outbound connections (i.e. which systems can communicate when low-speed communications are available, and which can communicate when higher speed communications are available). |
| 5.3.2. | The MCGR shall have the ability to configure rate limits on traffic coming to on-board systems (ingress interfaces). |
| 5.3.3. | The MCGR shall have the ability to configure rate limits on the outbound connection, in order to efficiently utilize a shared wireless environment (egress interfaces). |
| 5.3.4. | The MCGR shall automatically switch wide area traffic between available wireless |

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| | networks according to administrator-defined switching policies. Routing policies shall be based upon, at a minimum, network availability, network priority, time of day, vehicle location, and bandwidth capacity. |
| 5.3.5. | To assure that only appropriate application traffic is routed over each wireless infrastructure; the MCGR shall perform port filtering for each available wireless network. |
| 5.3.6. | The MCGR shall be equipped with a minimum of one (1) Gigabyte (GB) of internal storage. |
| 5.3.7. | The MCGR shall allow bulk data processing to be initiated whenever the vehicle is within WLAN coverage of an approved SSID and the time until scheduled departure the current location is more than a configurable period of time beyond current time. |
| 5.3.8. | It shall be possible for a person to manually force a high-priority download from the central software. |
| 5.3.9. | Any download of complete, non-incremental, data to all coaches must be completed within one (1) day. |
| 5.3.10. | The MCGR shall seamlessly continue data transfers, regardless of which wireless network last handled the data transfer. |
| **5.4.** | **MDC Integration** |
| 5.4.1. | The MDC shall upload and download all files to be exchanged with the central software via the MCGR. |
| 5.4.2. | The MDC shall initiate the process of receiving and sending data files to the central software via the MCGR. |
| **5.5.** | **Security** |
| 5.5.1. | The MCGR shall provide IPsec Virtual Private Network (VPN) services. |
| 5.5.2. | The MCGR shall provide stateful firewall services. |

# 6. BUSWAY OPERATIONS CENTER EQUIPMENT REQUIREMENTS

| **6.** | **Busway Operations Center (BOC) Equipment Requirements** |
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| **6.1.** | **General** |
| 6.1.1. | The Contractor shall provide all hardware required to operate all central software defined in these functional requirements (including the CAD/AVL central software, the APC management software, traveler information software, camera management software, ECB management software, network management software, equipment fault detection software, and fare management central software) including but not limited to software servers, video management servers, workstations, monitors, and other ancillary equipment. |
| 6.1.2. | The central system hardware shall have an uninterruptible power supply (UPS) to ensure continued system operation and preservation of data during power outages for a minimum of thirty (30) minutes. |
| 6.1.3. | The central system hardware shall be based on commercially available equipment as used in North America (e.g. HP or other reputable supplier), industry-standard operating system(s) such as Windows XP and Unix, and SQL-compliant database(s) such as Oracle. The headquarters computer shall be based on accepted client-server architecture |
| **6.2.** | **Interfaces** |
| 6.2.1. | The BOC equipment shall be connected with the busway communications system via the switch at the BOC communications hub. |
| **6.3.** | **Servers** |
| 6.3.1. | The contractor shall provide a redundant set of servers with automatic failover capabilities. The secondary server shall duplicate the functionality of the primary server and all data shall be continuously mirrored (i.e. both servers kept in “hot-standby” for each other) in such a way that one is instantly available for use when the other fails with both always containing identical information. |
| 6.3.2. | The servers shall be sufficient to support at least 30 concurrent users of the central software, without affecting real-time performance. For this project, “real-time” is defined as information reaching all users in a usable format within one second from when the information was first generated within the system. |
| 6.3.3. | The server databases shall be capable of storing one month worth of data in a real-time database for fast access. A separate archive database shall contain at least 10 years worth of historical data, such that it can be seamlessly utilized through the system reporting tools (e.g. comparative type reports, either within the archive database or between the archive database and the real-time database). A means shall be provided to place data older than the archive database limit into storage, such that it can be accessed for reporting purposes if needed. |
| **6.4.** | **Workstations/Monitors** |
| 6.4.1. | The contractor shall provide new workstation hardware that shall include a processor with the necessary speed, system memory, hard drive storage, graphics interface, and peripherals to execute the central software proposed for this project. The system memory shall be sufficient to support all graphics and hold the database in memory. |
| 6.4.2. | Each new processor shall have a graphics accelerator card capable of high |

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| | resolution graphics, with high speed pan and zoom and multiple simultaneous independent windows on each monitor. Graphics shall be displayed on the monitors within one second of the request. |
| 6.4.3. | For each workstation, dual monitors utilizing flat-screen Liquid Crystal Display (LCD) technology shall be employed, and shall provide a minimum 27 inches (measured diagonally) viewable area. Monitors shall support a minimum 1600x1200 resolution. |
| 6.4.4. | Additional monitors, with a minimum 1600x1200 resolution, shall be employed for viewing video from cameras located at stations and along the busway. |
| **6.5.** | **Reliability** |
| 6.5.1. | The central system (hardware and software) shall be reliable. System availability shall be 99.9% or better, computed as follows: availability shall be determined by comparing the total out-of-service time to the total operating time. Out-of-service time shall include reboots and system maintenance, excluding planned and approved preventative maintenance. The contractor shall employ industry-standard methods and tools to measure and monitor system performance and compliance with these system availability requirements throughout the term of the contract, including all ongoing technical support and maintenance periods. |
| **6.6.** | **Installation/ Placement** |
| 6.6.1. | All central system equipment shall be installed in the designated radio room located within the CTTRANSIT facility located at 100 Leibert Road in Hartford, Connecticut. All hardware and equipment shall meet the space constraints as dictated by available space. |
| 6.6.2. | All central system equipment shall be coordinated to fit into BOC furnishings (desks, chairs, lighting, etc.) to be provided by others. Space shall be reserved to accommodate voice radio communications equipment. |
| 6.6.3. | Existing facility shall be upgraded to provide necessary electrical and HVAC service to support new central system hardware. |
| 6.6.4. | Installation of equipment shall conform to all necessary height and space safety clearances and all relevant ADA requirements. |

# 7. CAD/AVL CENTRAL SOFTWARE REQUIREMENTS

| **7.** | **Computer Aided Dispatch/Automatic Vehicle Location (CAD/AVL) Central Software Requirements** |
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| **7.1.** | **General** |
| 7.1.1. | The CAD/AVL central software (henceforth termed as "central software") along with the Mobile Data Computers (MDCs) in vehicles, and any required hardware, shall form the CAD/AVL System. |
| 7.1.2. | The central software shall support the dispatch, management, and monitoring of all transit vehicles operating on busway routes. |
| 7.1.3. | The central software shall be made available for users in the Busway Operations Center (BOC) such as busway dispatchers or system administrators, users in the fields such as supervisors, and users at a 'home' operating company's control center, via a user-friendly Graphical User Interface (GUI). |
| 7.1.4. | A "desktop client" shall be provided to allow access to the central software to users in the BOC. |
| 7.1.5. | A "thin client" program shall be provided to allow remote access to the central software to users outside of the BOC. |
| 7.1.6. | The central software shall incorporate a core CAD/AVL application to perform the following functions:<br>▪ MDC Logon Verification<br>▪ Location Tracking<br>▪ Route and Schedule Adherence Tracking<br>▪ Location Playback<br>▪ Text Messaging<br>▪ Overt and Covert Alarm Handling<br>▪ Event Reporting<br>▪ Data Logging and Retrieval<br>▪ Reporting |
| **7.2.** | **Interfaces** |
| 7.2.1. | The central software shall be interfaced with the MCGR on busway vehicles via the cellular data communications gateway and the cell data network to exchange information with on-board MDCs. |
| 7.2.2. | The central software shall be interfaced with MCGR on busway vehicles via the bulk data gateway and the WLAN network to exchange information with on-board MDCs. |
| 7.2.3. | The central software shall be interfaced with the scheduling software (Trapeze FX - Version 11) at each "home" operating agency, so as to periodically import fixed route schedule data. |
| 7.2.4. | The central software shall be interfaced with the APC management software to automatically forward APC data records with raw passenger counts received from on-board MDCs to the APC management software. |

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| 7.2.5. | The central software shall be interfaced with the traveler information software to provide schedule updates and automatically forward latest location reports received from busway vehicles. |
| **7.3.** | **Central Software Logon and Logoff** |
| 7.3.1. | The central software shall support a logon, logoff feature that is password protected and shall allow a user to logon to a specific user access level. |
| 7.3.2. | The central software shall allow users to log on to the system with varying privileges depending on their access level. Access levels may include, but are not limited to:<br>▪ BOC System Administrator<br>▪ BOC Dispatcher<br>▪ BOC Read-only dispatcher<br>▪ Busway Supervisor<br>▪ 'Home' Operating Company Dispatchers |
| 7.3.3. | The central software shall allow users logged in as system administrators to assign specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| 7.3.4. | The central software shall support at least 30 concurrent users. |
| **7.4.** | **MDC Logon Verification** |
| 7.4.1. | The central software shall receive and validate a logon request from an MDC, if the operator ID and run ID are valid and not already logged in on another MDC, and otherwise respond that it is an invalid login attempt. |
| 7.4.2. | The central software shall receive and immediately process a logoff message from an MDC. |
| **7.5.** | **Graphical User Interface (GUI)** |
| 7.5.1. | The central software shall incorporate a Graphical User Interface (GUI), to display information to users and accept user input in a clear, logical manner. |
| 7.5.2. | The GUI shall support three types of display formats: graphical map displays, schematic route displays and tabular display. |
| 7.5.3. | The GUI shall support concurrent display of multiple windows, including map display windows or tabular windows. |
| 7.5.4. | At a minimum, the GUI shall support function key assignments, paging, scrolling, and shortcuts. |
| 7.5.5. | The GUI shall support repositioning and resizing each window as desired to present the maximum amount of useable information. |
| **7.6.** | **Map Display** |
| 7.6.1. | The central software shall support a Geographical Information System (GIS) based map display. |
| 7.6.2. | At a minimum, the map shall display the following major features and information along the busway service area and the surrounding New Britain-Hartford region:<br>▪ All garages, offices, and driver relief points in the service area.<br>▪ All street features (freeways, highways, major streets, and minor streets), as well as street names. |

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| | ▪ Railroads and railroad stations.<br>▪ All major water features (rivers, lakes, etc.).<br>▪ Transit centers, bus stops, bus routes, time points, transfer points and paratransit service areas.<br>▪ Region and city boundaries.<br>▪ Major landmarks, including:<br>▫ Hospitals<br>▫ Malls/major shopping centers<br>▫ Maintenance and operations facilities<br>▫ Police and fire stations<br>▫ Schools and universities |
| 7.6.3. | The central software shall display agency configured map overlays such as trip/route patterns on the GIS base map. |
| 7.6.4. | The central software shall support map import and conversion functions to allow for periodic updates of the maps from maintained GIS map sources available to CTDOT. |
| 7.6.5. | The central software shall be capable of displaying all logged-in vehicles as icons on the map display, positioned to accurately indicate real-time vehicle location and direction of travel. The vehicle icons shall be updated with the latest reported vehicle locations. Distinct symbols or colors shall be used in the vehicle icons to indicate vehicle status. At a minimum the vehicle status shall be defined as: out of service; on-time; late; early; on-route; off-route; overt alarm; covert alarm. The central software shall also allow a display of the ‘trail’ of where the vehicle has been when required. Icon display parameters, symbols, colors, and vehicle trail persistence shall be agency configurable. |
| 7.6.6. | The central software shall support the ability to click on a vehicle icon to display vehicle ID, operator ID, schedule adherence information, and time since the last location report was received. The user shall also be able to select a vehicle for subsequent action (such as sending a text message or creating an event) or to open its last location report. |
| 7.6.7. | The central software shall support zooming the map display, as a minimum, to: overall coverage area, individual routes, center on a vehicle, or zoom to a desired magnification factor. The central software shall allow the user to define zoom areas and activate from an agency configurable list. |
| 7.6.8. | The central software shall allow a user to zoom the map display to a route by picking from a list of all active routes. |
| 7.6.9. | The central software shall allow a user to zoom the map display to and center on a vehicle by picking from a list of all logged in vehicles. |
| 7.6.10. | The central software shall be capable of automatically adjusting the level of detail to minimize cluttering the map display, when zoomed. |
| 7.6.11. | The central software shall support activation of agency configurable filters, to control which information is displayed on the map. |
| 7.6.12. | The central software shall allow the user to calculate the distance along a line drawn on the map as a sequence of straight lines between points. |

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| **7.7.** | **Schematic Route Display** |
| 7.7.1. | The central software shall support a schematic representation of individual bus routes, with all logged in vehicles displayed as icons, positioned to indicate real-time vehicle location, and direction of travel. The vehicle icons shall be updated with the latest reported vehicle locations. Distinct symbols or colors shall be used in the vehicle icons to indicate vehicle status. At a minimum the vehicle status shall be defined as: out of service; on-time; late; early; on-route; off-route; overt alarm; covert alarm. The central software shall also allow a display of the 'trail' of where the bus has been when required. Icon display parameters, symbols, colors, and vehicle trail persistence shall be agency configurable. |
| 7.7.2. | The central software shall support the ability to click on a vehicle icon to display vehicle ID, operator ID, schedule adherence information, and time since the last location report was received. The user shall also be able to select a vehicle for subsequent action (such as sending a text message or creating an event) or to open its last location report. |
| **7.8.** | **Tabular Display** |
| 7.8.1. | At a minimum, the central software shall support tabular displays of the following information:<br>▪ Schedule assignments<br>▪ All vehicle pull-outs for the day from every garage. Pull-outs shall be automatically removed from the display once the vehicle has pulled out<br>▪ All vehicle pull-ins for the day from every garage. Pull-ins shall be automatically added to the display once the vehicle has pulled in<br>▪ Latest locations and status for all logged in vehicles<br>▪ Latest locations and status for all logged in vehicles on a particular route<br>▪ Events and Alarms<br>▪ Text messages<br>▪ Automatic passenger counts.<br>▪ Reports |
| 7.8.2. | The central software shall highlight vehicle IDs using distinct symbols, text styles, or colors to indicate vehicle status. At a minimum the vehicle status shall be defined as: out of service; on-time; late; early; on-route; off-route; overt alarm; covert alarm. Display parameters including symbols, text styles, and colors shall be agency configurable. |
| 7.8.3. | The central software shall support sorting of all information in tabular format by any field. |
| 7.8.4. | The central software shall support filtering of all information in tabular format by any field. |
| 7.8.5. | The central software shall support the ability to select a vehicle ID from a table for subsequent action (such as sending a text message or creating and an event) or to open its last location report. |
| **7.9.** | **Location Tracking** |
| 7.9.1. | The central software shall receive a location report from the MDC on each busway vehicle whenever sent by the vehicle MDC. |
| 7.9.2. | The central software shall store and display location reports. |
| **7.10.** | **Route and Schedule Adherence Tracking** |
| 7.10.1. | The central software shall receive reported schedule adherence information from |

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| | the latest reports from MDCs to designate vehicles' schedule adherence status as "early," "late" or "on time", based on agency configurable thresholds. |
| 7.10.2. | The central software shall receive reports from MDCs to designate vehicles' route adherence status as on-route or off-route. |
| 7.10.3. | The central software shall display the schedule adherence and route adherence status of vehicles on map and tabular displays by highlighting vehicle icons or vehicle IDs using distinct symbols, text styles, or colors. Display parameters including symbols, text styles, and colors shall be agency configurable. |
| 7.10.4. | The central software shall notify the user visually and audibly when a vehicle moves off route. Off-route alarms shall be self-extinguishing after an agency configurable time. |
| **7.11.** | **Location Playback** |
| 7.11.1. | The central software shall allow a user to replay and review the chronological sequence of reported locations for a selected vehicle over a selected time period from historical data on the map display or the schematic route display. |
| 7.11.2. | The central software shall allow selection of any time period for the historical data. |
| 7.11.3. | The central software shall provide controls to view the entire sequence of reported locations from the beginning of the selected time period or to step through the sequence incrementally, forwards or backwards. |
| 7.11.4. | The central software shall allow replay for a single vehicle, selected set of vehicles or all vehicles on the selected map display for selected time period. |
| 7.11.5. | The replay data shall include location reports, schedule adherence status and on-route status. |
| 7.11.6. | The central software shall allow the ability to use playback without exiting from the current CAD/AVL operational view. |
| 7.11.7. | The central software shall be able to be store a playback in a standard video format that can be exported for viewing on any computer equipped to view that video format. |
| **7.12.** | **Text Messaging** |
| 7.12.1. | The central software shall accept text messages from MDCs on vehicles, and store them in a database. |
| 7.12.2. | The central software shall allow a user to view received text messages in a tabular display that also indicates the vehicle ID and the time the message was sent. |
| 7.12.3. | The central software shall clearly indicate text messages that have not been viewed, and shall automatically mark them as read once a dispatcher views the text message. |
| 7.12.4. | The central software shall allow a dispatcher to mark a viewed text message as unread. |
| 7.12.5. | The central software shall allow users to archive or delete viewed text messages. |
| 7.12.6. | Unread text messages shall not be allowed to be archived until they are viewed. |
| 7.12.7. | The central software shall allow users to reply to a received message, by sending a text message back to the MDC on the vehicle from which the message was received. |

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| 7.12.8. | The central software shall allow a user to send a text message to a MDC on a single vehicle, a predefined group of vehicles, all vehicles within an area selected on the map display, all vehicles operating on the same route, run or block, or an ad-hoc group of vehicles. |
| 7.12.9. | The central software shall allow a user to create a text message, by selecting one of a set of agency configurable predefined messages or by manually entering text. |
| 7.12.10. | The central software shall allow agency staff logged on with appropriate privileges to add, edit, delete, or reorder the listing of predefined text messages on MDCs. |
| 7.12.11. | The central software shall allow agency staff logged on with appropriate privileges to add, edit, delete, or reorder the listing of predefined text messages on the central software. |
| 7.12.12. | The central software shall allow for any message sent by a user to MDC(s) to be flagged as requiring vehicle operator acknowledgement or a Yes/No response and shall allow a user to view a list of such messages that have not yet been acknowledged or responded to. |
| **7.13.** | **Overt Alarm Handling** |
| 7.13.1. | When an overt alarm message is received from an MDC on a vehicle, the central software shall create an overt alarm event, display it in the event tracking table to all users, and notify them using agency configurable visual and audio alerting methods. Overt alarm alerts shall continue until acknowledged by the user. |
| 7.13.2. | Once a user selects the overt alarm event, the central software shall indicate this to that and all other users. |
| 7.13.3. | The central software shall allow the user to end the overt alarm event at any time. |
| 7.13.4. | The central software shall send signals back to the MDC that generated the alarm when a user has selected the event and when the event has been ended. |
| 7.13.5. | The central software shall allow a vehicle in overt alarm mode to send location reports more frequently. The frequency of reports shall be agency configurable. |
| 7.13.6. | The central software shall display vehicles in overt alarm mode using a distinctly identifiable agency configurable symbol or color in the selected map display. |
| **7.14.** | **Covert Alarm Handling** |
| 7.14.1. | When a covert alarm message is received from an MDC on a vehicle, the central software shall create a covert alarm event, display it in the event tracking table to all users, and notify them using agency configurable visual and audio alerting methods. Covert alarm alerts shall continue until acknowledged by the user. |
| 7.14.2. | Once one of the users selects the covert alarm event, the central software shall indicate this to that and all others. |
| 7.14.3. | The central software shall allow the user to end the covert alarm event at any time. |
| 7.14.4. | The central software shall send signals back to the MDC that generated the alarm when a user has selected the event and when the event has been ended. |
| 7.14.5. | During a covert alarm event, the central software shall not allow users to send text messages to the MDC that generated the alarm, but all other location reporting and schedule/route adherence monitoring abilities shall remain operational. |
| 7.14.6. | The central software shall allow a vehicle in covert alarm mode to send location |

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| | reports more frequently. The required frequency of such reports shall be agency configurable. |
| 7.14.7. | The central software shall display vehicles in covert alarm mode using a distinctly identifiable agency configurable symbol or color in the selected map display. |
| **7.15.** | **Event Reporting** |
| 7.15.1. | The central software shall allow authorized users to manually declare an event to form the basis for an event report, with the event report form auto-populated with all information already known in the system about the event. Event information shall include as a minimum: event type; location; closure impacts; injuries; who declared it, and times of event. Information contained in an event report shall be agency configurable. Types of events may include:<br>▪ Accident involving the bus<br>▪ Accident affecting traffic flow<br>▪ Mechanical interference<br>▪ Maintenance alerts<br>▪ Overt alarm message<br>▪ Covert alarm message<br>▪ Passenger medical emergency<br>Certain types of events shall be graphically displayed with a distinctly identifiable agency configurable symbol or color on the map. |
| 7.15.2. | The central software shall transmit event information to on-board MDCs of vehicles that will be affected by the event. The type of information sent to on-board MDCs during different types of events shall be agency configurable. |
| 7.15.3. | The central software shall make one central event report accessible from the server so everyone sees the same current report information, but only one instance of the report can be open at a time. |
| 7.15.4. | The central software shall allow authorized users to append to an existing open event report, with other system users limited to read-only access. |
| 7.15.5. | The central software shall allow the user to view a list of currently open event reports in an event tracking table that can be sorted by date/time, event type, or initiating user. The open event report shall be able to be repeatedly accessed and modified, until it is marked closed after which further modifications shall not be possible. |
| 7.15.6. | The central software shall allow the selected event report to appear in a separate window and be available for editing. |
| 7.15.7. | The central software shall track the user and date/time when the event report is opened, modified or closed. |
| 7.15.8. | The central software shall allow authorized users to close an existing open event report. The user shall be able to select from a list of currently open event reports, which can be sorted by date/time, event type, or initiating user. The user shall be asked to confirm the selected event report before the event is closed. |
| 7.15.9. | The event tracking table shall indicate, for each event report, the date/time of opening the report, the event type, the initial event text, the initiating user, the date/time of each subsequent modification, each modified version of the text, the modifying user, the date/time the event was closed, and the closing user. |
| **7.16.** | **Data Logging and Retrieval** |
| 7.16.1. | The central software shall support the storage and archiving of the following |

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| | information in a historical database:<br>▪ All information exchanged with MDCs on vehicles including location data, route/schedule adherence data, logon/logoff data, overt alarms, covert alarms, text messages, and APC data.<br>▪ All information generated by the central software including user logons and logoffs, messages, events.<br>The information contained in the historical database shall be made available for retrieval, analysis, display, and printing. |
| 7.16.2. | The central software shall stamp stored data with the time and date, and include sufficient information to enable selective sorting and retrieval based on user-specified selection criteria. At a minimum, the following sorting and selection criteria shall be supported for accessing the historical data from both the online and archived storage: date and time, GPS latitude/longitude, vehicle ID, run ID, block ID, operator ID, user ID, stop ID, APC data, and event type (where needed). |
| 7.16.3. | The central software shall allow data items in the historical database to be read-only with modification only permitted to individual pre-defined fields. |
| 7.16.4. | The central software shall allow all such data to be retrieved, even if it has been archived. |
| 7.16.5. | The central software shall include a means of archiving transaction data, or restoring data from an archive, while the system is in operation. It shall not be necessary to shut down the database to perform a successful backup or restore operation. |
| **7.17.** | **Reporting** |
| 7.17.1. | At a minimum, the central software shall allow the following standard reports to be created based on the CAD/AVL data:<br>– National Transit Database (NTD) annual reports in accordance with Federal Transit Administration (FTA) rules<br>– On time performance<br>– Active fleet (weekday and weekend)<br>– Productivity<br>– Number of events/accidents<br>– Lost service time, by event type |
| 7.17.2. | The central software shall also allow reporting of actual revenue-hours, revenue-miles, layover-hours, deadhead-hours, deadhead-miles, actual-hours, and actual-miles. Deadhead should be broken down between to/from garage and interline types. |
| 7.17.3. | The central software shall allow authorized users to configure the information contained in the standard reports and their format. |
| 7.17.4. | The central software shall have the capability to generate reports based on exceptions as per agency configurable thresholds for various CAD/AVL components. |
| 7.17.5. | The central software shall have the capability to generate ad-hoc reports based on stored CAD/AVL data. |
| 7.17.6. | The central software shall use standard reporting tools (e.g., Crystal Reports or MS Access) and shall have the ability to export data into file formats that can be viewed and edited with standard office software (e.g., Microsoft Word and Excel). |

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| **7.18.** | **Bulk Data Files** |
| 7.18.1. | The central software shall prepare bulk data files (including schedule data, headsign display messages, or firmware updates when required) for download on on-board MDCs periodically, as controlled by users. |
| 7.18.2. | The central software shall download bulk data files to on-board MDCs automatically at certain dates or times or when instructed by a user. |
| 7.18.3. | The central software shall allow bulk data files from on-board MDCs to be uploaded as and when required. |
| **7.19.** | **Cellular Data Communications Gateway Integration** |
| 7.19.1. | The system shall be interfaced with the Cellular Data Communications Gateway to enable transmission of all real-time incoming and outgoing messages and bulk data files between the central software and the MDCs via the cellular data communication networks. |
| **7.20.** | **Bulk Data Gateway Integration** |
| 7.20.1. | The system shall be interfaced with the Bulk Data Gateway to enable transmission of bulk data files between the central software and the MDCs via the WLAN. |
| **7.21.** | **Scheduling Software Integration** |
| 7.21.1. | The central software shall support entering schedule information both manually and automatically through a download from another computer, through a LAN, or through removable media. |
| 7.21.2. | The central software shall support the file formats in which the schedules are made available by the Trapeze FX - Version 11 scheduling software at each “home” operating agency. |
| 7.21.3. | The central software shall be interfaced with the scheduling software (Trapeze FX - Version 11) at each “home” operating agency to:<br>- Automatically update schedules in the central software after they are changed in scheduling software.<br>- Automatically update the vehicle/block assignments in the central software as they made by the home agency.<br>- Automatically update operator run assignments and background information as they are made by the home agency. |
| 7.21.4. | The central software shall allow updates from the scheduling software to be performed periodically, as controlled by users. |
| **7.22.** | **APC Management Software Integration** |
| 7.22.1. | The central software shall receive and store APC data records with raw passenger counts from on-board APCs via the MDCs. |
| 7.22.2. | The central software shall accumulate incoming APC data records from the vehicles over an agency configurable period of time before they are forwarded to the APC management software. |
| **7.23.** | **Traveler Information Software Integration** |
| 7.23.1. | The central software shall periodically provide vehicle route/trip assignments and schedule updates to the traveler information software. |
| 7.23.2. | The central software shall automatically forward location reports received from on- |

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| | board MDCs and route/schedule adherence information to the traveler information software. |
| 7.23.3. | The central software shall accept and display the current messages on VMS signs and being broadcast on the PA speakers from the traveler information software. |

# 8. CELLULAR DATA COMMUNICATIONS GATEWAY REQUIREMENTS

| **8.** | **Cellular Data Communications Gateway Requirements** |
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| **8.1.** | **General** |
| 8.1.1. | A cellular data communications gateway shall be established with the cellular data carrier selected by CTDOT, to enable the central system to exchange real-time data messages and bulk data over the leased cellular accounts with vehicles |
| 8.1.2. | CTDOT shall provide the required data connectivity and firewall for the connection to the cellular data provider. |
| **8.2.** | **Interfaces** |
| 8.2.1. | The cellular data communication gateway shall be interfaced with the CAD/AVL central software to allow all incoming and outgoing messages between the central software and the MDCs to be transmitted using the cellular data communication networks. |
| **8.3.** | **Firewall** |
| 8.3.1. | The cellular data communications gateway shall provide a stateful firewall to secure incoming and outgoing data. |
| **8.4.** | **CAD/AVL Central Software Integration** |
| 8.4.1. | The cellular data communications gateway support software shall process data messages received from the vehicles and pass these to the central software in real-time. |
| 8.4.2. | The mobile data communications gateway support software shall process data messages received from the central software and pass these to the vehicles in real-time. Outgoing real-time messages shall be configurable to download to:<br>1) All busway vehicles;<br>2) All busway vehicles, in a specific selected group of vehicles; or<br>3) A specific busway vehicle. |

# 9. BULK DATA GATEWAY REQUIREMENTS

| **9.** | **Bulk Data Gateway Requirements** |
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| **9.1.** | **General** |
| 9.1.1. | A bulk data gateway shall be provided to enable the central system to exchange bulk data over the WLAN with vehicles when in range of bulk data transfer infrastructure. |
| **9.2.** | **Interfaces** |
| 9.2.1. | The bulk data gateway shall be interfaced with the CAD/AVL central software to allow all incoming and outgoing bulk data between the central software and the MDCs to be transmitted over the WLAN. |
| **9.3.** | **Firewall** |
| 9.3.1. | The bulk data gateway shall provide a stateful firewall to secure incoming and outgoing data. |
| **9.4.** | **CAD/AVL Central Software Integration** |
| 9.4.1. | The bulk data gateway support software shall process bulk data received from the vehicles and pass these to the central software. |
| 9.4.2. | The bulk data gateway support software shall process bulk data received from the central software and pass these to the vehicles. Outgoing bulk data shall be configurable to download to:<br>1) All busway vehicles;<br>2) All busway vehicles, in a specific selected group of vehicles; or<br>3) A specific busway vehicle. |

# 10. APC MANAGEMENT SOFTWARE REQUIREMENTS

| **10.** | **APC Management Software Requirements** |
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| **10.1.** | **General** |
| 10.1.1. | The APC management software shall support the processing, storage and reporting of APC data collected by on-board APC sensors. |
| 10.1.2. | The APC management software shall be a module of the CAD/AVL central software or a separate stand-alone software package. |
| **10.2.** | **Interfaces** |
| 10.2.1. | The APC management software shall be interfaced to accept APC data records with raw passenger counts from the CAD/AVL central software. |
| **10.3.** | **APC Management Software Logon and Logoff** |
| 10.3.1. | The APC management software shall support a logon, logoff feature that is password protected and shall allow a user to logon to a specific user access level. Users logged on or logged off to the CAD/AVL central software shall be automatically logged on or logged off respectively to the APC management software. |
| 10.3.2. | The APC management software shall allow users to log on to the system with varying privileges depending on their access level. Access levels may include, but are not limited to:<br>▪ BOC System Administrator<br>▪ BOC Dispatcher<br>▪ BOC Read-only dispatcher<br>▪ Busway Supervisor<br>▪ ‘Home’ Operating Company Dispatchers |
| 10.3.3. | The APC management software shall allow users logged in as system administrators to assign specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| 10.3.4. | The APC management software shall support at least 10 concurrent users. |
| **10.4.** | **Data Processing, Storage, and Reporting** |
| 10.4.1. | The APC management software shall store unprocessed (raw) APC data received from vehicles without alteration in database tables. The APC management software shall retain unprocessed APC data after post-processed APC data has been developed. |
| 10.4.2. | The APC management software shall initially flag in the unprocessed data (1) any “outlying” data; (2) instances where the calculated vehicle occupancy becomes negative; (3) instances where occupancy exceeds configurable thresholds; and (4) instances where the total number of boardings and alightings over the course of a block are not equal. The parameters controlling the automatic flagging of “outlying” data software shall be agency configurable. |
| 10.4.3. | The APC management software shall automatically adjust the flagged unprocessed APC data during regular rollup by application of agency configurable adjustment factors. The adjustment factors shall be based on typical counting patterns of individual APC devices. |
| 10.4.4. | The APC management software shall automatically discard erroneous, |

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| | questionable and incomplete unprocessed APC data during regular rollup by application of various agency configurable routines. The central software shall generate summary and detailed discard reports by discard reason and vehicle number. |
| 10.4.5. | The APC management shall store the post-processed version of the APC data received from vehicles in a database table. |
| 10.4.6. | The APC management software shall allow authorized users to manually enter manual ridecheck data for comparison/augmentation purposes. |
| 10.4.7. | The APC management software shall generate APC data reports, offering both tabular and graphical formats. The system shall also generate all specific reports required by the National Transit Database (NTD) program. |
| 10.4.8. | The APC management software shall allow the user to select between unprocessed and post-processed data and apply filters comprising any combination of route, pattern, direction, stops, date/time period and day-of-week. The user shall be able to select to view data including boardings by stop, boardings not assigned to a stop, alightings by stop, alightings not assigned to a stop, on-board passenger load by stop, and stops for which boardings/alightings were not recorded. |
| 10.4.9. | The APC management software shall be capable of exporting select APC data using standard reporting tools (e.g., Crystal Reports or MS Access) and shall have the ability to export data into file formats that can be viewed and edited with standard office software (e.g., Microsoft Word and Excel). |
| **10.5.** | **CAD/AVL Central Software Integration** |
| 10.5.1. | Once a user is logged on the CAD/AVL system, the central software shall send logon information to the APC management software to enable the user to be automatically logged on to the APC management software as well. |
| 10.5.2. | The APC management software shall accept APC records with raw passenger counts from the CAD/AVL central software at periodic intervals. |
| 10.5.3. | When a user logs off the CAD/AVL system, the central software shall send a request to log off the user from the APC management software. |

# 11. TRAVELER INFORMATION SOFTWARE REQUIREMENTS

| **11.** | **Traveler Information Software Requirements** |
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| **11.1.** | **General** |
| 11.1.1. | The traveler information software shall support generating vehicle arrival predictions and text messages for transmission to Traveler Information Station (TIS) Controllers, for display on Variable Message Signs (VMSs) and/or annunciation on speakers at busway stations. |
| 11.1.2. | The traveler information software shall be a module of the CAD/AVL central software or a separate stand-alone software package. |
| **11.2.** | **Interfaces** |
| 11.2.1. | The traveler information software shall be interfaced with the CAD/AVL central software to accept vehicle route/trip assignment and schedule updates at periodic intervals, and location reports in real-time. |
| 11.2.2. | The traveler information software shall be interfaced with the TIS controllers via the busway communications system. |
| **11.3.** | **Logon and Logoff** |
| 11.3.1. | The traveler information software shall support a logon, logoff feature that is password protected and shall allow a user to logon to a specific user access level. Users logged on or logged off to the CAD/AVL central software shall be automatically logged on or logged off respectively to the traveler information software. |
| 11.3.2. | The traveler information software shall allow users to log on to the system with varying privileges depending on their access level. Access levels may include, but are not limited to:<br>▪ BOC System Administrator<br>▪ BOC Dispatcher<br>▪ BOC Read-only dispatcher<br>▪ Busway Supervisor<br>▪ ‘Home’ Operating Company Dispatchers |
| 11.3.3. | The traveler information software shall allow users logged in as system administrators to assign specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| 11.3.4. | The traveler information software shall allow users logged in as system administrators to assign the following for the TIS controllers: specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| 11.3.5. | The traveler information software shall support at least 10 concurrent users. |
| **11.4.** | **Graphical User Interface (GUI)** |
| 11.4.1. | The traveler information software shall incorporate a Graphical User Interface (GUI), to display information to users and accept user input in a clear, logical manner. |
| 11.4.2. | The traveler information software shall be able to display in a tabular format the information being sent to station platforms for VMS display, the information being currently displayed by VMSs, and the information being sent for announcements |

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| | made by PA system speakers. |
| 11.4.3. | The traveler information software shall allow the user to filter the information for display by station platform, direction, and by individual VMSs. |
| 11.4.4. | The GUI shall support concurrent display of multiple windows. |
| 11.4.5. | At a minimum, the GUI shall support function key assignments, paging, scrolling, and shortcuts. |
| 11.4.6. | The GUI shall support repositioning and resizing each window as desired to present the maximum amount of useable information. |
| **11.5.** | **Arrival Prediction Generation** |
| 11.5.1. | The traveler information software shall employ a prediction algorithm to generate predictions to the nearest second, throughout the operational day, for vehicle arrival times for all routes at all stations on the busway. |
| 11.5.2. | The traveler information software shall have the ability to align real-time vehicle locations with available trip schedules. |
| 11.5.3. | If reported vehicle locations cannot be aligned with a specific timetable schedule, predictions shall be based on the nearest scheduled trip on the same route in the same direction, in terms of clock time in the schedule. |
| 11.5.4. | The traveler information software shall use latest reported vehicle locations, and may also use other information such as schedule adherence or archived segment travel time data, to accurately maintain current vehicle arrival time predictions for all stations on the busway. |
| 11.5.5. | The traveler information software shall account for the time lag in the vehicle location updates before they reach the prediction algorithm, making predictions based on the timestamp attached at the vehicle rather than the time at which the data was received. |
| 11.5.6. | The traveler information software shall allow configuration of 'early' and 'late' thresholds for a vehicle in operation based on the arrival predictions. |
| 11.5.7. | The traveler information software shall stop generating predictions when a vehicle departs its last station on the busway, is indicated as being off-route, is taken out of service by users or an agency configurable time has elapsed since the last location update. |
| 11.5.8. | The traveler information software shall resume generating predictions when a vehicle is reported on-route and still 'upstream' of its last busway station when a location update is received following suspension of updating due to elapsed time since the previous update. |
| 11.5.9. | For each station, the traveler information software shall generate vehicle arrival predictions for at least the next three vehicles serving that station. |
| 11.5.10. | The traveler information software shall provide the vehicle arrival predictions to TIS controllers in a format appropriate for display on station VMSs, and for conversion to announcements via text-to-voice engine. |
| 11.5.11. | For each station platform and direction, the prediction information shall include a time stamp in accordance with the central clock, and the following for the next three (3) expected vehicles: a route or service designation, the destination or an abbreviation thereof, and either the integer number of minutes until expected arrival or a status designation of up to 4 characters, such as 'due' or 'next'. |

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| 11.5.12. | The traveler information software shall allow the automatic delivery of vehicle arrival predictions to be programmed in terms of frequency by destination station platforms and by direction. |
| **11.6.** | **Real-Time Data Feed** |
| 11.6.1. | The traveler information software shall provide a data feed containing real-time vehicle locations and predicted times of arrival at each stop in one or more machine-readable formats (such as XML, JSON, TXT) for CTDOT to post on its website, the internet and other web enabled means designated by CTDOT. |
| **11.7.** | **Sign Message Generation** |
| 11.7.1. | The traveler information software shall support the generation of text messages for display on station VMSs. |
| 11.7.2. | The traveler information software shall provide a text message generation screen with the option of selecting a message from a list of canned messages or entering a freeform message manually. |
| 11.7.3. | The traveler information software shall allow maintaining a library of 'canned' text messages that shall be agency configurable. These messages may include: weather information, incident information, public safety information, and general transit information. |
| 11.7.4. | The traveler information software shall allow the user to assign a message as being either the ad hoc or emergency type. |
| 11.7.5. | The traveler information software shall allow the user to assign a specific single platform or a set of destination platforms and directions to the selected message. |
| 11.7.6. | The traveler information software shall allow the automatic delivery of text messages to be programmed in terms of frequency, specific times of day, day of week, and destination station platforms and direction. |
| 11.7.7. | The traveler information software shall allow the user to manually select a text message for immediate delivery to the assigned station platforms and direction, or to be programmed in terms of frequency and destination station platforms and direction. |
| **11.8.** | **Announcement Generation** |
| 11.8.1. | The traveler information software shall support the recording of announcements for playing on the PA system. |
| 11.8.2. | The traveler information software shall provide an announcement generation screen with the option of selecting from a list of prerecorded announcements or recording a freeform announcement. |
| 11.8.3. | The traveler information software shall allow maintaining a library of prerecorded announcements that shall be agency configurable. These messages may include: weather information, incident information, public safety information, and general transit information. |
| 11.8.4. | The traveler information software shall allow the user to assign an announcement as being either the ad hoc or emergency type. |
| 11.8.5. | The traveler information software shall allow the user to assign a specific single platform or a set of destination stations to the selected announcement. |
| 11.8.6. | The traveler information software shall allow the automatic delivery of |

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| | announcements to be programmed in terms of frequency, specific times of day, day of week, and destination stations. |
| 11.8.7. | The traveler information software shall allow the user to manually select an announcement for immediate playing at the assigned stations, or to be programmed in terms of frequency and destination stations. |
| **11.9.** | **CAD/AVL Central Software Integration** |
| 11.9.1. | Once a user is logged on the CAD/AVL system, the central software shall send logon information to the traveler information software to enable the user to be automatically logged on to the traveler information software as well. |
| 11.9.2. | The traveler information software shall accept vehicle route/trip assignments and schedule updates from the CAD/AVL central software as soon as such updates are available. |
| 11.9.3. | The traveler information software shall accept real-time location updates from the CAD/AVL central software at all times. |
| 11.9.4. | When a user logs off the CAD/AVL system, the central software shall send a request to log off the user from the traveler information software. |
| 11.9.5. | The traveler information software shall be able to send the current messages displayed on any or all VMS signs or the message being played on the PA speakers to the CAD/AVL central software. |
| **11.10.** | **Traveler Information Station (TIS) Controller Integration** |
| 11.10.1. | The traveler information software shall send regular prediction information updates to the appropriate TIS controller based on the assigned destination station platform and direction. |
| 11.10.2. | The traveler information software shall send ad-hoc and emergency text message updates to the appropriate TIS controller based on the assigned destination station platform and direction. |
| 11.10.3. | The traveler information software shall send announcements to the appropriate TIS controller based on the assigned destination stations. |
| 11.10.4. | The traveler information software shall be able to periodically request a TIS controller for information currently being displayed on the VMS and being announced through the PA system speakers, and store the information in a database. The frequency of requests to a TIS controller shall be agency configurable. |
| 11.10.5. | The traveler information software shall be able to query any TIS controller for the current messages displayed on any or all VMS signs it controls, and to support the display of those messages. |
| 11.10.6. | The traveler information software shall control log on log off functionalities at TIS controllers. |
| 11.10.7. | The traveler information software shall receive fault/failure alerts from the TIS controllers. Loss of communication with the TIS controllers shall also trigger an alert in the traveler information software. |

# 12. TRAVELER INFORMATION SYSTEM (TIS) CONTROLLER REQUIREMENTS

| **12.** | **Traveler Information System (TIS) Controller Requirements** |
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| **12.1.** | **General** |
| 12.1.1. | The TIS controller at each busway station shall include both software and hardware at a station platform to manage and control the VMSs and PA speakers for that station. |
| 12.1.2. | The TIS controller at each busway station shall be capable of being controlled remotely from the BOC through the traveler information software or locally (in case of emergency or loss of communications with the BOC). |
| 12.1.3. | The TIS controller at each busway station shall accept information from the traveler information software to control the PA system speakers and VMSs on all platforms at each busway station. |
| 12.1.4. | When communication to the traveler information software is lost or during emergency situations, the TIS controller shall allow local control through a local microphone to the PA system speakers on all platforms at each busway station. The TIS controller shall also allow local control of VMSs through a local keyboard on station platforms. |
| 12.1.5. | The major features of each TIS controller shall consist of:<br>• equipment/communications case<br>• digital clock<br>• microphone<br>• local data entry keyboard<br>• driving electronics<br>• environmental control and protection<br>• mounting hardware<br>• associated cables and wiring |
| 12.1.6. | All hardware provided as part of the TIS controller shall be field-hardened and suitable for outdoor environmental conditions and vibration associated with nearby bus and train travel. |
| 12.1.7. | It is preferred that the TIS controller be NTCIP compliant. |
| **12.2.** | **Interfaces** |
| 12.2.1. | The TIS controller shall be interfaced with the traveler information software via the busway communications system. |
| 12.2.2. | The TIS controller shall be interfaced with each VMS furnished at the station, as well as its integrated speaker and associated VMS Readout Activation Device through an Ethernet Interface**.** |
| 12.2.3. | The TIS controller shall be interfaced with all PA system speakers associated with the station through an Ethernet Interface. |
| **12.3.** | **Logon and Logoff** |
| 12.3.1. | The TIS controller shall support a logon, logoff feature that is password protected and shall allow a user to logon to a specific user access level. |

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| 12.3.2. | The TIS controller shall allow users to log on with varying privileges depending on their access level. |
| 12.3.3. | The TIS controller shall allow users logged in as system administrators to assign specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| **12.4.** | **Digital Clock** |
| 12.4.1. | The TIS controller shall incorporate a digital, real-time clock that shall be capable of maintaining the current date/time for a period of time without external power supply. |
| 12.4.2. | The TIS controller shall be capable of receiving updated date/time data from the fare management central software and using this data to update the real-time clock. |
| **12.5.** | **General Control** |
| 12.5.1. | The TIS controller shall have dedicated, redundant hard drives rated for high reliability. |
| 12.5.2. | The VMS and PA system speakers shall be able to be configured and managed remotely via the TIS controller. |
| 12.5.3. | The TIS controller shall be able to accept messages of three classes from the traveler information software: bus arrival predictions, *ad hoc*, and emergency at the station. |
| 12.5.4. | The TIS controller shall be able to maintain and execute priority rules for the three classes of message, and whether messages of each type should be interrupted or completed before delivering a message that has been assigned a higher priority. These rules should be able to be established remotely from the BOC. |
| 12.5.5. | The TIS controller shall be able to direct a voice and text message of any of the three classes received from the BOC to the VMS and PA speakers associated with any set of destination platforms associated with the stations. Its delivery will be subject to the priority rules for this class of message. |
| 12.5.6. | The TIS controller shall be able, when configured to do so remotely from the BOC, include the current clock time in the contents of all VMSs at the station. |
| 12.5.7. | The TIS controller shall be able to be placed in a local mode of operation by a button or switch within the equipment cabinet. |
| 12.5.8. | All communications parameters and settings shall be user configurable remotely from the BOC and through a local maintenance port. |
| 12.5.9. | Every TIS controller using the busway communications network shall be assigned an IP address. |
| **12.6.** | **Workstations** |
| 12.6.1. | The TIS controller shall allow a laptop computer to be connected locally through a separate RS232 or similar communication method and to operate as programmed in response to information in the same format as provided by the traveler information software. |
| 12.6.2. | The TIS controller shall include a local entry keyboard. |
| 12.6.3. | The TIS controller shall include a microphone station with the capability to create |

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| | recorded announcements, initiate live messages, and carry out other system actions in emergency situations. |
| **12.7.** | **VMS Integration** |
| 12.7.1. | All the functionality discussed under the VMS functional requirements shall be supported by the TIS controller. |
| 12.7.2. | The TIS controller shall be able to deliver messages directed to any possible combination of station platforms by the traveler information software at the BOC in any of three classes: bus arrival predictions, *ad hoc*, and emergency to any VMS at the station. |
| 12.7.3. | Unless overridden by a requirement to display emergency information, and when communication with the traveler information software via the controller is operating, each VMS associated with a station platform shall be able to display information for up to the next three buses which the traveler information software indicates as expected to stop at that platform, with each bus displayed on a separate line, as well as ad hoc messages on the fourth line. |
| 12.7.4. | Each update of the bus arrival time predictions (vehicle plans) from the traveler information software shall cause an update of the list of expected arrivals and arrival times for each platform VMS. This update from the BOC may include all vehicles that have a vehicle plan at the BOC. |
| 12.7.5. | Each platform VMS shall be programmable locally and remotely from the traveler information software to establish the minimum and maximum number of buses to be shown. |
| 12.7.6. | One line of the VMS shall be used for ad hoc messages originating at the traveler information software or locally at the TIS controller, scrolling and interleaving them as needed to present all such information. |
| 12.7.7. | The entire VMS message area shall be usable by the BOC dispatcher or local intervention at the TIS controller to display messages under emergency conditions, overriding “next bus'' content. |
| 12.7.8. | The VMSs and integrated speakers at each platform shall be usable by the BOC dispatcher or local intervention at the TIS controller to broadcast messages under emergency conditions, overriding any ad hoc content. |
| 12.7.9. | In local mode, the TIS controller shall accept keyboard entry of a temporary default message and program its delivery in terms of frequency and platform (direction of travel) to overwrite the one established for any VMS, and shall direct the display of the current default messages at all associated VMSs. |
| **12.8.** | **PA System Speaker Integration** |
| 12.8.1. | All the functionality discussed under the PA System Functional Requirements shall be supported by the TIS controller. |
| 12.8.2. | The TIS controller shall be able to convert text messages into voice messages, and shall cause these voice messages to be broadcast from both station PA speakers and speakers associated with VMSs as required. These voice messages shall be synchronized with the text being displayed on the VMSs. |
| 12.8.3. | The TIS controller shall be able to direct ad hoc and/or emergency messages directed to any possible combination of station platforms by the Traveler Information Software at the BOC to the associated platforms' PA Systems. |

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| 12.8.4. | In the local mode of operation, when the microphone provided is connected, it shall be possible to record live messages and direct the output to all PA speakers in the station or to speakers by platform. |
| 12.8.5. | When in local mode, temporary default messages entered via keyboard shall be directed to the PA speakers. |
| 12.8.6. | Ad hoc messages shall be able to be broadcast over the PA system at regular intervals. |
| 12.8.7. | The PA system shall allow for manual control of speaker volumes. |
| 12.8.8. | The PA system shall be usable by the BOC dispatcher or local intervention at the TIS controller to broadcast messages under emergency conditions, overriding any ad hoc content. |
| **12.9.** | **Traveler Information Software Integration** |
| 12.9.1. | The TIS controller shall accept prediction information for a minimum of the next three (3) expected buses, to be refreshed when an update is sent or at a regular interval as defined by the traveler information software at the BOC. |
| 12.9.2. | Upon request from the traveler information software, the TIS controller shall be capable of sending the information it is presently directing to each VMS and PA system speaker back to the traveler information software for display. |
| 12.9.3. | The logon, logoff functionalities at TIS controllers shall be controlled by the traveler information software. |
| 12.9.4. | Automatic reset/reboot and firmware upload shall be supported. |
| **12.10.** | **Failure Modes** |
| 12.10.1. | The TIS controller shall be able to receive and maintain a default message for each VMS with which it is interfaced, and shall direct it to be displayed in the absence of communication from the BOC. |
| 12.10.2. | The TIS controller shall be able to receive and maintain a default message for each PA system speaker with which it is interfaced, and shall direct it to be announced in the absence of communication from the BOC. |
| 12.10.3. | The TIS controller shall communicate faults and failure messages to the traveler information software. Loss of communication with the TIS controller shall also trigger an alert to the traveler information software. |

# 13. VARIABLE MESSAGE SIGN (VMS) REQUIREMENTS

| **13.** | **Variable Message Sign (VMS) Requirements** |
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| **13.1.** | **General** |
| 13.1.1. | The VMS shall be able to display textual information generated by and received from the TIS controller. |
| 13.1.2. | The VMS shall be able to display the current time of day in digital format, as received from the TIS controller, if a user-configurable flag in the TIS controller is set to require this. |
| 13.1.3. | The VMS shall be able, upon receiving an indication from a customer-actuated device, to request the TIS controller to send the textual contents of the sign plus the current time, if displayed, to a speaker logically associated with that device by the TIS controller, for annunciation by that speaker. |
| 13.1.4. | The major features of each VMS shall consist of:<br>• sign case/housing<br>• sign face<br>• display modules<br>• speaker<br>• driving electronics<br>• mounting hardware<br>• associated cables and wiring |
| 13.1.5. | It is preferred that the VMS be NTCIP compliant. |
| **13.2.** | **Interfaces** |
| 13.2.1. | All VMSs associated with a station shall be able to interface with the TIS controller located at the station through an Ethernet Interface. |
| **13.3.** | **Customer Display** |
| 13.3.1. | Two VMS configurations shall be provided:<br>• One sided display - a four (4) line display shall be shown on one side of the sign with a sign case on the backside<br>• Two-sided display - a four (4) line display shall be shown on both sides of the sign. Both sides of a two-sided display shall be housed in one cabinet. Information displayed on two-sided displays shall be the same on both sides. |
| 13.3.2. | The VMS shall be able to display three (3) types of messages: static messages, flashing messages, and scrolling messages. |
| 13.3.3. | The VMS shall be able to display a message composed of any combination of alphanumeric character fonts, punctuation symbols and full graphics. |
| 13.3.4. | VMS display characteristics shall include variable and fixed width fonts, proportional spacing and fully configurable fonts. |
| 13.3.5. | The VMS shall provide legible four-line matrices with a minimum of 24 fixed width font characters per line. |
| 13.3.6. | The VMS sign shall support display of current clock time from the TIS controller in a portion of any one of the four line matrices, using a subset of the matrix's |

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| | characters configured in the TIS controller. |
| 13.3.7. | Modules shall be comprised of a minimum of 5 pixel columns by 7 pixel rows. |
| 13.3.8. | Each display line shall be separated by a minimum distance of 4 pixel spaces or have a border around each line. |
| 13.3.9. | The VMS shall use Light Emitting Diodes (LED) technology, all of which shall be of identical make and model from the same manufacturer. |
| 13.3.10. | VMS LEDs shall be amber on a black background |
| 13.3.11. | Each pixel shall contain sufficient LEDs so that the entire sign considering the background and the polycarbonate sheet in front of the pixels shall fulfill the optical output, contrast, viewing angle, legibility and reliability requirements. |
| 8.3.12 | The LED pixel design shall be such that it minimizes the effect of heat buildup within the pixel. The LEDs shall operate within the LED's manufacturer's rated temperature range under the worst case operating conditions. |
| 13.3.12. | The LED pixels shall be suitably housed for proper heat dissipation. |
| 13.3.13. | The LED pixels shall be waterproofed to protect the LEDs. |
| 13.3.14. | The soldering of the LEDs shall be in accordance with the manufacturer's recommended guidelines. |
| 13.3.15. | All modules shall be securely mounted so that the nominal axis of the light output shall be perpendicular to the sign face. |
| 13.3.16. | When operating at full intensity, the sign display shall be clearly legible from any viewing distance between 3ft and 75ft on a line perpendicular to the face of the sign. This legibility shall be required:<br>• during all normally encountered weather and lighting conditions, and at all times of the day; and<br>• during dawn and dusk hours when sunlight is shining directly on the display face or when the sun is shining from directly behind the VMS |
| 13.3.17. | At least 50% of this viewing distance shall be maintained within a cone spanning 22 degrees in any direction from this perpendicular axis. |
| **13.4.** | **VMS Speaker** |
| 13.4.1. | The VMS shall incorporate a speaker that can be addressed by the TIS controller as configured therein. |
| 13.4.2. | The speaker shall provide good coverage and high level of speech intelligibility to overcome limitations such as reverberation, echo, delay and feedback to the most extreme listening positions. |
| 13.4.3. | The speaker or speaker casing shall be designed for outdoor operations and inclement conditions and shall be weatherproofed and vandal resistant. |
| 13.4.4. | The audio volume shall automatically adjust to ensure that it is only loud enough to be understandable within a 15 foot radius from the sign. |
| **13.5.** | **VMS Readout Activation Device** |
| 13.5.1. | A button or similar easily operated device shall be placed in close proximity to each VMS that, when pressed or actuated, shall indicate to the TIS controller that |

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| | a request to annunciate the content lines of the VMS through the incorporated speaker has been made. |
| 13.5.2. | Actuation of this device shall result in the audible reading of the sign text once in English annunciated through the incorporated VMS speaker. |
| 13.5.3. | The height of the push button shall meet ADA requirements and shall be placed at a consistent and accessible location adjacent to the sign. |
| 13.5.4. | The button shall indicate its location to the sight impaired. |
| **13.6.** | **TIS Controller Interface** |
| 13.6.1. | The VMS shall be able to be networked to the TIS controller through an Ethernet Interface. |
| 13.6.2. | The VMS display shall be refreshed whenever the TIS controller sends an update to any content. |
| 13.6.3. | Automatic reset/reboot and firmware download shall be supported. |
| 13.6.4. | All VMS communications parameters and settings shall be user configurable through a local maintenance port. |
| **13.7.** | **Failure Modes** |
| 13.7.1. | Failure of a pixel or module shall not cause failure of any other pixel. |
| 13.7.2. | The LED pixels shall be highly reliable for the intended applications. |
| 13.7.3. | Failure and reset recovery time for both hard and soft reset shall be less than forty-five (45) seconds. |
| 13.7.4. | When communication with the TIS controller is lost, and if not overridden for emergency messages, the VMS shall display a preset default message, which can be updated from the TIS controller when it is in communication with the VMS. |
| 13.7.5. | When communication with the TIS controller is lost, the activation of the VMS Readout Actuation Device shall cause a preset default message to be broadcast over the associated VMS speaker, which can be updated from the TIS controller when it is in communication with the VMS. |
| **13.8.** | **Enclosure** |
| 13.8.1. | The VMS exterior shall be designed to conform to the colors and graphics of New Britain-Hartford Busway stations as approved by CTDOT. |
| 13.8.2. | The display housing shall protect internal components from external contaminates including: rain, ice, salt, break dust, and corrosive elements. |
| 13.8.3. | For displays in direct sunlight continually, an optional sunshade shall be available. The sunshade shall minimize solar gain and maximize the contrast of the display. |
| 13.8.4. | The display housing design shall be tested to NEMA 4X. |
| 13.8.5. | Internal display component hardware (nuts, bolts, screws, standoffs, rivets, fasteners, etc.) shall be fabricated from stainless steel, aluminum, nylon, or other durable corrosion-resistant materials suitable for the signage application. |
| 13.8.6. | Electrical display components shall be 100% solid-state. |
| 13.8.7. | The presence of ambient radio signals and magnetic or electromagnetic |

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| | interference, including those from power lines, transformers, and motors, shall not impair performance of the display system. The display system shall not radiate electromagnetic signals that adversely affect any other electronic device. |
| 13.8.8. | Connection to power shall be inside the housing. A knock-out shall be provided in the housing to allow for the entrance of the power conductors. This entrance shall provide a seal around the power conductors. |
| 13.8.9. | The enclosure shall include heating elements as necessary to prevent build up of ice that might obscure sign readability. |
| 13.8.10. | The sign casing should be vandal/graffiti resistant and washable. |
| **13.9.** | **Installation/Placement** |
| 13.9.1. | The display element assemblies and mounting hardware shall be secured to sustain the shock and vibration that prevail in locations adjacent to railroads and high-speed highways. |
| 13.9.2. | The VMS sign shall be mountable so that the lower edge of the sign is at a height that meets safe head clearance requirements. |
| 13.9.3. | The VMS readout activation button shall be located in proximity to the VMS sign and meet ADA requirements. |
| 13.9.4. | VMS housing dimensions, including the integrated speaker, shall not exceed the footprint as defined in station designs. |
| 13.9.5. | The VMS weight shall enable either overhead or pole mounting. |
| 13.9.6. | All wiring shall conform to the National Electric Code. |
| **13.10.** | **Security/Maintenance** |
| 13.10.1. | The display housing shall provide safe and convenient front service access for all modular assemblies, components, wiring, and other materials located within the housing. |
| 13.10.2. | All internal components shall be removable and replaceable by a single technician with basic hand tools. |
| 13.10.3. | The display shall contain an internal power switch to keep maintenance personnel safe during maintenance. |
| 13.10.4. | Service access shall be easily obtained by unlocking and lowering a removable hinged front face panel. |
| 13.10.5. | Removal of a module will not be required to access the internal components of the display. |
| 13.10.6. | Displays shall be designed with service features that minimize potential bodily harm. |

# 14. PUBLIC ADDRESS (PA) SYSTEM REQUIREMENTS

| **14.** | **Public Address (PA) System Requirements** |
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| **14.1.** | **General** |
| 14.1.1. | The Public Address system at each busway station shall be used to deliver audio information generated by and received from the TIS controller at proper level and with sufficient clarity to make those announcements easily understood by passengers at the station. |
| 14.1.2. | Each PA system shall consist of:<br>• audio amplifier<br>• PA speakers<br>• ambient noise level sensors<br>• associated cables and wiring |
| **14.2.** | **Interfaces** |
| 14.2.1. | The PA system at each busway station shall be able to interface with the TIS controller located at the station through audio output circuits. |
| **14.3.** | **Microphone and Auxiliary Audio Inputs** |
| 14.3.1. | Each audio input shall have capability of controlling and managing audio gain, dynamics, filtering and ducking. |
| **14.4.** | **Audio Amplifier** |
| 14.4.1. | The PA Audio Amplifiers shall incorporate audio digital signal processing including at a minimum audio equalization, feedback cancelation, ambient noise level monitoring and digital gain control. |
| 14.4.2. | Each PA Audio Amplifier shall be capable of supporting 10 speakers as a minimum. |
| **14.5.** | **PA Speakers** |
| 14.5.1. | The PA speakers shall demonstrate through testing good coverage, the correct Sound Pressure Level (SPL) and good intelligibility, with a Speech Transmission Index (STI) of 0.5 or better under all conditions. |
| 14.5.2. | Automatic Level Control (ALC) shall be provided for automatic adjustment of the volume of audible media to overcome varying ambient noise levels. |
| 14.5.3. | The requirements of local noise by-laws shall be respected by the PA system. |
| 14.5.4. | The PA speakers shall support a frequency range of 275 Hz - 14 KHz and shall have a suitable input power rating based on the required drive level. |
| 14.5.5. | The PA speakers shall have input impedance matching the output impedance of the amplifier. |
| **14.6.** | **TIS Controller Interface** |
| 14.6.1. | The PA system amplifier shall be connected to the TIS controller using audio output circuits. |
| 14.6.2. | The message being played by the PA speakers shall be whatever audio is output by the TIS controller. |

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| 14.6.3. | Manual control of PA speaker volume shall be possible through the TIS Controller. |
| 14.6.4. | Automatic reset/reboot and firmware upload shall be supported. |
| 14.6.5. | All PA system communications parameters and settings shall be user configurable remotely from the BOC and through a local maintenance port. |
| **14.7.** | **Enclosure** |
| 14.7.1. | The PA system speakers shall be designed for outdoor operations and shall be weatherproof and vandal resistant. |
| 14.7.2. | The PA system speaker components shall be resistant to corrosive elements, including salt and brake dust. |
| **14.8.** | **Installation/Placement** |
| 14.8.1. | The PA system speakers shall be discreetly mounted into platform canopies. |
| 14.8.2. | The PA system speakers mounted to platform canopies shall conform to the size constraints and form factors as defined in the platform and station designs. |
| 14.8.3. | The PA system speakers shall be installed in such a manner as to facilitate ease of maintenance. No special tools shall be required to access or maintain system components. Speakers shall be capable of being quickly removed and replaced by spares. |

# 15. FARE MANAGEMENT CENTRAL SOFTWARE REQUIREMENTS

| **15.** | **Fare Management Central Software Requirements** |
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| **15.1.** | **General** |
| 15.1.1. | The fare management central software shall monitor status data sent from individual ticket vending machines (TVMs), including status and levels for vault and ticket stock. |
| 15.1.2. | The fare management central software shall monitor status data sent from individual ticket validators, including status and levels for ticket stock. |
| 15.1.3. | The fare management central software shall manage information relevant for TVMs, ticket validators, and Mobile Enforcement Devices (MEDs), including fare table information and a list of individuals with prior fare violations (badlist). |
| 15.1.4. | The system shall include features to download/transfer sales and transaction data to CTDOT data systems. |
| **15.2.** | **Interfaces** |
| 15.2.1. | The fare management central software shall act as the gateway to the credit and debit card processing systems. CTDOT will separately procure the necessary transaction processing and backend financial clearinghouse systems. |
| 15.2.2. | The fare management central software shall interface with TVMs via the busway communications system. |
| 15.2.3. | The fare management central software shall interface with ticket validators via the busway communications system. |
| 15.2.4. | The fare management central software shall accept uploaded data from the MEDs. |
| **15.3.** | **Fare Management Central Software Logon and Logoff** |
| 15.3.1. | The fare management central software shall support a logon, logoff feature that is password protected. |
| 15.3.2. | The fare management central software shall allow users to log on to the system with varying privileges depending on their access level. Access levels may include, but are not limited to:<br>▪ System Administrator<br>▪ General User<br>▪ View Only User |
| 15.3.3. | The fare management central software shall allow users logged in as system administrators to assign specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| 15.3.4. | The fare management central software shall support multiple concurrent users. |
| **15.4.** | **Graphical User Interface (GUI)** |
| 15.4.1. | The GUI shall provide an easy, user friendly and efficient way to (1) schedule data retrieval, (2) run reports, (3) define reconfiguration data (or references to data files containing reconfiguration data or software updates) and schedule when it is to be sent to TVMs, ticket validators, or MEDs, and (4) monitor TVMs, ticket validators, and MEDs. |

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| 15.4.2. | Through the GUI, users shall be able to perform all necessary functions for system diagnostics, configuration of TVMs and ticket validators, and addition and removal of TVMs and ticket validators. |
| **15.5.** | **Configuration Options** |
| 15.5.1. | The fare management central software shall support managing fare tables, including the ability to specify:<br>• Fares for all fare categories<br>• Types (length) and prices of all period passes<br>• Whether period passes will “activate on first use” or “activate immediately” (i.e. when loaded), with it being possible to specify different settings based on length of period pass or sale mechanism (i.e. attended or online)<br>• Transfer validity period |
| 15.5.2. | The fare management central software shall support modifying the types of fare categories that can be encoded on fare media. |
| **15.6.** | **Badlist Management** |
| 15.6.1. | The fare management central software shall include the ability to maintain and update a badlist of individuals for use issuing citations. The fare management central software shall not preclude the ability to maintain and update a badlist of fare media in case of future use of smart cards, which would result in the automatic rejection of badlisted media from use within the system. |
| 15.6.2. | The fare management central system shall automatically transfer updates to the badlist to relevant system components (MEDs) at least once daily. |
| **15.7.** | **Data Processing, Storage, and Reporting** |
| 15.7.1. | The fare management central software shall support the storage and archiving of sales and transaction data in a database. Data shall be maintained in a transactional format and shall not be aggregated, consolidated, or combined within the database. The information contained in the database shall be made available for retrieval, analysis, display, and printing. |
| 15.7.2. | The fare management central software shall allow data items in the database to be read-only with modification only permitted to individual pre-defined fields. |
| 15.7.3. | The fare management central software shall store 25 months of detailed (full transactional) data, and up to ten years (for comparison and trend analysis purposes) of summary data. |
| 15.7.4. | The fare management central software shall allow all such data to be retrieved after it has been archived. |
| 15.7.5. | The fare management central software shall include a means of archiving transaction data, or restoring data from an archive, while the system is in operation. It shall not be necessary to shut down the database to perform a successful backup or restore operation. |
| 15.7.6. | It shall be possible to use archived data to process comparative type reports, such as but not limited to reports utilizing and comparing data from non-consecutive month periods in two different years, or day-of-week comparisons over multiple month or annual periods. |
| 15.7.7. | Daily, monthly, quarterly and annual sales transaction reports shall be provided system wide, by station, and by individual TVM, and shall include at a minimum the following: sale summaries by ticket type (e.g. paper, smart card), fare type (e.g. |

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| | single trip, multi-day passes), concession fares (e.g. children, senior/disabled), payment type (e.g. cash, credit), and transaction and detail reports for all credit and check card transactions, including denials or reversals. |
| 15.7.8. | Daily, monthly, quarterly and annual validation transaction reports shall be provided systemwide, by station, and by individual TVM or ticket validator, including at a minimum the number of tickets validated by ticket type and the fare type by location validated (at TVMs and ticket validators). |
| 15.7.9. | Daily, monthly, quarterly and annual enforcement reports shall be provided system wide, by station, and by individual TVM, including at a minimum the date and location of all tickets checked, employee ID, percentage of invalid tickets by date and location, and types and amounts of citations by date and location. |
| 15.7.10. | The system shall provide maintenance and performance reports. |
| 15.7.11. | The system shall generate reconciliation reports (e.g. to compare ticket validations to ticket sales, to compare smart card values with revaluing transactions and purchases). |
| 15.7.12. | The system shall include functionality to generate reports for a user-specified date range. |
| 15.7.13. | Functionality shall be included to generate transaction detail reports listing all daily transaction data for a specific TVM, ticket validator, or MED upon request by the user. |
| **15.8.** | **Credit and Debit Card Processing Systems Integration** |
| 15.8.1. | The fare system central software shall send the necessary data to the credit and debit card processing systems to facilitate payment processing, and obtain confirmation of successful payment from these systems before issuing/revaluing fare media. |
| 15.8.2. | The fare system central software shall receive the necessary data to facilitate transaction reporting. |
| **15.9.** | **Ticket Vending Machine (TVM) Integration** |
| 15.9.1. | The fare management central software shall be able to issue a command to the TVM controller to send, and the central software shall receive, the current coin and bill counting register values and ticket/voucher/receipt stock levels. |
| 15.9.2. | The fare management central software shall be able to issue a command to the TVM controller to send, and the central software shall receive, stored database records accumulated since the previous such transmission to the fare management central software. |
| 15.9.3. | The fare management central software shall send confirmation once database records are successfully received and processed. |
| 15.9.4. | The fare management central software shall be able send reconfiguration data to the TVM controller, including: updated fare types, updated fare prices, updated touch screen display configuration data, updated ticket/receipt printer configuration data, and software updates/patches for the TVM controller or the firmware of internal components. |
| 15.9.5. | Upon activation of a TVM alarm, the fare management central software shall immediately receive a message from the TVM noting the date/time of alarm activation and the alarm type. |

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| 15.9.6. | The fare management central software shall be able to synchronize date and time stored in the TVM at a user configurable interval and whenever the fare management central software connects with TVM. |
| 15.9.7. | The fare management central software shall be able to automatically calculate calendar day duration for short period passes (e.g. weekly passes) based on whether intervening days are operating days, non-operating days, or special service days and communicate that information to TVMs. |
| 15.9.8. | The fare management central software shall be able to receive and recognize cached data from a time period when a TVM operated offline. |
| **15.10.** | **Ticket Validator Integration** |
| 15.10.1. | The fare management central software shall be able to issue a command to the ticket validator controller to send, and the central software shall receive, all validation records accumulated since the previous such transmission to the fare management central software. |
| 15.10.2. | The fare management central software shall be able to send reconfiguration data to the ticket validator controller that will be sent to internal components, including: updated fare types, updated fare prices, updated display configuration data if a display is incorporated, updated printer configuration data, and software updates/patches for the ticket validator controller or the firmware of internal components. |
| 15.10.3. | The fare management central software shall send confirmation once database records are successfully received and processed. |
| 15.10.4. | Upon activation of a ticket validator alarm, the fare management central software shall immediately receive a message from the ticket validator noting the date/time of alarm activation and the alarm type. |
| 15.10.5. | The fare management central software shall be able to synchronize date and time stored in the ticket validator at a user configurable interval and whenever the fare management central software connects with the ticket validator. |
| **15.11.** | **Mobile Enforcement Device (MED) Integration** |
| 15.11.1. | The integration with the fare management central software shall allow the automatic data transfer of the current badlist at least once daily. |
| 15.11.2. | The fare management central software shall be able to synchronize date and time stored in the MEDs at a user configurable interval and whenever the fare management central software connects with the MEDs. |
| **15.12.** | **Maintenance/Diagnostics** |
| 15.12.1. | If periodic system rebooting is required, the central system shall include functionality to schedule such reboots at the TVMs and/or at the central system. |
| 15.12.2. | The fare management central software shall monitor communications connectivity to the TVMs, credit card acquirer, and ticket validators, activating an alarm if connectivity is lost. |
| 15.12.3. | The fare management central software shall report all errors and alarms from TVMs and ticket validators, including at a minimum:<br>• Coin jam in TVMs;<br>• Bill jam in TVMs;<br>• Malfunctioning of ticket issuer or receipt printer in TVMs and ticket |

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| | validators;<br>• Ticket or receipt printer jam in TVMs and ticket validators;<br>• Low ticket or receipt supply in TVMs and ticket validators;<br>• Bill and coin vault capacity in TVMs;<br>• Ticket inventory in TVMs;<br>• Customer Display / Touch Screen malfunctioning in TVMs and ticket validators;<br>• Malfunctioning of PIN pad in TVMs;<br>• Defective read/write device in TVMs and ticket validators;<br>• Opening of TVM housing;<br>• Tampering alarms:<br>• Communications failure; and<br>• Power failure or malfunctioning of TVMs and ticket validators. |
| 15.12.4. | The fare management central software shall provide a GUI to display status of faults and failures with the TVMs and ticket validators. The GUI shall present this status data at the component level for ease of fault or failure detection, and shall indicate levels of criticality and urgency. |
| 15.12.5. | The fare management central software shall monitor the devices for which maintenance activities are being performed at the field. |
| **15.13.** | **Backup/Security** |
| 15.13.1. | The fare management central software shall monitor intrusion and fault alarms, and isolate such alarms to specific stations and individual TVM and ticket validators. |
| 15.13.2. | Central systems shall include data backup hardware and software, and shall include automated backup scripts. |

# 16. TICKET VENDING MACHINE (TVM) REQUIREMENTS

| **16.** | **Ticket Vending Machine Requirements** |
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| **16.1.** | **General** |
| 16.1.1. | Each TVM shall provide the means for passengers in busway stations to select and purchase current fare products (on magnetic stripe and paper tickets only), as well as dispense fare products, in a self-contained and integrated assembly of components. |
| 16.1.2. | The TVM shall have full functionality that will include processing of current fare medium (magnetic stripe and paper tickets). TVM fare media shall be limited to a single type of magnetic stripe ticket stock and paper stock for single and round trip tickets/vouchers/and receipts. The design of the TVM shall not preclude the future installation and functional integration of smart card read/write devices into the TVM and shall support future smart card functionality. |
| 16.1.3. | The TVM shall consist of:<br>• Customer interface, including a screen display (touch screen or with buttons)<br>• A coin handling mechanism (including acceptance, escrow, and vaults).<br>• A bill handling mechanism (including acceptance, escrow, and vaults).<br>• A debit/credit card reader and pin pad<br>• A magnetic stripe ticket read/write<br>• A magnetic stripe ticket printer/dispenser<br>• A ticket, voucher, and receipt printer/dispenser<br>• Driving electronics<br>• Environmental control and protection<br>• Associated cables and wiring<br><br>The design of the TVM shall not preclude the future addition of smart card reader/writer. |
| 16.1.4. | It is preferred that the TVM be NTCIP compliant. |
| **16.2.** | **Interfaces** |
| 16.2.1. | The TVM shall be networked to the fare management software through the busway communications system. |
| 16.2.2. | The TVM shall be connected to other TVMs through the busway communications system. |
| **16.3.** | **Fare Products** |
| 16.3.1. | The TVM shall be able to accept and print all current fare medium (magnetic stripe tickets and paper tickets) and shall not preclude the future acceptance, programming, and validation of smart card medium. |
| 16.3.2. | The TVM shall issue paper single and round trip tickets. |
| 16.3.3. | The TVM shall vend and issue multiple-ride tickets in at least six (6) quantities, up to and including 31, of tickets in one transaction. The TVM shall also vend single- and multi-day passes of variable lengths as magnetic stripe tickets. The lengths of these passes shall be configurable. |

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| 16.3.4. | The TVM shall vend and issue single day passes for the current day as magnetic stripe tickets. |
| 16.3.5. | The TVM shall vend and issue multiple-day passes for agency configurable periods as magnetic stripe tickets. Multiple-day passes shall be capable of being activated by any TVM or ticket validator located at busway stations. |
| 16.3.6. | The TVM shall have the ability to vend and issue zone passes for trips originating in and destined to any combination of at least six (6) zones for all required types of fares. |
| 16.3.7. | The TVM shall have the ability to vend and issue each fare product in at least three (3) versions, full fare and at least two (2) types of concession fare (e.g. children, youth, senior/disabled). |
| **16.4.** | **Customer Display** |
| 16.4.1. | The layout of all TVM displays and customer interfacing components shall be based on human factors engineering and provision should be made for wheelchair, sight impaired, and other disabled customers to the degree feasible and reasonable. |
| 16.4.2. | The height of all front facing components that need to be accessed by the customer to complete a transaction shall meet ADA requirements. |
| 16.4.3. | The TVM shall have an ergonomic exterior design and a validation sequence with customer-friendly information displays. The system is intended to interact with the customer without staff assistance. |
| 16.4.4. | The customer display shall be resistant to damage and vandalism ("Lexan" or approved equal) that shall have a useful screen area of a size that allows for easy legibility and is in compliance with ADA requirements. |
| 16.4.5. | The customer display shall utilize color LCD or other high-brightness and contrast technology. |
| 16.4.6. | The customer display shall be legible in conditions ranging from direct sunlight to dark night. |
| 16.4.7. | The customer display shall incorporate an anti-glare coating and sun hood to avoid direct sun glare. |
| 16.4.8. | The customer display shall be legible when viewed off-axis (horizontally or vertically), within at least a 60º cone of visibility centered on the perpendicular axis to the display face. |
| 16.4.9. | The TVM shall have a debit card encrypted pin pad that is shielded or recessed to help avoid over-the-shoulder viewing of customer PIN entry information. |
| **16.5.** | **Customer Interface** |
| 16.5.1. | The TVM customer interface shall not preclude the ability to integrate future smart card functionality into the TVM (in addition to or as well as the current fare medium. |

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| 16.5.2. | The customer interface shall have a hierarchical menu system, with a top-level "home" screen presenting the option to either add a value or pass to an existing magnetic stripe ticket or purchase a fare using cash or credit card. Either on the top-level or secondary screen the customer shall be able to select among the available fare products (e.g. single, round trip, multi-trip, single- and multi-day). Secondary screens shall allow the customer to select more specific variations on fare products requiring selection of a duration or effective date (e.g. 1-day versus 31-day passes) and shall allow them to choose applicable discount or concession rates (e.g. senior/disabled). |
| 16.5.3. | If the customer is adding value or a pass to an existing magnetic stripe ticket, the customer will be asked to insert the magnetic stripe ticket into the read/write device. |
| 16.5.4. | After the customer has selected a ticket type for purchase at regular or discount prices the TVM shall present to the customer the options to cancel a transaction, change selection, make the purchase, and purchase additional tickets. In each case on the same screen the total number of tickets of each type selected so far during the transaction shall be presented. It shall also be clear that no change can be provided except as a voucher. |
| 16.5.5. | After the customer has selected the payment method, the TVM shall continue to display the total price and shall present the customer with the option to choose between canceling the transaction, changing the selection, and continuing with a purchase. |
| 16.5.6. | After the customer has been provided instructions on how to use the TVM to pay using the selected payment method and the customer either (1) begins to insert cash or (2) swipes/dips a credit/debit card, the TVM shall continue to display the total price and shall also display information on the progress and completion status of the transaction. |
| 16.5.7. | If payment is by cash: the TVM screen shall indicate the current total amount tendered, incrementing this total as each additional bill or coin is accepted, with the option to cancel the transaction. The customer shall be able to indicate that he/she is ready to complete the purchase. If sufficient funds have been tendered, the screen shall indicate that the transaction is complete, indicate the amount of change being provided by a paper voucher, and provide instructions about how to retrieve the printed ticket(s) and retrieve and use the voucher. If the printer is unable to dispense all of the tickets, the TVM shall track the value of the tickets that were not able to be dispensed and automatically issue a voucher. |
| 16.5.8. | If payment is by credit card: the TVM screen shall indicate (after the customer has swiped/dipped the card) that the transaction is being processed, and then that the transaction is either authorized or not authorized. If the payment is by debit card, the TVM shall indicate when to enter the PIN using the PIN pad. If the transaction is authorized, the screen shall indicate that the transaction is complete, and provide instructions about how to retrieve the printed ticket(s). If the transaction is authorized but the printer is unable to dispense all of the tickets, the TVM shall track the value of the tickets that were not able to be dispensed and automatically complete a credit/debit card reversal transaction for this amount. |
| 16.5.9. | In each payment method, the customer shall be provided with an option as to whether they wish to receive a printed receipt, and the TVM shall issue a receipt if requested. |

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| 16.5.10. | If any form of payment is not authorized or cannot be processed, the user shall be informed and be provided the option of using another method of payment or canceling the transaction. |
| **16.6.** | **Coin Handling Mechanism** |
| 16.6.1. | The coin mechanism shall have de-jam capabilities. |
| 16.6.2. | The coin mechanism shall be designed in a way to prevent "stringing" or similar techniques that would allow the customer to extract a coin after it has been accepted. |
| 16.6.3. | The coin vault volume shall facilitate daily revenue servicing, allowing for a minimum a daily passenger volume of 2,500 total boardings per TVM located at a station and a missed day of revenue servicing (two [2] days of revenues). |
| 16.6.4. | There shall be spare coin vaults (at least two [2]) to allow for one vault to be with the TVM, another with the revenue servicing personnel, and a third with revenue counting personnel. All shall be electronically labeled for the TVM's recognition. |
| 16.6.5. | The coin mechanism shall be able to accept U.S. 5 cent, 10 cent, 25 cent, and $1 coins, with the ability to hold them in escrow and circulate them to the coin vault. |
| 16.6.6. | An escrow shall allow a minimum of 25 coins to be held and returned to the customer if the transaction is cancelled before completion. Once the transaction is complete, coins held in escrow shall be transferred into the coin vault. |
| 16.6.7. | If change is due on the amount paid, it shall be issued in the form of a voucher that shall be able to be read by the TVMs and applied towards future fares. |
| 16.6.8. | The coin mechanism shall reject and return Canadian and other foreign coinage. |
| 16.6.9. | Coin vaults shall already be locked, with the interior inaccessible, when removed from the TVM. |
| 16.6.10. | The validation software shall validate and correctly identify the following denominations of coins: 5 cent, 10 cent, 25 cent, $1. |
| 16.6.11. | Coins not accepted shall be immediately returned to the customer. |
| 16.6.12. | The validation software and parameters shall be updatable and configurable. |
| 16.6.13. | The validation software shall maintain registers that count the number of accepted and rejected coins for each denomination. |
| **16.7.** | **Bill Handling Mechanism** |
| 16.7.1. | The bill insertion slot shall be narrow enough to prevent the insertion of coins. The validator shall apply friction to an inserted bill and pull it gently into the slot. |
| 16.7.2. | The bill mechanism shall be designed to prevent the use of any “stringing” or similar technique that would allow the customer to extract the bill after it has been accepted. |
| 16.7.3. | The bill vault volume shall allow for daily revenue servicing, allowing for a minimum daily passenger volume of 2,500 total boardings per TVM located at a station and a missed day of revenue servicing (two [2] days of revenues). |
| 16.7.4. | There shall be spare sets of vaults (at least two [2]), allowing for one vault to be with the TVM, another with the revenue servicing personnel, and a third with revenue counting personnel. All 3 shall be electronically labeled for the TVM's recognition. |

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| 16.7.5. | An escrow shall allow up to 15 bills to be held and returned to the customer if the transaction is cancelled before completion. Once the transaction is complete, bills held in escrow shall be transferred into the bill vault by a stacker. |
| 16.7.6. | The bill mechanism shall reject and return foreign currency. |
| 16.7.7. | The bill vault shall already be locked, with the interior inaccessible, when it is removed from the TVM, and shall have security measures that allow it to be identifiable as a valid bill vault. |
| 16.7.8. | The TVM shall be inoperable with the bill vault removed. |
| 16.7.9. | The validation software, using both dimensional and optical characteristics, shall validate and correctly identify $1, $5, $10 and $20 denominations for bills inserted lengthwise with any of the four possible orientations. This shall include the ability to correctly validate wrinkled and damp bills. Bills of $50 and higher shall not be accepted, but provisions to update for accepting $50 shall be provided. |
| 16.7.10. | Bills not accepted shall be immediately returned to the customer. |
| 16.7.11. | The bill validator shall maintain registers that count the number of accepted bills for each denomination and the number of rejected bills. |
| 16.7.12. | The bill validation software shall be updateable, and validation parameters shall be configurable using the fare management central software. The updating capability shall include accepting $50 bills. |
| **16.8.** | **Credit/Debit Card Mechanism and Processing** |
| 16.8.1. | The TVM shall incorporate a reader for magnetic stripe plastic cards accepting the Visa and MasterCard branded credit cards, as well as any ATM card issued by any financial institution bearing the Visa or MasterCard logo. |
| 16.8.2. | The credit card and debit reader shall be able to process standard bank card dimensions and magnetic stripe dimensions/encoding as defined under ISO 7810 and ISO 7811. |
| 16.8.3. | The TVM shall incorporate a built-in debit card encrypted PIN pad certified by Visa and MasterCard. |
| 16.8.4. | The TVM shall include a diagram adjacent to the insertion slot that indicates the correct card insertion orientation for reading the magnetic stripe. |
| 16.8.5. | The credit/debit card mechanism shall include the capability for online authorization of credit and debit cards. |
| 16.8.6. | The TVM shall have configurable lower and upper limits for debit and credit card transactions. |
| **16.9.** | **Magnetic Stripe Read/Write/Print Device** |
| 16.9.1. | The TVM shall be equipped with a read/write device that shall add value to existing magnetic stripe tickets or shall produce a new magnetic stripe ticket with fare information printed on it. |
| 16.9.2. | The insertion slot shall be narrow enough to prevent the insertion of coins. The validator shall apply friction to an inserted magnetic stripe ticket and pull it gently into the slot. |
| 16.9.3. | The following information shall be printed on a new or updated ticket for easy visual inspection and so as to meet ADA requirements for legibility: |

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| | • Color and background graphics (visible and invisible) including anti-fraud features to indicate that it is an authentic ticket (e.g., fluorescent images on back of ticket)<br>• A special security code that provides supporting validation information<br>• Fare type<br>• Location of validation<br>• Date and time of expiry |
| **16.10.** | **Smart Card Read/Write Device** |
| 16.10.1. | The TVM shall not preclude being equipped with a contactless smart card read/write device and shall not preclude being able to add value to the smart card or deduct payment for a fare. |
| 16.10.2. | The design of the TVM shall not preclude the ability to have a stored badlist of smart cards, updated at least daily. |
| 16.10.3. | The design of the TVM shall not preclude the ability to initially check if a smart card presented to a smart card read/write device is badlisted or is dormant. If the card is badlisted or is dormant, the TVM shall not preclude the ability to display a message that the transaction cannot be completed. The TVM shall not preclude the ability to record this as an event. |
| 16.10.4. | The design of the TVM shall not preclude the ability to allow a user to add value to the smart card or purchase a pass through the user interface if a smart card is not badlisted or dormant. |
| 16.10.5. | The design of the TVM shall not preclude the ability to present the need the smart card to the TVM again on the user interface if the TVM cannot complete a transaction due to an inability to read the smart card. |
| 16.10.6. | The design of the TVM shall not preclude the ability to allow a future smart card read/write device to process payment in the following order:<br>• If there is a valid pass, it will be used for payment.<br>• If there is no pass, the reader will check for a valid stored ride.<br>• If there is no stored ride, the reader will use stored value. |
| 16.10.7. | The design of the TVM shall not preclude the ability to inform the user of the option of adding value if payment cannot be processed. |
| 16.10.8. | The design of the TVM shall not preclude the ability to have security features to verify that only valid smart cards are communicated with, and to mitigate the potential for interception of data. |
| 16.10.9. | The design of the TVM shall not preclude the ability to have anti-tear functionality so that, in the event a transaction is not fully completed, data on a smart card are not corrupted. |
| 16.10.10. | The design of the TVM shall not preclude the ability to have features to verify that a transaction with a smart card has successfully occurred before confirming a customer add-value charge. |
| **16.11.** | **Ticket and Receipt Printers** |
| 16.11.1. | The TVM shall include a printer capable of separately printing single ride or round trip tickets and receipts on an easily replaceable common stock. |
| 16.11.2. | Receipts separate from the ticket shall be provided to meet credit/debit card receipt requirements, and provide customers with a means of documenting |

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| | expenses. |
| 16.11.3. | The ticket printer shall be designed for use including at minimum a daily passenger volume of 2,500 total boardings per TVM located at a station). |
| 16.11.4. | The printer shall be able to print receipts that enable a customer to receive a voucher or a fare refund if payment cannot be returned, as well as print local TVM status/maintenance reports. |
| 16.11.5. | All print, with the possible exception of terms of use or security information, shall comply with all ADA requirements for size and legibility. The intent is also that key fare information will be easily visible to fare inspectors. |
| 16.11.6. | Tickets shall have, at a minimum, the information printed on the magnetic stripe tickets (see 16.9.3) to support easy visual inspection and security and anti-fraud measures. |
| **16.12.** | **Controller and Network Integration** |
| 16.12.1. | The TVM shall incorporate a microprocessor-based controller, using internal communications connections to send and receive data with each of the internal components and manage the overall integrated TVM operation. |
| 16.12.2. | A hard drive in the TVM shall store the TVM operating system, TVM software and a local database. This database shall include records for the following events: date/time and alarm type for each alarm activation; date/time, ticket type(s)/quantity purchased, purchase amount, payment method and receipt number for each completed ticket purchase transaction; and times when the TVM entered or left maintenance mode or revenue servicing mode, and all actions undertaken while in that mode. |
| 16.12.3. | Memory shall use non-volatile storage so that a power supply is not required to retain the stored TVM data records. |
| 16.12.4. | The TVM shall incorporate a real-time clock capable of maintaining the current date and time for up to 14 days without external power supply. |
| 16.12.5. | All communications parameters and settings shall be user configurable through a local maintenance port. |
| 16.12.6. | Every TVM using the busway communications network shall be assigned an IP address. |
| **16.13.** | **Fare Management Central Software Integration** |
| 16.13.1. | Automatic reset/reboot and firmware upload shall be supported. |
| 16.13.2. | The integration with the fare management central software shall not preclude the automatic data transfer of the current badlist at least once daily. |
| 16.13.3. | In response to a command received from the fare management central software, the TVM controller shall send the stored database records accumulated since the previous such transmission to the fare management central software. The TVM controller shall not allow database records to be overwritten until receiving confirmation from the fare management central software that the database records were successfully received and processed. |
| 16.13.4. | In response to a command received from the fare management central software, the TVM controller shall send the current coin and bill counting register values and ticket/receipt stock levels. |

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| 16.13.5. | In response to a command received from the fare management central software, the TVM controller shall receive reconfiguration data from the fare management central software that will be sent to internal components, including: updated fare types, updated fare prices, updated touch screen display configuration data, updated ticket/receipt printer configuration data, and software updates/patches for the TVM controller or the firmware of internal components. |
| 16.13.6. | After applying the reconfiguration data, the TVM controller shall send a reconfiguration completion status message to the fare management central software. |
| 16.13.7. | Upon activation of a TVM alarm, the TVM shall immediately send a message to the fare management central software noting the date/time of alarm activation and the alarm type. |
| 16.13.8. | Each transmission to the fare management central software from the TVM controller shall include the date/time of transmission and the TVM identification information. |
| 16.13.9. | The TVM controller shall be capable of receiving updated date/time data from the fare management central software and using this data to update the real-time clock. |
| **16.14.** | **Failure Modes** |
| 16.14.1. | The TVMs shall be capable of operating on-line or off-line, and shall be able to “gracefully degrade” (operate with limited functionality) in the event a component fails or communications are lost. |
| 16.14.2. | If the TVM is operating offline, it shall cache all data for later upload to the fare management central software once communications are restored. |
| 16.14.3. | If either the credit card reader or the communications for on-line credit card transaction authorization, or both, are not operational, but the bill validator, coin acceptor and printer are operational, the TVM shall enter a degraded mode of operation and the initial screen display shall indicate “cash only”. |
| 16.14.4. | If the bill validator is not operational, but the coin acceptor, printer, credit card reader, and communications for on-line credit card transaction authorization are operational, the TVM shall enter a degraded mode of operation and the initial screen display shall indicate “coin and credit cards only”. |
| 16.14.5. | If the coin acceptor is not operational, but the bill validator, printer, credit card reader, and communications for on-line credit card transaction authorization are operational, the TVM shall enter a degraded mode of operation and the initial screen display shall indicate “bills and credit cards only”. |
| 16.14.6. | If both the bill validator and the coin acceptor are not operational, but the printer, credit card reader and communications for on-line credit card transaction authorization are operational, the TVM shall enter a degraded mode of operation and the initial screen display shall indicate “credit cards only”. |
| 16.14.7. | If the voucher/receipt stock is not available, the TVM shall enter a degraded mode of operation and the initial touch screen display shall indicate “correct change only” and “receipts not available” in addition to any other relevant degraded mode indication messages. |
| 16.14.8. | If the TVM is not able to produce fare media (such as if stocks have been depleted) or print information on fare media (such as the printer not being operational), the initial touch screen display shall indicate that it is out of service |

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| | and other TVMs should be used in addition to any other relevant indication messages. |
| 16.14.9. | If the TVM is temporarily out of service, due to maintenance or repair, the initial touch screen display shall indicate that it is out of service and other TVMs should be used in addition to any other relevant indication messages. |
| **16.15.** | **Enclosure** |
| 16.15.1. | The TVM exterior shall be designed to conform to the colors and graphics of New Britain-Hartford Busway stations. |
| 16.15.2. | All components requiring customer access shall be incorporated into the front face of the TVM enclosure, securely attached to the enclosure in such a manner that they cannot be removed from the exterior with hammer, screwdriver or pry-bar. |
| 16.15.3. | Components that are exposed to ambient conditions through the TVM front face shall be able to operate within the range of environmental conditions. All necessary heating elements shall be provided to prevent the buildup of ice on the face of the TVM that may hinder customer access. |
| 16.15.4. | Connection to power shall be inside the housing. A knock-out shall be provided in the housing to allow for the entrance of the power conductors, or power shall be brought into the base from below through embedded conduit. Any enclosure entrance shall provide a seal around the power conductors. |
| **16.16.** | **Installation/Placement** |
| 16.16.1. | The display element assemblies shall be secured to sustain the shock and vibration that prevail in locations adjacent to railroads and high-speed highways. |
| 16.16.2. | The TVM shall not exceed the footprint as defined in station design plans. |
| 16.16.3. | The TVM shall be placed in a location so that it does not conflict with ADA accessibility guidelines in normal operation. To the extent practical, the placement should not cause a conflict even when the doors are open for revenue servicing or maintenance. |
| 16.16.4. | All power supply and communications wiring, conduit and connections shall be installed in accordance with all applicable electrical and building codes. |
| 16.16.5. | The TVM placement shall include all necessary replacement of pavement to be consistent with the station design. |
| 16.16.6. | The TVM shall be installed with a built-in shelter to protect the TVM and TVM customers from rain, ice, sleet, and snow. The shelter shall be structurally rated to handle environmental conditions at the stations. Precipitation runoff shall be directed away from the customers and in accordance with station design. |
| **16.17.** | **Security/Maintenance** |
| 16.17.1. | The enclosure shall incorporate a side-hinged door into the front face that opens to allow unimpeded maintenance access to the interior of the TVM for diagnosis/replacement of all internal components and revenue servicing by removing coin/bill vaults as well as replenishing ticket stock and receipt paper. |
| 16.17.2. | All internal components shall be removable and replaceable by a single technician with basic hand tools. |
| 16.17.3. | The TVM shall contain an internal power switch to keep maintenance personnel safe during maintenance. |

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| 16.17.4. | Removal of a module will not be required to access the internal components of the TVM. |
| 16.17.5. | TVM shall be designed with service features that minimize potential bodily harm. |
| 16.17.6. | All locks for entering the TVM front door shall use the same key. Locks for opening bill/coin vaults shall use the same key, which shall be a different key from that used to open the TVM front door. |
| 16.17.7. | Locks and keys shall be pick-resistant, including being of the multi-tumbler type. |
| 16.17.8. | Keyways shall only allow keys to be inserted or removed at specific rotational positions. |
| 16.17.9. | Keys shall incorporate angled faces, so that a facsimile made from an impression or with a key duplication machine shall not produce a useable key. |
| 16.17.10. | Keys shall be registered, with new or duplicate keys only available from the manufacturer to authorized personnel. |
| 16.17.11. | The TVM shall be equipped with alarm circuits to transmit the following alarm conditions to the fare management central software, noting the date/time of alarm activation and the alarm type. Alarms shall include:<br>• Coin jam;<br>• Bill jam;<br>• Malfunctioning of ticket issuer or receipt printer;<br>• Ticket or receipt printer jam;<br>• Low ticket or receipt supply;<br>• Bill vault capacity;<br>• Coin vault capacity;<br>• Ticket inventory;<br>• Customer Display / Touch Screen malfunction;<br>• Malfunctioning of PIN pad;<br>• Defective card reader;<br>• Power failure;<br>• Communications failure;<br>• Door is open without having been unlocked first;<br>• Coin or bill vault is out without door having been unlocked first;<br>• TVM is not on the base mounting; and<br>• Invalid bill vault or coin vault inserted. |
| 16.17.12. | The “percentage full” parameters for triggering alarm conditions shall be configurable through the fare management central software. |
| 16.17.13. | Alarm conditions shall be terminated by detecting that the alarm condition no longer exists. |
| 16.17.14. | After the onset of an alarm condition and the subsequent termination of that alarm condition, the onset of that alarm condition shall be ready to be re-triggered without need for manual reset. |
| 16.17.15. | Once an alarm condition has been activated, the TVM shall illuminate an exterior light to provide a visual indication to station staff. The TVM shall turn off this exterior indicator light once the alarm condition has been terminated. |
| 16.17.16. | The design of the TVM shall not preclude the ability to have security features to verify that only valid smart cards are communicated with, and to mitigate the potential for interception of data. |

# 17. TICKET VALIDATOR REQUIREMENTS

| **17.** | **Ticket Validator Requirements** |
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| **17.1.** | **General** |
| 17.1.1. | Each ticket validator shall provide the means for passengers in busway stations to validate existing fare products in a self-contained and integrated assembly of components. |
| 17.1.2. | The ticket validator shall have full functionality that will include processing of current fare medium (magnetic stripe). The design of the ticket validator shall not preclude the future use of smart card medium. |
| 17.1.3. | The ticket validator shall consist of:<br>• a customer interface consisting of instructions, either by text/diagram or screen<br>• a magnetic stripe ticket read/write device<br>• a magnetic stripe ticket printer/dispenser<br>• driving electronics<br>• environmental control and protection<br>• associated cables and wiring<br><br>The design of the ticket validator shall not preclude the future installation and integration of a smart card reader/writer. |
| 17.1.4. | It is preferred that the ticket validator be NTCIP compliant. |
| **17.2.** | **Interfaces** |
| 17.2.1. | Each ticket validator shall interface with the fare management central software through the busway communications network. |
| **17.3.** | **Customer Display** |
| 17.3.1. | The layout of all ticket validator displays shall be based on human factors engineering and provision should be made for wheelchair, sight impaired, and other disabled customers to the degree feasible and reasonable. |
| 17.3.2. | The height of all front facing components that need to be accessed by the customer for validation shall meet ADA requirements. |
| 17.3.3. | The ticket validator shall have an ergonomic exterior design and a validation sequence with customer-friendly information displays. The system is intended to interact with the customer without staff assistance. |
| 17.3.4. | The customer display shall include graphics and text to communicate instructions, complying with all ADA access requirements for size and legibility. |
| 17.3.5. | Information displayed to the customer shall be legible in conditions ranging from direct sunlight to dark night, shall be legible when viewed off-axis (horizontally or vertically), shall be of a size that allows for easy legibility and is in compliance with ADA requirements. |

| **17.4.** | **Validation** |
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| 17.4.1. | Each ticket validator shall be able to perform the following validation functions:<br>• Validate a ride on a pre-purchased multi-ride magnetic stripe ticket.<br>• Initiate magnetic stripe multi-day passes.<br><br>The design of the ticket validator shall not preclude the ability to perform the following smart card validation functions:<br>• Deduct a trip or value of a trip from a smart card.<br>• Initiate a multi-day pass on a smart card. |
| 17.4.2. | The ticket validator shall be capable of printing the following information on one side of a magnetic stripe ticket for easy visual inspection and meeting ADA requirements for legibility:<br>• Color and background graphics (visible and invisible) including anti-fraud features to indicate that it is an authentic ticket (e.g., fluorescent images on back of ticket)<br>• A special security code that provides supporting validation information<br>• Fare type<br>• Location of validation<br>• Date and time of expiry |
| 17.4.3. | Information printed by the ticket validator on the tickets shall comply with all ADA requirements for size and legibility. |
| 17.4.4. | The ticket validator shall be able to be equipped with a contactless smart card read/write device in the future and shall not preclude the ability to update stored information on a smart card, including deducting appropriate fares or trips or activate multi-day passes. |
| 17.4.5. | The ticket validator shall not preclude the ability to initially check if a smart card is badlisted or is dormant when it is presented to a smart card reader. If the card is badlisted or is dormant, the ticket validator shall not preclude the ability to display a message that the validation cannot be completed. The ticket validator shall not preclude the ability to record this as an event. |
| 17.4.6. | The ticket validator shall not preclude the inclusion of a smart card reader that shall validate in the following order:<br>• If there is a valid pass, use it for validation. Un-activated multi-day passes shall be activated.<br>• If there is no pass, check for a valid stored ride.<br>• If there is no stored ride, use stored value. |
| 17.4.7. | The ticket validator shall not preclude the ability to have anti-tear functionality so that, in the event a transaction is not fully completed, data on a smart card is not corrupted. |
| 17.4.8. | The ticket validator shall not preclude the ability to verify that a transaction with a smart card has successfully occurred before completing and confirming validation. |
| **17.5.** | **Controller and Network Integration** |
| 17.5.1. | The ticket validator shall incorporate a microprocessor-based controller, using internal communications connections to send and receive data with each of the internal components and manage the overall integrated ticket validator operation. |
| 17.5.2. | A hard drive shall store the ticket validator operating system, ticket validator software and a local database. This database shall include records for the |

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| | following events: date/time and alarm type for each alarm activation; date/time, ticket type(s)/quantity validated; and times when the ticket validator entered or left maintenance mode or revenue servicing mode, and all actions undertaken while in that mode. |
| 17.5.3. | Memory shall use non-volatile storage so that a power supply is not required to retain the stored ticket validator data records. |
| 17.5.4. | Each transmission to the fare management central software from the ticket validator controller shall include the date/time of transmission and the ticket validator identification information. |
| 17.5.5. | The ticket validator shall incorporate a real-time clock capable of maintaining the current date/time for up to 14 days without external power supply. |
| 17.5.6. | All communications parameters and settings shall be user configurable through a local maintenance port. |
| 17.5.7. | Every ticket validator using the busway communications network shall be assigned an IP address. |
| **17.6.** | **Fare Management Central Software Interface** |
| 17.6.1. | Automatic reset/reboot and firmware upload shall be supported. |
| 17.6.2. | The integration with the fare management central software shall not preclude the automatic data transfer of the current badlist at least once daily. |
| 17.6.3. | In response to a command received from the fare management central software, the ticket validator controller shall send the stored database records accumulated since the previous such transmission to the fare management central software. The ticket validator controller shall not allow database records to be overwritten until receiving confirmation from the fare management central software that the database records were successfully received and processed. |
| 17.6.4. | In response to a command received from the fare management central software, the ticket validator controller shall receive reconfiguration data from the fare management central software that will be sent to internal components, including: updated fare types, updated fare prices, updated display configuration data if a display is incorporated, updated printer configuration data, and software updates/patches for the ticket validator controller or the firmware of internal components. |
| 17.6.5. | After applying the reconfiguration data, the ticket validator controller shall send a reconfiguration completion status message to the fare management central software. |
| 17.6.6. | Upon activation of a ticket validator alarm, the ticket validator shall immediately send a message to the fare management central software noting the date/time of alarm activation and the alarm type. |
| 17.6.7. | The ticket validator controller shall be capable of receiving updated date/time data from the fare management central software and using this data to update the real-time clock. |
| **17.7.** | **Failure Modes** |
| 17.7.1. | The ticket validators shall only operate when the unit is “online”. |
| 17.7.2. | The ticket validator shall be able to display that it is inoperable when in failure mode that prevents validation from occurring. |

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| 17.7.3. | The ticket validator shall be equipped with alarm circuits to transmit the following alarm conditions to the fare management central software, noting the date/time of alarm activation and the alarm type. Alarms shall include:<br>• Malfunctioning of ticket issuer or receipt printer;<br>• Ticket or receipt printer jam;<br>• Low ticket or receipt supply;<br>• Customer Display / Touch Screen malfunction;<br>• Defective card reader;<br>• Power failure;<br>• Communications failure;<br>• Ticket validator is not on the base mounting; and<br>• Unauthorized access |
| **17.8.** | **Enclosure** |
| 17.8.1. | The ticket validator exterior shall be designed to conform to the colors and graphics of New Britain-Hartford Busway stations. |
| 17.8.2. | All components requiring customer access shall be incorporated into the front face of the ticket validator enclosure, securely attached to the enclosure in such a manner that they cannot be removed from the exterior with hammer, screwdriver or pry-bar. |
| 17.8.3. | Components that are exposed to ambient conditions through the ticket validator front face shall be able to operate within the range of environmental conditions. |
| 17.8.4. | Connection to power shall be inside the housing. A knock-out shall be provided in the housing to allow for the entrance of the power conductors, or power shall be brought into the base from below through embedded conduit. Any enclosure entrance shall provide a seal around the power conductors. |
| **17.9.** | **Installation/Placement** |
| 17.9.1. | The display element assemblies shall be secured to sustain the shock and vibration that prevail in locations adjacent to railroads and high-speed highways. |
| 17.9.2. | The ticket validator shall be field-hardened to withstand the outdoor environmental conditions at the stations. Any necessary heating elements shall be included to prevent the buildup of ice on the face of the ticket validator. |
| 17.9.3. | The ticket validator shall not exceed the footprint as defined in station design plans. |
| 17.9.4. | The ticket validator shall be placed in a location on the platform so that it does not conflict with ADA accessibility guidelines. |
| 17.9.5. | All power supply and communications wiring, conduit and connections shall be installed in accordance with all applicable electrical and building codes. |
| **17.10.** | **Security/Maintenance** |
| 17.10.1. | The ticket validator housing shall provide safe and convenient front service access for all modular assemblies, components, wiring, and other materials located within the housing. |
| 17.10.2. | All internal components shall be removable and replaceable by a single technician with basic hand tools. |
| 17.10.3. | The ticket validator shall contain an internal power switch to keep maintenance personnel safe during maintenance. |

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| 17.10.4. | Service access shall be easily obtained by unlocking and lowering a removable hinged front face panel. |
| 17.10.5. | Removal of a module will not be required to access the internal components of the display. |
| 17.10.6. | The ticket validator shall be designed with service features that minimize potential bodily harm. |
| 17.10.7. | The ticket validator shall have security features to verify that only valid smart cards are communicated with, and to mitigate the potential for interception of data. |

# 18. MOBILE ENFORCEMENT DEVICE (MED) REQUIREMENTS

| **18.** | **Mobile Enforcement Device (MED) Requirements** |
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| **18.1.** | **General** |
| 18.1.1. | The MED shall be a portable device that allowing for the entry of citation information and printing of citations. |
| 18.1.2. | The MED shall either incorporate or be networked to a similarly portable printer, with the same maximum weight. |
| 18.1.3. | The MED shall have the following components:<br>• A digital clock<br>• A removable, rechargeable battery with a life of at least 10 hours of normal use<br>• A printer (integrated or separate but networked)<br>• Software components that allow it to store and transmit data |
| 18.1.4. | Cradles shall be provided for charging and data transfer. |
| 18.1.5. | It is preferred that the MED be NTCIP compliant. |
| **18.2.** | **Interfaces** |
| 18.2.1. | The MED shall interface with the fare management central software through an Ethernet connection when inserted in its cradle. |
| **18.3.** | **Enforcement Staff Display** |
| 18.3.1. | The layout of the screen, keypads, readers, and printer shall be based on human factors engineering and provision should be made for sight impaired and other disabled enforcement to the degree feasible and reasonable. |
| 18.3.2. | The MED shall have an ergonomic exterior design and user friendly display and interface. |
| 18.3.3. | The display shall be resistant to damage and vandalism ("Lexan" or approved equal) that shall have a useful screen area of a size that allows for easy legibility and is in compliance with ADA requirements. |
| 18.3.4. | The display shall utilize color LCD or other high-brightness and contrast technology. |
| 18.3.5. | The display shall be legible in conditions ranging from direct sunlight to dark night. |
| 18.3.6. | The display screen or associated buttons shall have suitably sized and spaced buttons so they can be used by enforcement staff with gloves. |
| **18.4.** | **Enforcement Staff Interface** |
| 18.4.1. | The MED interface shall allow an enforcement staff to enter his/her operator ID. |
| 18.4.2. | When identification information is entered into the MED, the MED shall initially check this information against a badlist (list of individuals with prior fare violations). If the information does match with the badlist, the handheld validator shall display a “badlisted” message. |
| 18.4.3. | The MED shall allow for the entry of the following information at a minimum to create a citation, and assign a date and time stamp associated with the creation of |

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| | the citation:<br>• Identification information of the violator<br>• Type of citation<br>• Amount of citation |
| **18.5.** | **Digital Clock** |
| 18.5.1. | The MED shall incorporate a digital, real-time clock that shall be capable of maintaining the current date/time for a period of time without external power supply. |
| **18.6.** | **Printer** |
| 18.6.1. | The MED shall include a printer capable of separately printing citations. |
| 18.6.2. | The printer shall contain adequate paper stock for printing at least 50 citations per day. |
| 18.6.3. | The ticket stock for the printer shall be field replaceable without tools, with field replacement time (from end of operation with previous paper stock to beginning of operation with new paper stock) not to exceed one minute. |
| 18.6.4. | All print, with the possible exception of terms of use or security information shall comply with all ADA requirements for size and legibility. |
| 18.6.5. | Citations shall have, at a minimum, the following information printed on them: Color and background graphics (visible and invisible) including anti-fraud features to indicate that it is an authentic citation, type of citation, amount of fine, and instructions on paying fine. |
| **18.7.** | **Battery** |
| 18.7.1. | The MED shall be powered by an internal battery. |
| 18.7.2. | The battery shall be field replaceable without tools for any loss of data, with field replacement time (from end of operation with previous battery to beginning of operation with new battery) not to exceed one minute. |
| 18.7.3. | The battery shall hold sufficient power such that a full charge will power the MED for 10 hours of continuous operation, This requirement must be met during the first 1000 charge cycles of each battery. |
| 18.7.4. | The MED shall have a port to connect the MED to an AC power source through the cradle. When connected, the MED shall run fully off of AC power, and the battery (if attached) shall be charged. |
| **18.8.** | **Data Storage** |
| 18.8.1. | The date and time shall be stored in the memory so that it is not lost if a battery life expires. |
| 18.8.2. | The MED shall store data on all citations entered and printed. |
| 18.8.3. | All data storage shall be done such that data is not lost or corrupted if battery power is lost. |
| 18.8.4. | Data storage shall be sufficient to store one week’s worth of data. |
| 18.8.5. | The MED shall maintain a badlist periodically updated by the fare payment central system. |

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| 18.8.6. | The MED shall have on-board storage sized appropriately to store a badlist of 100,000 items. |
| **18.9.** | **MED Cradle** |
| 18.9.1. | The contractor shall provide and install a cradle for charging and data transfer from central system at the end of shift. |
| 18.9.2. | The cradle shall recharge a discharged battery to a full charge in less than four hours, and complete data transfer in less than 5 minutes. |
| **18.10.** | **Fare Management Central Software Integration** |
| 18.10.1. | Automatic reset/reboot and firmware upload shall be supported. |
| 18.10.2. | The date and time shall be synchronized with the fare management central software at a user defined interval and whenever the MED connects with the fare management central software. |
| 18.10.3. | The MED shall not allow database records to be overwritten until receiving confirmation from the fare management central software that the database records were successfully received and processed. |
| 18.10.4. | Data transfer shall include downloading the current badlist to the MED. |
| **18.11.** | **Enclosure** |
| 18.11.1. | The MED, including the physical buttons, shall be protected to prevent liquid or dirt from entering. |
| 18.11.2. | The MED shall be of rugged ergonomic design, to be carried and used in one hand. |
| 18.11.3. | The MED shall weigh no more than two (2) lbs and easily be carried in hand. |
| **18.12.** | **Security/Maintenance** |
| 18.12.1. | All data shall be stored in an encrypted format while on the MED. |

# 19. CCTV CAMERA FIELD EQUIPMENT REQUIREMENTS

| **19.** | **Closed Circuit Television (CCTV) Camera Field Equipment** |
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| **19.1.** | **General** |
| 19.1.1. | Busway cameras shall provide operations control center staff with a view of the strategic locations of operational importance, suitable for dispatching and monitoring purposes and to inform drivers of unsafe conditions at points of limited visibility. |
| 19.1.2. | Station area cameras shall provide coverage of stations to fulfill a security surveillance function by providing deterrence and forensic evidence. |
| 19.1.3. | The CCTV camera field equipment shall consist of:<br>• Camera dome assembly<br>• Power supply<br>• All necessary cabling and connections |
| 19.1.4. | Every CCTV camera using the busway communications network shall be assigned an IP address. |
| 19.1.5. | It is preferred that CCTV cameras be NTCIP compliant. |
| **19.2.** | **Interfaces** |
| 19.2.1. | The CCTV camera field equipment shall be interfaced with the DVR system located at the BOC using the busway communications system. |
| 19.2.2. | The CCTV busway cameras not located within suitable copper cabling distance of a busway station or intersection communications hub shall be connected to the busway communications system through Ethernet switches in cabinets at the base of poles or other structures to which cameras are mounted. |
| **19.3.** | **Camera Dome Assembly** |
| 19.3.1. | The cameras shall be digital Internet Protocol (IP) cameras which transmit MPEG-4 video over Ethernet Cat6 cables. |
| 19.3.2. | The camera dome assembly shall support high-speed pan/tilt/zoom (PTZ) functionality. |
| 19.3.3. | The pan/tilt mechanism shall provide 360° of continuous rotation. |
| 19.3.4. | The tilt mechanism shall provide for 110° of travel. |
| 19.3.5. | Precise manual panning and tilting shall be achievable through a combination of variable-speed operator control (speed ranges) and automatic adjustment of these speed ranges dependent upon zoom factor. Pan and tilt speeds shall be automatically adjusted by the zoom factor to allow the user the same ease of control, regardless of the field of view. |
| 19.3.6. | PTZ motors shall maintain high torque through the entire operating range. |
| 19.3.7. | Cameras shall provide 35X optical zoom and 12X digital zoom for 420X total zoom. |
| 19.3.8. | Cameras shall provide clear visibility in widely varying degrees of light including bright daylight conditions and unlit nighttime conditions. |

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| 19.3.9. | Cameras shall provide Wide Dynamic Range (WDR) for viewing of detailed images when observing scenes with widely varying degrees of light. |
| 19.3.10. | Cameras shall provide autoflip functionality. |
| 19.3.11. | Cameras shall provide autoiris functionality. |
| 19.3.12. | Cameras shall provide autobloom functionality. |
| 19.3.13. | Cameras shall support up to six (6) preset positions, and panorama positioning functionality. |
| 19.3.14. | Cameras shall be capable of creating privacy zones / privacy screens. |
| 19.3.15. | Cameras shall provide Digital Slow Shutter (DSS) allowing more light accumulation within the CCD imager. |
| 19.3.16. | Cameras shall provide Electronic Image Stabilization (EIS) to compensate for physical movement and vibration of the dome with a user-selectable bandwidth of 5 or 10Hz. |
| 19.3.17. | The dome shall incorporate a twist-lock release base for ease of installation and service. |
| 19.3.18. | The camera shall be capable of automatically reestablishing video and data communications upon the restoration of communications or power to the cameras. |
| 19.3.19. | Upon initial power up and after dome resets, diagnostic tests shall be run, including communication loopback, camera loopback, and motor circuit tests. After initialization, the dome shall automatically pan, tilt, and zoom to its previous position. |
| 19.3.20. | The outdoor dome housing shall protect against water and dust intrusion. |
| 19.3.21. | The outdoor dome housing shall contain a sunshade, thermostat, heater and fan to control temperatures inside the dome. |
| 19.3.22. | The outdoor dome housing shall prevent ice accumulation and the heater shall be capable of melting any ice that does accumulate. |
| 19.3.23. | The outdoor dome housing shall prevent the intrusion of moisture or glare and allow a high-quality clear view from the camera lens. |
| **19.4.** | **DVR System Integration** |
| 19.4.1. | The CCTV cameras shall send digitized video stream to the DVR system. |
| **19.5.** | **Installation/Placement** |
| 19.5.1. | Busway cameras shall be mounted on new camera poles or on existing traffic signal mast arms (the provision of each of which is outside the scope of this contract), as per busway design plans. When mounted on a pole of greater height than 30 feet, the camera shall be able to be lowered by means of a Camera Lowering System (CLS), also to be provided by others. |
| 19.5.2. | Busway cameras shall provide clear views of key points in the busway corridor for operational and safety purposes. |
| 19.5.3. | Station area cameras shall provide coverage of key station areas including clear views of TVMs, platforms, plazas immediately outside the fare area and pedestrian approaches as per station design plans. |

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| 19.5.4. | Station area cameras shall be mounted on existing structures. Structures and conduit to be provided outside the scope of this contract. |
| 19.5.5. | All cameras shall be mounted in vandal proof locations out of normal human reach and on surfaces or structures that are not easily scalable. |
| 19.5.6. | All cameras shall be accompanied by signage indicating the presence of cameras and warning passerby that they are being recorded. |

# 20. DVR SYSTEM REQUIREMENTS

| **20.** | **DVR System Requirements** |
|---|---|
| **20.1.** | **General** |
| 20.1.1. | A Digital Video Recorder (DVR) shall be installed in the BOC which receives and stores video feeds from all cameras via the busway communications system, and provides user access to these video feeds through the CCTV camera central software. |
| **20.2.** | **Interfaces** |
| 20.2.1. | The DVR shall receive video feeds from the CCTV camera field equipment through the busway communications system. |
| 20.2.2. | The DVR shall function as a central server from which individual dispatcher workstations can access video through camera management software. |
| **20.3.** | **Digital Video Recorder (DVR)** |
| 20.3.1. | The DVR shall record in MPEG-4 format. |
| 20.3.2. | The DVR shall provide a recorder capable of storage and playback of images from a minimum of 200 camera inputs at a simultaneous recording rate of up to 480 images per second. |
| 20.3.3. | The DVR shall be able to record at resolutions up to 4CIF (704 x 480, NTSC), with the ability to record up to 480 images per second at CIF resolution (352 x 240 NTSC). Individual adjustments to both resolution and ips (images per second) shall be possible per input to meet a given installation requirement for video retention. |
| 20.3.4. | The DVR shall use MPEG-4 compression, allowing the user the ability to view and control the DVR across a local or wide area network. |
| 20.3.5. | The DVR shall have the ability to store 30 days of video at 4CIF resolution and 7.5 ips with automatic rewrite of the oldest video as its storage term expires. |
| 20.3.6. | The DVR shall allow the export of video via USB port, DVD±RW optical drive, or other approved means. |
| 20.3.7. | When video is exported from the DVR, encryption protocols shall be used to prevent tampering and allow enforcement personnel to establish chain of custody. |
| 20.3.8. | The DVR shall support external backup and archiving of video data. |
| 20.3.9. | The DVR shall support automatic programming for daylight saving time updates whenever needed. |
| 20.3.10. | The DVR shall support event notifications by e-mail. |
| **20.4.** | **CCTV Camera Field Equipment Integration** |
| 20.4.1. | The DVR shall receive video feeds from all busway and station area cameras. |
| **20.5.** | **Camera Management Software Integration** |
| 20.5.1. | The DVR shall provide user access to video through the camera management software installed on dispatcher workstations. |

| **20.6.** | **Enclosure** |
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| 20.6.1. | The DVR system shall be enclosed in a brushed steel or aluminum casing suitable for indoor operation. |

# 21. CCTV CAMERA MANAGEMENT SOFTWARE REQUIREMENTS

| 21. | CCTV Camera Management Software Requirements |
|---|---|
| **21.1.** | **General** |
| 21.1.1. | Camera management software shall be installed on each dispatcher workstation in the BOC which provides access to all video stored on the DVR. |
| **21.2.** | **Interfaces** |
| 21.2.1. | The camera management software will interface with the DVR System. |
| **21.3.** | **Logon/Logoff** |
| 21.3.1. | The camera management software shall support a logon, logoff feature that is password protected and shall allow a user to logon to a specific user access level. Users logged on or logged off to the CAD/AVL central software shall be automatically logged on or logged off respectively to the camera management software. |
| 21.3.2. | The camera management software shall allow users to log on to the system with varying privileges depending on their access level. Access levels may include, but are not limited to:<br>▪ BOC System Administrator<br>▪ BOC Dispatcher<br>▪ BOC Read-only dispatcher<br>▪ Busway Supervisor |
| 21.3.3. | The camera management software shall allow users logged in as system administrators to assign specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| 21.3.4. | The camera management software shall support multiple concurrent users. |
| **21.4.** | **Graphical User Interface (GUI)** |
| 21.4.1. | The camera management software shall support the following camera views at a minimum:<br>• Single camera full window view<br>• Four-camera tiled view<br>• Sixteen-camera tiled view |
| 21.4.2. | The camera management software shall display configurable labels, including camera name, unique ID and location information, under each video view. |
| 21.4.3. | The camera management software shall support a navigation bar (navbar) with names of each camera. |
| 21.4.4. | The camera management software shall allow designated users to give descriptive names to cameras. |
| 21.4.5. | The camera management software shall allow users to obtain a full window view by double clicking on a camera name. |
| 21.4.6. | The camera management software shall allow users to drag and drop a camera from the navbar onto an existing camera view to replace that view with the new camera. |
| 21.4.7. | The camera management software shall allow users to control the pan/tilt/zoom |

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| | functions of one camera at a time by clicking on that camera's video feed to obtain control and then clicking on on-screen buttons for zoom in, zoom out, pan left, pan right, tilt clockwise, tilt counterclockwise. |
| 21.4.8. | The camera management software shall allow users to play back any and all video stored on the DVR by specifying the date, time and camera of video footage they would like to view. |
| 21.4.9. | The camera management software shall support replay of recorded video with 0.25x, 0.5x, 1x, 2x, 4x, 8x, 16x and 32x speed forwards and backwards. |
| 21.4.10. | The camera management software shall allow designated users to create descriptive category headings and group cameras into these categories. |
| 21.4.11. | The camera management software shall allow users to flag video segments for long term archival by specifying the beginning and ending date and time and camera to which the video segment belongs. |
| 21.4.12. | The camera management software shall store all video segments flagged for long term archival with a username and timestamp referring to the flagging. |
| 21.4.13. | The camera management software shall store all video segments flagged for long term archival in a separate space on DVR where they shall not be overwritten. |
| 21.4.14. | The camera management software shall raise an alert to administrators when utilization of the DVR storage space used for long term archival of flagged videos reaches 90% of capacity. |
| 21.4.15. | Once video segments flagged for long term archival have been transferred to a separate data storage unit off the DVR, the camera management software will allow for users to confirm that archived data files can now be overwritten. |
| 21.4.16. | The camera management software shall allow users to store a descriptive name for video segments stored in long term archival. |
| 21.4.17. | The camera management software shall allow users to export any recorded video segment stored on DVR, including long term archival video, to external media such as a DVD±RW optical drive, USB drive, or other approved means. |
| 21.4.18. | The camera management software shall allow users to flag a video segment for forensic storage. |
| 21.4.19. | The camera management software shall immediately encrypt any videos flagged for forensic storage so that they cannot be altered and shall apply an immutable timestamp and location stamp and export the videos to a removable hard drive. |
| 21.4.20. | The camera management software shall be capable of running in the background or foreground concurrently with CAD/AVL software without degradation of performance. |
| 21.4.21. | The camera management software shall provide a drag-and-drop interface to provide users with control over wall-mounted monitors which cycle through different camera views (monitor control interface). |
| 21.4.22. | The monitor control interface shall show each of the monitors and a list of camera views currently cycling on each monitor. The interface shall allow users to add (by drag-and-drop) or remove cameras from each monitor. |

| **21.5.** | **Installation/Placement** |
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| 21.5.1. | The camera management software shall be installed on all dispatcher workstations in BOC and shall be capable of running in the background while CAD/AVL software is running, without degrading performance. |

# 22. EMERGENCY CALL BOX MANAGEMENT SOFTWARE REQUIREMENTS

| **22.** | **Emergency Call Box Management Software Requirements** |
|---|---|
| **22.1.** | **General** |
| 22.1.1. | The Emergency Call Box (ECB) management software shall support the configuration of ECB devices, and the storage and reporting of indications received from field ECB devices. |
| 22.1.2. | The ECB management software shall be a module of the CAD/AVL central software or a separate stand-alone software package. |
| **22.2.** | **Interfaces** |
| 22.2.1. | The ECB management software shall be interfaced with the field ECB devices to exchange information via the fiber network. |
| **22.3.** | **ECB Management Software Logon and Logoff** |
| 22.3.1. | The ECB management software shall support a logon, logoff feature that is password protected and shall allow a user to logon to a specific user access level. Users logged on or logged off to the CAD/AVL central software shall be automatically logged on or logged off respectively to the ECB management software. |
| 22.3.2. | The ECB management software shall allow users to log on to the system with varying privileges depending on their access level. Access levels may include, but are not limited to:<br>▪ System Administrator<br>▪ Read-only User |
| 22.3.3. | The ECB management software shall allow users logged in as system administrators to assign specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| 22.3.4. | The ECB management software shall support at least 10 concurrent users. |
| **22.4.** | **ECB Configuration** |
| 22.4.1. | The ECB management software shall allow users with appropriate privileges to configure individual ECB field devices, including the stored emergency numbers, speakerphone and microphone volumes, and resetting ECB activation. |
| **22.5.** | **Data Storage and Reporting** |
| 22.5.1. | The ECB management software shall accept and store notifications of activation from the field ECB devices. With each notification of activation, the ECB management software will record the location of the activated ECB. |
| 22.5.2. | The ECB management software shall accept indications of fault detection from field ECB devices. With each indication, the ECB management software will record the location of the faulty ECB device. |
| **22.6.** | **ECB Device Integration** |
| 22.6.1. | The ECB management software shall send configuration data to or accept notifications from all ECB field devices via the fiber network. |

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| 22.6.2. | The ECB management software shall alert a user if communication with an ECB device has been lost. |

# 23. EMERGENCY CALL BOX REQUIREMENTS

| **23.** | **Emergency Call Box (ECB) Requirements** |
|---|---|
| **23.1.** | **General** |
| 23.1.1. | The ECB shall provide passengers at each station a quick and reliable means of reporting emergencies or summoning assistance in time of need. The ECB shall allow passengers to communicate with local public safety dispatch authorities as determined by the station location via the public telephone system. |
| 23.1.2. | Each ECB shall consist of the following major features:<br>• tamper and vandal-proof casing<br>• single push button operation<br>• blue LED strobe light while the ECB is in use (i.e. when the push button has been operated)<br>• built-in loudspeaker and microphone for hands-free operation<br>• bi-directional communication |
| 23.1.3. | All ECBs shall be managed by an ECB central software to be installed on central systems at the BOC. |
| 23.1.4. | The ECB shall be ADA compliant and be accessible for all users including the hearing and speaking impaired, the visually impaired, and the mobility impaired. |
| 23.1.5. | The ECB shall have a UPS to ensure continued system operation during power outages for a minimum of eight (8) hours. |
| 23.1.6. | It is preferred that the ECB be NTCIP compliant. |
| **23.2.** | **Interfaces** |
| 23.2.1. | Each ECB shall interface with BOC central systems via the busway communications system. |
| 23.2.2. | Each ECB shall interface with the public telephone system to complete all outgoing emergency calls. |
| **23.3.** | **Push Button** |
| 23.3.1. | The button shall be uniquely identified with lettering on the button or beside it. |
| 23.3.2. | The button shall be ADA compliant with features such as Braille “HELP” label. |
| 23.3.3. | Pushing and releasing the button shall initiate a call-in to an agency configurable, pre-programmed auto-dial number. |
| 23.3.4. | Once the button is pushed, hands free operation shall occur. |
| **23.4.** | **Loudspeaker** |
| 23.4.1. | The loudspeaker shall demonstrate through testing good coverage, the correct Sound Pressure Level (SPL) and good intelligibility, with a Speech Transmission Index (STI) of 0.5 or better under all conditions. |

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| 23.4.2. | Automatic Level Control (ALC) shall be provided for automatic adjustment of the volume of audible media to overcome varying ambient noise levels. |
| 23.4.3. | The loudspeaker shall be accompanied by an assistive listening system (ALS) that allows those with hearing impaired persons to use the ECB. |
| **23.5.** | **Microphone** |
| 23.5.1. | The microphone shall be capable of clearly picking up voice communications despite the presence of background noise, such as buses and trains. |
| **23.6.** | **Communications** |
| 23.6.1. | There shall be at least two programmable auto-dial numbers associated with the push button. |
| 23.6.2. | The ECB shall automatically dial subsequent numbers if the first number is busy or unavailable. |
| 23.6.3. | The ECB shall have ringing tone to indicate progress of call when button is pressed; Confidence tone to indicate call is still connected when on hold; and recorded message in case the line is busy. |
| 23.6.4. | The ECB shall automatically end the call connection without the user having to push any buttons when the far end telephone is disconnected. |
| 23.6.5. | “Call Received” LED indicators shall be provided for hearing impaired users. |
| **23.7.** | **ECB Management Software Integration** |
| 23.7.1. | The ECB shall send notification of activation, along with an indication of the location of the activated ECB, to the BOC via the ECB management software. Loss of communication with the ECB shall trigger an alert at the BOC. |
| 23.7.2. | In case of loss of communication with the BOC, the ECB shall keep records of all call events locally on a hard disk, or other approved medium. |
| 23.7.3. | The ECB shall send indications of fault detections to the ECB management software. |
| 23.7.4. | The ECB, including the emergency numbers, speakerphone and microphone volumes, and resetting ECB activation, shall be remotely configurable via the ECB management software. |
| **23.8.** | **Diagnostics and Failure Modes** |
| 23.8.1. | The ECB shall have in-built features for automatic fault detection and diagnosis in case of damages such as line faulty, low DC voltage, defective speaker or microphone. |
| 23.8.2. | Once a fault is detected, the ECB shall be capable of automatically reporting to the ECB management software. |
| 23.8.3. | The ECB control system shall allow remote diagnostics and provide printed reports of diagnostics and operations information. |
| 23.8.4. | The ECB control system shall allow for permanent trouble-shooting and maintenance test-result information to be stored locally on a hard disk, or other medium. |

| **23.9.** | **Enclosure** |
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| 23.9.1. | The ECB shall be easily identified through unique markings, striping or paint, signage or lighting. ECB markings and designations shall be approved by CTDOT. |
| 23.9.2. | The ECB shall remain easily visible during low light conditions. |
| 23.9.3. | Visual recognition devices such as strobes or beacons shall be provided to identify the activated ECBs. |
| 23.9.4. | Components that are exposed to ambient conditions shall be able to operate within the range of environmental conditions. |
| 23.9.5. | The sign casing should be vandal/graffiti resistant and washable. |
| **23.10.** | **Installation/Placement** |
| 23.10.1. | An ECB shall be installed on each station platform and other station locations as designated in station design plans. |
| 23.10.2. | In areas where phones are not visible, signs or markings shall be placed to indicate the direction and approximate distance to the closest call box. |
| 23.10.3. | The ECB shall be meet all ADA and accessibility requirements. |
| 23.10.4. | The ECB shall be installed on rigid structures, columns, walls, poles, and/or freestanding pedestals. |

# 24. NETWORK MANAGEMENT SYSTEM REQUIREMENTS

| **24.** | **Network Management System Requirements** |
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| **24.1.** | **General** |
| 24.1.1. | The network management system shall monitor the operational status of all the ITS components on the system. |
| 24.1.2. | The network management system shall provide routine reports of the operational status of the communications system and ITS components interfaced to that communications system. |
| 24.1.3. | The network management system shall provide operator alerts when any element(s) of the communications system or ITS component(s) under observation are operating outside of their normal operating range. |
| 24.1.4. | The network management system shall allow a designated operator to remotely access and control any of the ITS component on the communications network. |
| 24.1.5. | The network management system shall allow automated remote access and control of any of the ITS components on the communication network. |
| 24.1.6. | The network management system shall have configurable functionality for automated remote access and control of any of the ITS or communication system components on the network. |
| 24.1.7. | The network management system shall facilitate remote access and control of the components in the network through a secured channel. |
| **24.2.** | **Interfaces** |
| 24.2.1. | The network management system shall interface with all ITS and communications components on the busway communications system that are assigned a serial or IP address. |
| 24.2.2. | A database of all components of the communication system shall be maintained at the BOC. |
| **24.3.** | **Log on and Log off** |
| 24.3.1. | The network management system shall be locally accessible at the BOC. |
| 24.3.2. | The network management system shall be remotely accessible. |
| 24.3.3. | The network management system shall support a logon, logoff feature that is password protected and shall allow a user to logon to a specific user access level. |
| 24.3.4. | Users logged on or logged off to the network management system shall be automatically logged on or logged off respectively to the network management system. |
| 24.3.5. | The network management system shall allow users to log on to the system with varying privileges depending on their access level. Access levels may include, but are not limited to:<br>▪ BOC System Administrator<br>▪ BOC Network Management System Administrator<br>▪ BOC Network Management System Personnel<br>▪ Busway Supervisor<br>▪ Field Network Management Personnel |

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| 24.3.6. | The network management system shall allow users logged in as system administrators or BOC Network Management System Administrator to assign specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| 24.3.7. | The network management system shall allow users logged in as BOC System Administrator(s) or BOC Network Management System Administrator(s) to assign the following for the communications and ITS components: specific privileges to each access level; add, remove, or change access levels; assign access levels to each user; and add/remove users. |
| 24.3.8. | The network management system shall support at least 10 concurrent users. |
| **24.4.** | **Graphical User Interface** |
| 24.4.1. | The Network Management System shall incorporate a Graphical User Interface (GUI), to display information to users and accept user input in a clear, logical manner. |
| 24.4.2. | The Network Management System shall allow the user to filter the information for display by alert type, time of alert, station location, busway location, communication component, and by ITS component. |
| 24.4.3. | The GUI shall support concurrent display of multiple windows. |
| 24.4.4. | At a minimum, the GUI shall support function key assignments, paging, scrolling, and shortcuts. |
| 24.4.5. | The GUI shall support repositioning and resizing each window as desired to present the maximum amount of useable information. |
| **24.5.** | **Alerts** |
| 24.5.1. | The network management system shall alert the BOC controller when communications system and ITS components are non-responsive or when there is a loss of a communication link on the network. |
| 24.5.2. | The network management system shall include a configurable ranking scale to communicate the severity of the component alert. |
| 24.5.3. | The network management system shall have fully configurable alert delivery options to designated users via email, on terminal screen, cell-phone text message and alarm sound in the BOC. |
| 24.5.4. | The network management system shall provide operator alerts when any elements of the communications system or ITS component(s) are operating outside of their normal operating range. |
| 24.5.5. | The network management system shall alert the BOC operator of scheduled maintenance. |
| 24.5.6. | The network management system scheduled maintenance alerts shall have configurable due-date arrival time in order to arrange a suitable response in a timely fashion. |
| **24.6.** | **Database Management** |
| 24.6.1. | The network management system shall be hosted at the BOC. |
| 24.6.2. | The network management system shall act as a central repository for all maintenance reports of the communication system and ITS components. |

| **24.7.** | **Automatic Control of Communication and ITS Components** |
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| 24.7.1. | The network management system shall automatically reroute the flow of data in the network to the most resilient throughput configuration possible in the event of a loss of a communication link on the network. |
| 24.7.2. | The network management system automatic control functionality shall be configurable by users designated by BOC System Administrators and BOC network Management System Administrators. |

# 25. BUSWAY COMMUNICATIONS SYSTEM REQUIREMENTS

| **25.** | **Busway Communications System Requirements** |
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| **25.1.** | **General** |
| 25.1.1. | The busway communications system shall provide data, voice and video communication capability between all the field deployed ITS equipment and the Busway Operations Center (BOC). |
| 25.1.2. | The communications system shall be an Ethernet-TCP/IP and fiber optic based network backbone with electrical Ethernet connections as required between ITS equipment and network switches. |
| 25.1.3. | All communication links and components shall enable bi-directional information flow. |
| 25.1.4. | The busway communications system shall consist of a fiber optic backbone and a set of communications hubs that connect to that backbone. |
| 25.1.5. | Each communications hub shall consist of:<br>• Optical ‘drop’ fiber(s) on to the fiber backbone<br>• Optical fiber termination patch panel (OFTPP)<br>• Ethernet media converter(s)<br>• Terminal port server (if required for serial outputs)<br>• Ethernet switch(es)<br>• Ethernet cabling |
| 25.1.6. | Each busway station shall act as a communications hub, at which information (voice, data and video) can be inserted onto or removed from the network backbone. |
| 25.1.7. | Each busway station communications hub shall interface with the ITS components at the station either directly via an Ethernet-TCP/IP interface or via a terminal port server where the ITS components have serial outputs. |
| 25.1.8. | Each signalized intersection on the busway shall act as a communications hub, at which information (voice, data and video) can be inserted onto or removed from the network backbone. |
| 25.1.9. | In cases where CCTV cameras are located more than suitable copper cabling distance of a busway station or intersection communications hub, the busway CCTV location shall act as a communications hub, at which information can be inserted onto or removed from the network backbone. |
| 25.1.10. | The BOC shall act as a central communications hub, at which information can be inserted onto or removed from the network backbone. |
| 25.1.11. | Each communications hub shall be capable of routing information to neighboring communications hubs in the network. |
| 25.1.12. | The BOC shall house the network management system. |
| 25.1.13. | The network management system shall monitor and manage the network. |
| 25.1.14. | The communications system between the BOC and all communications hubs shall have a reliability rating of better than 99.99% (no more than one [1] hour of downtime per year of operation), with no single point of failure, and resiliency to communications hub or link failures. |

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| 25.1.15. | The communications system between the BOC and the system communications hubs and all field equipment shall provide sufficient effective bandwidth to meet double the operational requirements of the entire system. |
| **25.2.** | **Interfaces** |
| 25.2.1. | The busway communications system shall be connected with the BOC equipment via the Ethernet switch at the BOC communications hub. |
| 25.2.2. | The busway communications system shall be connected with the TIS Controller (covering the PA and VMS systems) at each busway station via the Ethernet switch at the busway station communications hub. |
| 25.2.3. | The busway communications system shall be connected with the TVM(s) at each busway station via the Ethernet switch at the busway station communications hub. |
| 25.2.4. | The busway communications system shall be connected with the ticket validators at each busway station via the Ethernet switch at the communications hub. |
| 25.2.5. | In cases where CCTV cameras are located at busway stations, the CCTV camera shall be connected directly to the Ethernet switch at that station communications hub. |
| 25.2.6. | In cases where CCTV cameras are located between busway stations, but within suitable copper cabling distance of a busway station communications hub, the CCTV camera shall be connected directly to the Ethernet switch at that communications hub. |
| 25.2.7. | In cases where CCTV cameras are located between busway stations, but within suitable copper cabling distance of a signalized intersection communications hub, the CCTV camera shall be connected directly to the Ethernet switch at that communications hub. |
| 25.2.8. | In cases where CCTV cameras are located between busway stations, but beyond suitable copper cabling distance of a busway station communications hub or signalized intersection communications hub, the CCTV camera shall be connected directly to the Ethernet switch at the communications hub located at that CCTV camera location. |
| 25.2.9. | The busway communications system shall be connected with ECB systems at each busway station via the Ethernet switch at the communications hub. |
| **25.3.** | **Fiber Optic Network** |
| 25.3.1. | The fiber optic network shall consist of a backbone cable running the length of the busway. At the northern terminus of the busway, near Myrtle Street, the backbone fiber cable shall be connected to a new cable to be installed in existing conduit along I-84 to the existing communications hub at the I-84/I-91 interchange. At the communications hub, the fiber optic cable shall be routed through an existing vault and into the existing conduit running along I-91 north of the interchange, and ultimately connecting to the Bus Operations Center in Hartford. On the busway, each of the stations shall connect to the backbone cable using fiber optic “drop” cables. |
| 25.3.2. | The fiber optic communication network shall be implemented as a collapsed ring, with one side of the ring connecting to every communications hub along the busway, and the other side of the collapsed ring connecting directly from the southern terminus of the busway to the BOC. |
| 25.3.3. | The fiber optic cable shall be terminated with CTDOT-approved connectors. |

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| 25.3.4. | The fiber optic cable shall be suitable for bi-directional optical transmission. |
| **25.4.** | **Fiber Optic “Drop”** |
| 25.4.1. | The fiber optic backbone shall connect to each communications hub on the network using a fiber optic “drop” cable spliced to the backbone installed in a splicing vault or handhole near the communications hub. |
| **25.5.** | **Optical Fiber Terminator Patch Panel (OFTPP)** |
| 25.5.1. | The OFTPP at a communications hub shall connect the fiber optic “drop” cable(s) at the communications hub to the Ethernet media converter(s) at the communications hub. |
| 25.5.2. | The OFTPP at each communications hub shall be sized to accommodate existing fiber optic needs, as well as facilitate future spare communications capacity. |
| **25.6.** | **Ethernet Media Converter** |
| 25.6.1. | The Ethernet media converter at a communications hub shall be the media converting interface between the OFTPP at the communications hub and the Ethernet switch at the communications hub. The Ethernet media converter may also be integrated into the Ethernet switch. |
| 25.6.2. | The Ethernet media converter shall convert electrical Ethernet signals over copper wire to optical signals over optical fiber. |
| 25.6.3. | Ethernet media converters shall transmit and receive 1Gbps data over single mode fiber. It shall function as a 1Gbps Ethernet link without degradation or adjustments. |
| 25.6.4. | Ethernet media converters shall operate at 1310 nm. Where Ethernet media converters must connect to a single fiber strand, the media converters shall operate at 1310 nm and 1550 nm on single mode fiber. |
| 25.6.5. | Ethernet media converters shall be assigned an IP address and shall be configurable remotely. |
| 25.6.6. | Ethernet media converters shall be able to transmit for distances up to 20 km on single mode fiber. |
| **25.7.** | **Ethernet Switches** |
| 25.7.1. | The Ethernet switch at a communications hub shall be the interface between the Ethernet media converter at the communications hub and the ITS components at the communications hub, and if required, the terminal port server(s) at the communications hub. |
| 25.7.2. | The Ethernet switches shall be capable of transmitting Ethernet packets at a rate of a gigabit per second (1 Gbps), as defined by the IEE 802.3-2005 in a full duplex communications mode. |
| 25.7.3. | The Ethernet switch at a communications hub shall aggregate all ITS components at the communications hub with an Ethernet interface. |
| 25.7.4. | The Ethernet switch at a communications hub shall aggregate all terminal port servers at the communications hub. |
| 25.7.5. | Ethernet switches shall be assigned an IP address and shall be configurable remotely. |

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| **25.8.** | **Ethernet Cabling (Copper)** |
| 25.8.1. | All Ethernet cabling used in the busway communications system shall be Category 6 type. |
| 25.8.2. | Ethernet cables shall be suitable for the environment in which they will be installed. |
| **25.9.** | **Terminal Port Servers** |
| 25.9.1. | The terminal port server(s) at a communications hub shall be the media converting interface between serial communicating ITS components at the communications hub and the Ethernet switch at the communications hub if required for serial outputs. |
| 25.9.2. | Terminal port servers shall support EIA-232, 422 and 485 serial interfaces and other serial interfaces (e.g. Manchester) as may be required by serial devices to be connected to the Ethernet switch. |
| 25.9.3. | Terminal port servers shall be assigned an IP address and shall be configurable remotely. |
| **25.10.** | **BOC Equipment Integration** |
| 25.10.1. | The communications system shall support communication between the BOC equipment and field devices, including the TIS controller, TVMs, ticket validators, CCTV cameras, and ECBs. |
| **25.11.** | **Traveler Information Station (TIS) Controller Integration** |
| 25.11.1. | The communications system shall support communication between the BOC and the busway station PA system and VMSs via the TIS controller. |
| 25.11.2. | Customer requests for audio readout of the VMS shall be triggered by a wired Audio Command Point (ACP) that is part of the VMS system. The communications system shall support the interface between the ACP and the TIS controller. |
| **25.12.** | **Ticket Vending Machine (TVM) Integration** |
| 25.12.1. | The communications system shall support communication between the fare management central software at the BOC and the busway station TVMs. |
| **25.13.** | **Ticket Validator Integration** |
| 25.13.1. | The communications system shall support communication between the fare management central software at the BOC and the busway station validators. |
| **25.14.** | **CCTV System Integration** |
| 25.14.1. | The communications system shall support communication between the BOC and the CCTV camera field equipment on the busway and at each station. |
| **25.15.** | **Emergency Call** Box **System Integration** |
| 25.15.1. | The busway communications system shall provide an interface to the ECBs at busway stations to allow transmission of a signal from the ECB to the BOC when a 911 call is made from the ECB. |
| 25.15.2. | The busway communications system interface to the ECB shall be distinct and separate from the conventional 911 telephone exchange networking. |
| **25.16.** | **Installation** |
| 25.16.1. | Each fiber optic cable shall be suitable for placement in an underground duct or |

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| | aerial installation. |
| 25.16.2. | All communications hub components shall be housed in appropriate environmentally ruggedized housings with appropriate access for maintenance, repair, upgrade and decommissioning. |
| 25.16.3. | All communications hub enclosures shall meet the appropriate electrical safety and electromagnetic susceptibility, and electromagnetic emissions requirements. |
| **25.17.** | **Security/Maintenance** |
| 25.17.1. | The busway communications system shall support encryption and decryption of information transmitted between communications hubs to an industry recognized security standard. |
| 25.17.2. | The busway communications system shall include firewalls to prevent unauthorized access or attack on the busway ITS systems. |

# 26. SUMMARY AND NEXT STEPS

Consistent with the standard Systems Engineering approach for ITS projects as required by FHWA rule and FTA policy, this document specifies the Functional Requirements for the ITS and Communications systems for the planned New Britain-Hartford Busway. These Functional Requirements are designed to help stakeholders identify “what the system will do”, “how well”, and “under what conditions”. These Functional Requirements are intended to help guide the development of detailed system design and to assist CTDOT in the verification and validation of their eventual system.

Concurrent with the completion and acceptance of these Functional Requirements, the ITS Concept of Operations will be updated to reflect any changes resulting from the evolving system design. Detailed design of the system will also commence, based on the functional requirements identified herein.

# P-25 Radio System Documentation

*[Excerpt of requirements from Connecticut State Police radio procurement documentation.]*

# 4. Voice and Data Communication Requirements

## 4.1 General

The Contractor shall describe in sufficient technical and logistical detail the provisions and methodologies necessary to integrate the ITS components speechified herein with the CTDPS wireless Motorola ASTRO-25 network. More specifically, the Contractor shall describe in detail how the CTDPS wireless network shall be interfaced to the following:

- CTDPS Network interface between the central system and fixed-route revenue vehicles;
- CTDPS Network interface between the central system and supervisor vehicles;
- CTDPS Network interface between the central system and support vehicles;
- CTDPS Network interface (or other telecommunication) between wayside Variable Message Signs (VMS) and the central system; and
- CTDPS Network interface (or other telecommunication) between vehicles located at the garages and the central system.

The Contractor shall identify the specific on-board and central hardware and software that will be required to establish wired and wireless communication infrastructure.

The Contractor shall be required to interface with the following CTDPS radio communication systems:

- For all CTTransit Operations with the exception of S.E.A.T, the Contractor shall interface the ITS systems to the the CTDPS 700 Mhz Motorola Astro 25 voice and data network.
- For S.E.A.T, Operations, the Proposal shall interface the ITS systems to the Cellular Service Provider mutually as directed by the Project Manager.

Further details about the required interfaces are described in the following subsections.

## 4.2 Integration with Motorola Radio System

### 4.2.1 Existing/Planned Radio Solution for Voice and Data

The CAD/AVL solution shall utilize the CTDPS) ASTRO25 system for both voice and data services. The CTDPS system is currently at version 7.11 and there is a planned upgrade to 7.14 in Q1 2014. The CTDPS system will be expanded to cover the CTTransit operational area by Q4 2012. Wireless coverage will be provided by four simulcast subsystems. CTTransit users will generally operate in one of the four simulcast subsystems but it is possible for the devices to roam throughout the system's coverage area.

The CTDPS system shall support all CTTransit voice and data communication. The system will support classic IV&D data through 2013. A planned upgrade will add Enhanced Data capability to the system in Q1 2014.

Enhanced Data is the next step in Motorola's continued effort to make the ASTRO 25 IV&D platform a more effective data solution for transit and public safety Automatic Vehicle Location (AVL) users. It is a value added feature that works alongside the P25 standard to provide a more efficient method of transmitting short inbound data messages such as vehicle location updates. Enhanced data increases the number of users per channel and the allowable location update rate by minimizing contention on the inbound channel. Both enhanced data and classic IV&D can be used on the same system.

The proposed CAD solution shall utilize classic IV&D for all data services through Q1 2014. The Contractor shall coordinate with CTTransit Project Manager to determine the optimum AVL cadence to be deployed in each operational territory until the Enhanced Data solution is deployed by CTDPS and Motorola. When Enhanced Data is available, the CAD vendor shall transition the fleet to Enhanced Data operation.

### 4.2.2 Integration with Radio System

The CAD vendor shall be responsible for the integration of the proposed CAD/AVL solution, the CTDPS system, and CTTransit owned radio system elements such as radio communications dispatch consoles and field unit subscribers. It is CTTransit's expectation that the CAD vendor shall subcontract specific integration support services to Motorola Solutions. These services include licenses for all required system interfaces, participation in the detailed design review and planning process, capacity analysis and measurement, development and testing support, and transition support. It is the CAD vendor's responsibility to identify and include all required integration services.

### 4.2.3 Interfaces with the Motorola ASTRO25 system

The CAD vendor shall implement and provide the following interfaces to the CTTransit radio equipment:

- MCC7500 Console API
- APX6500 XCMP Radio Control Interface
- ASTRO25 IV&D Data Interface
- ASTRO25 Enhanced Data Interface

#### *4.2.3.1 MCC 7500 API*

The MCC7500 Workstation client API allows the CAD dispatch software to control the MCC7500 client GUI. Functionality such as logging on, talk group selection, and radio identification shall be controlled by the CAD/AVL application. CAD vendors shall work directly with Motorola Solutions to obtain the appropriate license, SDK documentation, and development support for this interface.

The CAD vendor shall determine if a single or dual workstation will best suit their dispatch configuration. CTTransit will supply a standard Motorola Solutions MCC7500 Workstation at each operator position. The CAD vendor is responsible for all network and MCC7500 workstation configuration changes required to support the CAD solution.

### *4.2.3.2 APX6500 Radio Control Interface*

The Motorola APX 6500 is equipped with a Mobile Mic Port (MMP) and a Mobile Accessory Port (MAP). The MMP supports connections for audio and radio control head interfaces. The MAP supports connections for discrete signals and data communications. The CAD vendor's on-board equipment will interface to the APX6500 via these connections.

The MMP interface includes the Motorola XCMP/RNDIS/USB connection for radio control. XCMP allows external devices to emulate the standard Motorola control head by sending instructions to the radio. Instructions include initialization, mode select, etc. Complete documentation on XCMP can be obtained from Motorola.

The APX6500 supports two connection types for data transmission: UDP/IP/PPP/RS-232 or UDP/IP/RNDIS/USB 2.0. The data connection allows the on-board computer to communicate with a host application via the APX subscriber and P25 infrastructure. CAD vendors shall use the data connection to transfer data between the CAD Vendor's on-board equipment and the fixed end CAD/AVL servers via the CTDPS ASTRO 25 radio solution. All data messaging shall be transferred via UDP/IP transport and delivery protocols and Enhanced Data message size limitations. Enhanced Data implementation details can be obtained from Motorola.

The MMP connector also provides connections for audio communications to and from the CAD Vendors on-board equipment. Mobile receive audio is routed from the APX 6500 RxAudio output lines to the CAD vendor's on-board controller, where it can be routed to the interior AVA speakers, the exterior AVA speakers, the driver's cab speaker, or handset. Mobile transmit audio is routed through the CAD vendor's on-board multiplexer from one of two sources; the handset microphone, or the covert microphone to the APX 6500 through the AuxTx connection. Volume and muting capabilities can be adjusted via XCMP. The radio is turned on and off utilizing the Switched B+ input and it is keyed up using the AuxPTT input signal. The radio emergency alarm is also utilized with the Emergency Alarm pin. When an emergency alarm is depressed, both a Motorola radio EA (which is received by the MCC 7500 dispatch application) and a CAD/AVL alarm are sent to the fixed end dispatch center.

Further vendors will be required to perform capacity analysis and provide storm plan as follows:

#### *4.2.3.2.1 Capacity Analysis*

CAD vendors shall supply a detailed capacity analysis as part of their RFP response. The capacity analysis shall address system loading for both classic IV&D and Enhanced Data on each simulcast subsystem. The classic IV&D analysis will address operation of the system prior to the availability of Enhanced Data. The analysis shall include the following elements:

- Application load profiles
- Active Units
- Channels Required

The load profiles shall describe the size and rate of each application message and acknowledgement that will be presented to the P25 system. Vendors shall provide separate profiles for both classic IV&D and Enhanced Data operation. CTTransit anticipates that the AVL rate will be the only difference between the profiles. However, vendors may make other changes if necessary and provide a detailed description of any resulting functional changes. The profiles shall be provided in the following format:

| Message Type | Size (bytes) | Messages / user / hour | In / Out / Broadcast |
|---|---|---|---|
| XXX | XXX | XXX | XXX |
| | | | |

CTTransit has conducted an initial assessment of the user distribution and estimated the number of users expected to operate on each of the simulcast cells. The table below indicates the estimated number of active users and the maximum number of data channels available per simulcast subsystem. CAD vendors shall use the following number of active units per simulcast subsystem for the capacity analysis.

| Simulcast Subsystem | Active Users | Max Wireless Data Channels |
|---|---|---|
| Simulcast PSE New Haven | 135 | 3 |
| Simulcast PSE (1) Hartford | 175 | 3 |
| Simulcast PSE (2) Stamford | 60 | 2 |
| Simulcast PSE (3) Waterbury | 132 | 3 |

Note that the total number of active subscribers does not directly correspond to the number of CTTransit subscribers. These quantities represent the typical number of subscribers on each of the simulcast subsystems for the purpose of the capacity analysis. Users from each of the CTTransit areas may operate on adjacent simulcast subsystems due to overlapping coverage.

The classic IV&D capacity analysis results shall indicate the average number of IV&D channels required to support the CAD system's operation. This analysis will indicate the number of data channels required for operation during the interim period between initial deployment and Enhanced Data availability. It will also indicate the maximum AVL rate that can be supported using the available data channels.

The Enhanced Data capacity analysis shall indicate the average number of classic IV&D and Enhanced Data channels required to support CAD system operation using a 60 second AVL rate.

The capacity analysis shall be repeated during the detailed design phase of the project. The updated analysis shall utilize message profiles based on the final CAD features and functionality documented during the design review.

#### *4.2.3.2.2 Storm Plan*

During the detailed design review, the CAD Vendor shall provide a storm plan that describes operation of the integrated CAD / CTDPS system during unusual operating conditions. These include scenarios with unusual concentrations of users such as evacuations. In these situations a large percentage of the

CTTransit fleet may need to operate within a single CTDPS simulcast subsystem. The plan shall describe how the integrated system will operate in the event that data capacity demands exceed CTDPS system capacity.

### 4.2.4 Classic IV&D Implementation

The CAD solution will be initially deployed on a Motorola ASTRO25 7.11 system. Prior to the CAD vendor's fleet installation the bus fleet will be equipped with APX6500 remote mount subscribers and APX control heads configured for open mike operation.

During the detailed design review, the CAD vendor shall define the fleet map and radio templates required for integrated CAD and radio operation.

During the deployment, the CAD vendor will work with CTDPS to update the CTDPS system's fleet map to reflect the configuration defined during the detailed design review. The CAD vendor shall to coordinate the fleet map changes with the CTDPS system manager.

During the fleet installation process, the CAD vendor shall update the APX6500 mobile template to the version defined during the detailed design review. The Motorola Solutions control head and cable shall be removed and replaced with the CAD vendor's on-board equipment. Data channel utilization shall be monitored on a daily basis during the installation process to assure that system utilization corresponds to the capacity analysis projections.

### 4.2.5 Enhanced Data Implementation and Transition

When Enhanced Data is enabled on the CTDPS system the CAD vendor shall transition operation to the new data channel. During the detailed design review, the CAD vendor will prepare a detailed Enhanced Data Transition Plan that incorporates the following steps:

1. Unit Test – Test one typical bus equipment configuration to verify the configuration change process and operation on Enhanced Data. This test shall repeat all functional tests originally performed using the classic IV&D configuration.
2. Pilot Fleet Test – Flash upgrade the APX subscriber to the software release required to support Enhanced Data. Configure a fleet of 10 buses to utilize Enhanced Data and operate at the 60 second AVL rate. Verify operation of the pilot fleet vehicle equipment and assure that they are ready for production operation. Monitor the fleet for a period of two weeks to assure proper operation.
3. APX Upgrade – Flash all remaining APX subscribers to correct software release. This upgrade cannot be performed over the air.
4. Enhanced Data Transition – Systematically transition the fleet to Enhanced Data operation. The new configuration should be pushed to the on-board equipment via the WLAN. Devices in the Stamford area should be transitioned to Enhanced Data first. These users are likely to operate only in the Stamford simulcast subsystem. This will allow CTTransit and the CAD vendor to assess the data system performance with a larger user group. The remaining users shall be transitioned to Enhanced Data in an orderly fashion that is sensitive to the CTDPS system capacity limits. The CTDPS system's operation and data utilization should be monitored during this process to assure proper operation.

5. Transition Report – Prepare a report documenting the transition process. The Transition Report shall include actual data system utilization statistics obtained from the CTDPS system.

## 4.3 Wireless Data Communications

### 4.3.1 On-board Hardware

#### *4.3.1.1 Motorola APX IV&D Subscriber*

The Contractor shall interface with Motorola radio and data modem hardware as described in Section 0 for all agencies.

#### *4.3.1.2 On-board Mobile Gateway/Router*

##### *4.3.1.2.1 Hardware and Connectivity*

The Contractor shall provide an On-board Mobile Gateway/Router (OMGR) for CTTransit vehicles to accomplish wired and wireless connectivity.

The OMGR shall comply with on-board hardware requirements described in Section **Error! Reference source not found.**.

The OMGR shall provide the following connectivity capabilities:

- Cellular Modem: the OMGR shall be equipped with built-in modem card slots for cellular data connectivity, compliant with each major cellular carrier network available in the CTTransit service area. The OMGR shall have at least three (3) built-in card slots. The OMGR shall accept cards compliant with Peripheral Component Interconnect (PCI) and Universal Serial Bus (USB) standards.
- Wi-Fi: The OMGR shall be equipped with built-in Institute of Electrical and Electronics Engineers (IEEE) 802.11x card for Wi-Fi Connectivity to an external access point. Please see Section **Error! Reference source not found.** for further requirements for wireless data exchange at CTTransit garages.
- Ethernet: The OMGR shall be equipped with a built-in Ethernet adaptor for local area network (LAN) connectivity in-vehicle: The OMGR shall consist of at least four (4) built-in Ethernet ports and shall have the ability to extend to eight (8) Ethernet ports by utilizing an external network switch.
- Data Radio Connectivity: The OMGR shall have the ability to utilize the data connectivity link available from on-board Motorola APX IV&D Subscriber.

The OMGR shall have the ability to perform as a mobile hotspot.

The OMGR shall be equipped with at least two USB 2.0 connection ports.

The OMGR shall be equipped with at least one RS-232 connectivity port.

The OMGR shall have built-in information security capabilities (e.g., encryption) to protect the data routed over wired or wireless networks. The Contractor shall describe all built-in security capabilities..

The OMGR shall be configurable locally (via Ethernet) or remotely (via wireless network).

The OMGR shall support port filtering/blocking and port forwarding capabilities.

##### *4.3.1.2.2 Data Communications*

The OMGR shall support quality of service (QoS) to ensure protected bandwidth for multiple sub-channels when multiple sub-channels are enabled for connectivity of individual on-board systems (e.g., CAD/AVL and video surveillance system).

The OMGR shall be configurable to control which on-board system can perform outbound communication based on the speed of data connection available at a given time (e.g., video transmission shall be allowed only when 4G cellular connectivity is available).

The OMGR shall have the ability to configure the data rate limits for inbound and outbound data communications.

The OMGR shall be able to automatically switch to an available network based on the agency configuration. The configuration parameters shall include but shall not be limited to available network(s) and their priorities, time of day, current geographic location and CTTransit division.  The OMGR shall automatically fallback to cellular communication in the event no data radio coverage is available.

The OMGR shall have the capability use port filtering/blocking to ensure only appropriate data traffic is routes on an available wireless network.

The port forwarding feature shall allow a host application at the central system (e.g., video Playback Software) to connect to a desired on-board system (e.g., DVR).

The OMGR shall support Dynamic Host Control Protocol (DHCP) for connected devices and provide the capability to turn on and off the DHCP server as needed.

The OMGR shall have at least 10GB of built-in storage.

##### *4.3.1.2.3 MDT Connectivity*

The MDT shall be connected with the OMGR via Ethernet port for the following data exchange activities

Sending and receiving of CAD/AVL, APC, VCM data via available wireless networks

Upload and download of data listed in Section **Error! Reference source not found.** via WLAN at CTTransit garages.

#### ***4.3.1.3 Antenna Hardware***

Vendors shall propose hardware that will help limit the number of antenna hardware to be installed on each vehicle. An antenna which can support a combination of global positioning system (GPS) connection, cellular network connection and wireless fidelity (Wi-Fi) connection using a single unit (e.g., dual-mode antenna, tri-band antenna) may be used for the proposed solution.

The Contractor must use low-profile antenna hardware.

#### *4.3.1.4 Driver Handset and Speaker*

The Contractor shall interface with existing Motorola handsets. The APX radios will be initially installed with control heads and hand mics. Both the hand mic and control head will need to be removed during the on-board CAD/AVL installation process. The CAD/AVL vendor must supply a telephone handset with PTT button and a hang-up cup (Audio Sears or similar). If the APX is installed with an external speaker this could potentially be reused for the CAD installation.