Bus Priority Measures Corridor Case Study

Washington Street, Belgrade Avenue, and Centre Street

MARCH 2014

VHB Planning | Transportation | Land Development | Environmental

Memorandum	To:	Tom Nally Planning Director A Better City	Date:	March 28, 2014
			Project No.:	12050.00
	From:	Albert Ng, Senior Transportation Engineer	Re:	Boston Surface Transportation Optimization Project
				Phase B: Corridor Modeling Exercise Results

This memorandum provides an overview of the results from Phase B of the Boston Surface Transportation Optimization Pilot Study. Within this memorandum, the process used to select a corridor to study and model, the methodology used to model the corridor, and the results of the modeling are described.

Corridor Selection Criteria

The project developed a list of criteria to evaluate and select a suitable corridor to study and with which to model and determine the benefits of implementing bus priority measures. Exhibit 1 presents the corridor selection criteria with which the corridors were evaluated and the reasoning for choosing the criteria.

Exhibit 1 Corridor Selection Criteria

Criteria	Reasoning
Corridor does not include Key bus route and has not been studied at length	• Bus priority measures have been studied on Key Bus Routes. • Several less popular routes would potentially provide less risk if used in pilot. • Potential to increase ridership (long-term).
Within the jurisdiction of BTD's central traffic control system	• Provides opportunity to affect bus priority
Corridor with overlapping bus routes	• Ability to develop control group on a corridor if bus priority measure affects specific route rather than all routes. • Ability to affect multiple routes and increase the number of customers who benefit from the changes
Corridor carrying healthy number of daily riders	• Maximize person-benefit

A key feature of the selection criteria is choosing a corridor with overlapping bus routes. By choosing a corridor serving multiple routes, the benefits generated by physical bus priority infrastructure changes increases significantly.

Corridor Selection

Based on the corridor selection criteria, three corridors emerged as candidates for evaluation. Exhibit 2 presents the three candidate corridors and their characteristics.

Exhibit 2 Candidate Corridors

Corridor	Description	Bus Routes on Corridor	Weekday Daily Ridership*	Number of Signalized Intersections	Length (mi)
Brookline Avenue (Longwood Medical Area)	Kenmore Square to Route 9	8, 19, 47, 60, 65, CT2, and CT3	16,711	10	1.40
Washington Street (Roslindale)	Forest Hills to Roslindale Square	30, 34, 34E, 35, 36, 37, 40, 50, and 51	20,047	7	1.25
E Broadway (South Boston)	Dorchester Street to Farragut Road	5, 9, 10	7,318	5	1.04

Total for all routes (not segment specific) from MBTA Blue Book 2010

After discussions with the Massachusetts Bay Transportation Authority (MBTA), the Washington Street corridor was selected and per the MBTA's suggestion, extended to Belgrade Avenue and Centre Street (to Lagrange Street). By lengthening the corridor, we can increase impact along the three routes that run along the full length of the extended corridor. Data was requested from and provided by the MBTA, including:

- Automated passenger count (APC)
- Automated Vehicle Location (AVL)

Existing Conditions

The Washington Street, Belgrade Avenue and Centre Street (WBC) corridor is located approximately five miles southwest of North Station (see Exhibit 3). The northern terminus of the corridor is Forest Hills station and the bus routes along the study corridor generally act as feeder service to Forest Hills. The study corridor does not include a key bus route and the trunk along Washington Street serves over 20,000 weekday daily riders. The three routes that run span the full length of the WBC corridor are the 35, 36 and 37 routes.
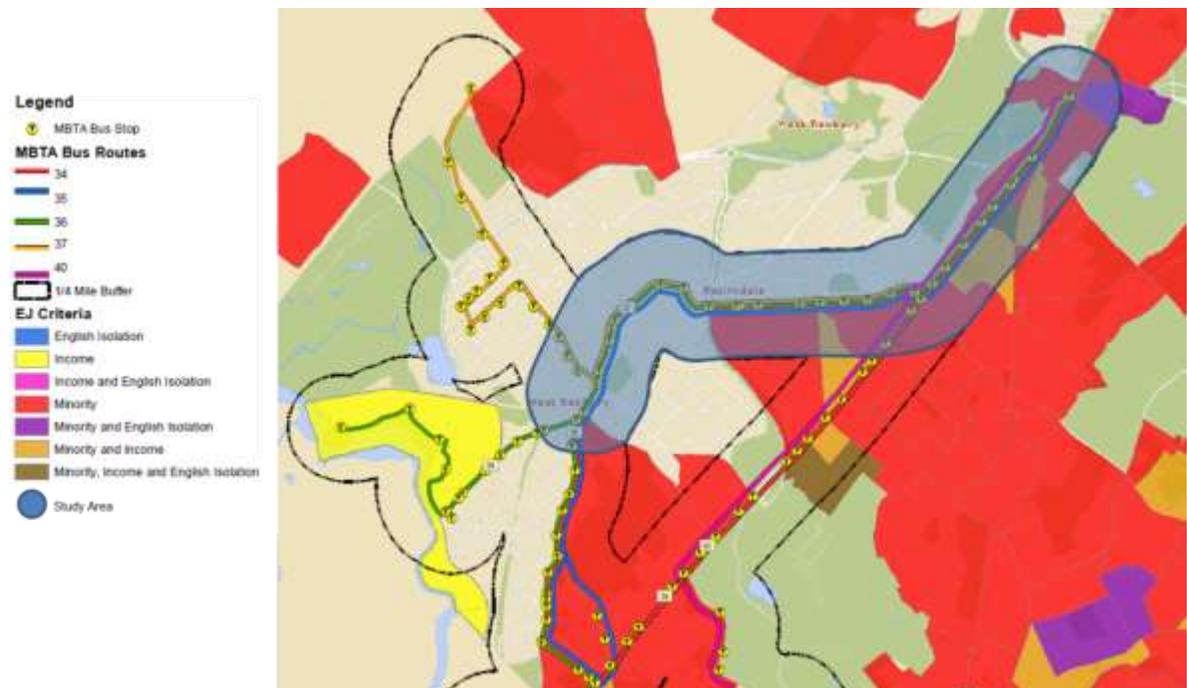
Exhibit 3 Corridor Location

Exhibit 4 Bus Route Near WBC Corridor
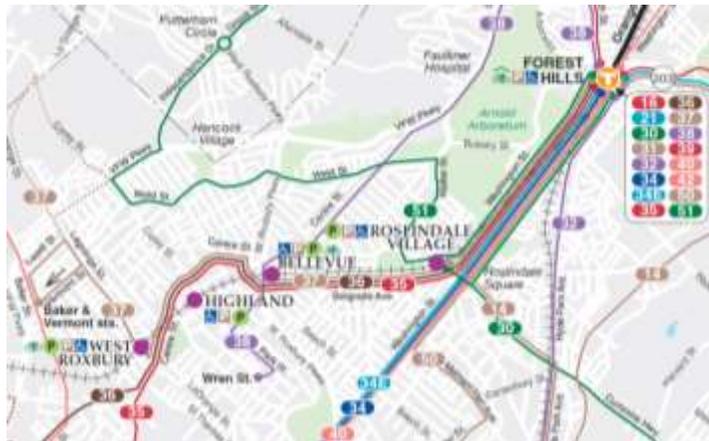
The corridor also runs adjacent to environmental justice areas including minority, income and English isolation populations as shown in Exhibit 5.

Exhibit 5 Environmental Justice Areas Adjacent to Study Corridor

Corridor Characteristics

The corridor is adjacent to a mix of land uses and their characteristics vary along each section. In summary, there are several known challenges in working with the selected study corridor including:

- Providing bus priority measures that significantly improve bus travel time but do not significantly compromise community needs (e.g., on street parking)
- Work with limited right-of-way
- Compete with other roadway needs

The following sections provide a general description of corridor characteristics.

Washington Street

The Washington Street corridor extends between Forest Hills and Roslindale Square. Roslindale Square and the area adjacent to Forest Hills are retail and commercial while the area between the two nodes is largely multi-family residential buildings with local retail and service stores. There is one travel lane in each direction. On-street parking and a bicycle lane run along the full length of Washington Street on each side of the street within the study area.

Transit Service Characteristics

Exhibit 6 Washington Street, Near Forest Hills

- Routes: 30, 34, 34E, 35, 36, 37, 40, 50 and 51

- 8 Inbound, 9 Outbound bus stops

- Average bus speeds between 4 and 25 MPH (speeds are slower at western end of corridor)

- 7 traffic signals, 4 on Boston Transportation Department Central Traffic Control System

**Exhibit 7 Typical Washington Street Cross-Section**
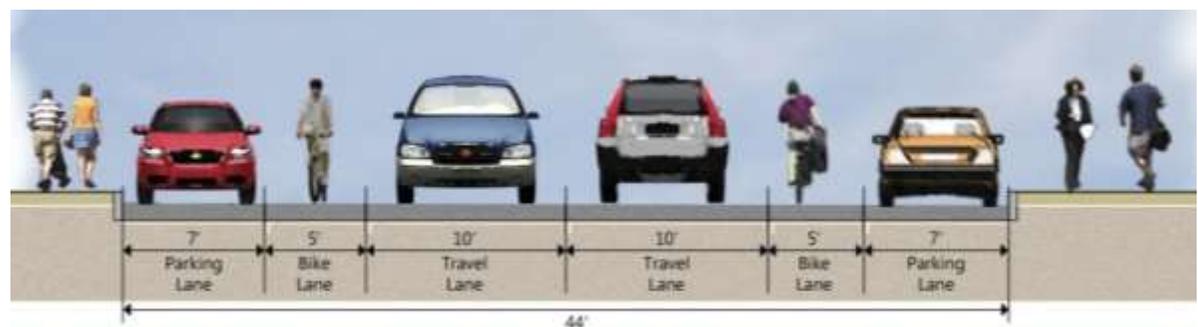
Belgrade Avenue

Exhibit 8 Belgrade Avenue

Belgrade Avenue runs between Roslindale Square and Centre Street within the study corridor. The area is typically multi-family residential with some small local retail and commercial uses in this corridor. There is one travel lane in each direction. On-street parking and a bicycle lane run along the length of Belgrade Avenue.

Transit Service Characteristics

- Routes: 35, 36, 37

- 8 Inbound, 9 Outbound bus stops

- Average bus speeds between 10 and 26 MPH (slowest speeds near West Roxbury Parkway)

- 5 traffic signals, none on BTD Central System

Exhibit 9 Belgrade Avenue Typical Cross Section
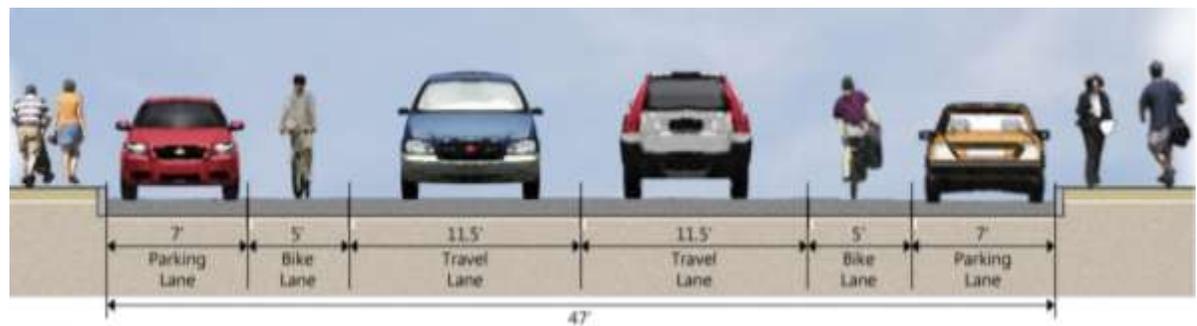
Centre Street

The Centre Street corridor within the study corridor extends between Belgrade Avenue and Lagrange Street. The area is largely commercial. There are two travel lanes in each direction. On-street parking runs along the full length of Centre Street on each side of the street within the study corridor. There are no bicycle lanes.

Transit Service Characteristics

Exhibit 10 Centre Street Corridor

- Routes: 35, 36, 37

- 4 Inbound, 4 Outbound bus stops

- Average bus speeds between 14 and 18 MPH (slowest speeds near intersection of Centre and Belgrade)

- 6 traffic signals, none on BTD Central System

Exhibit 11 Centre Street Typical Cross-Section
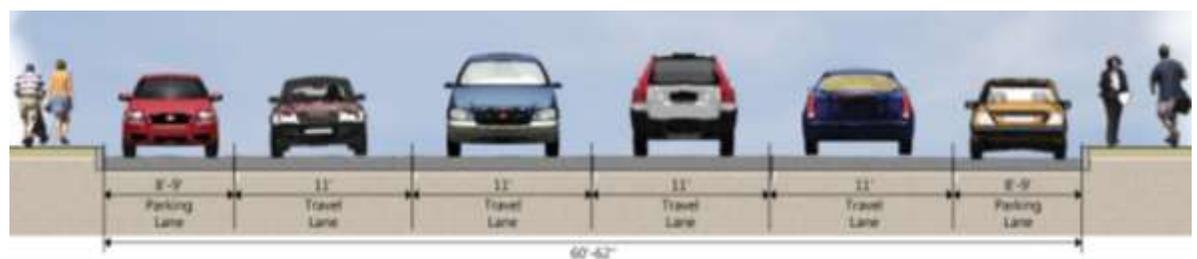
Analysis and Bus Priority Measure Selection

Using data provided by the MBTA, an analysis was performed to determine general hot spots through the study corridor. Using the AVL data provided by the MBTA, the average vehicle speed between stops was calculated and used to review the locations where the lowest speeds occur (hotspots). A sample of the results of this analysis is presented in Exhibit 12.

Exhibit 12 Calculated Average Speeds (Route 36 Inbound Morning Peak)
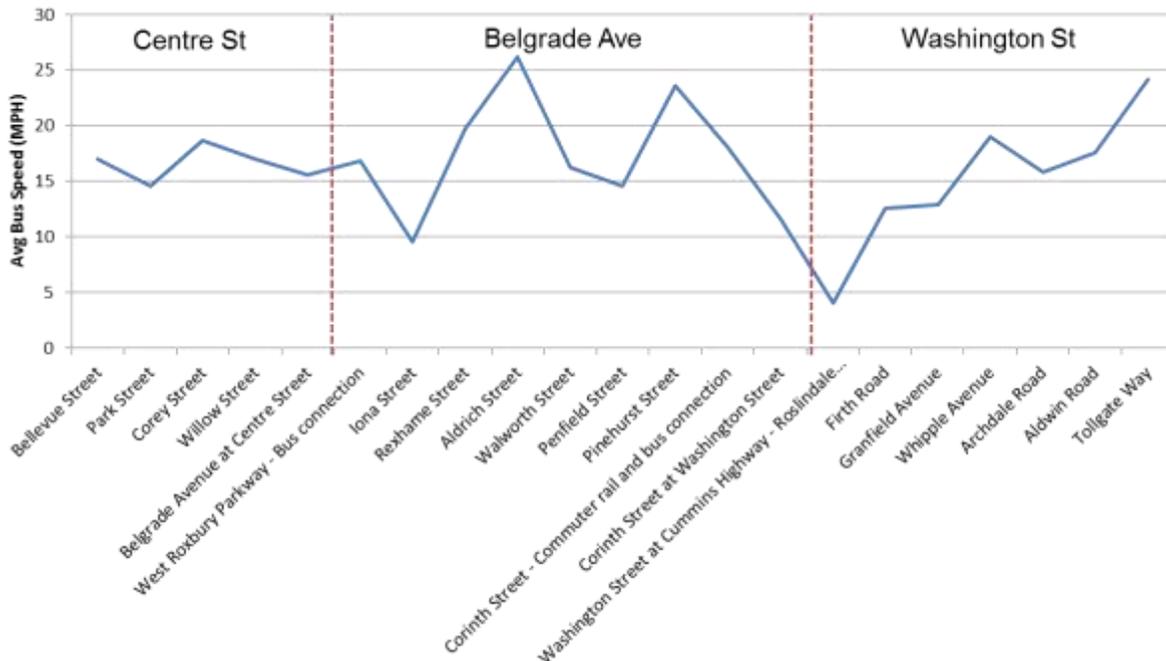
As shown, the lowest average speed occurs in Roslindale Square. Centre Street speeds are relatively steady while Belgrade Ave speeds fluctuate throughout the corridor. It should be noted that the speeds presented in the analysis seem relatively high based on observations in the corridor (this is corroborated by the MBTA); however, the results presented appear to represent the *relative* differences between speeds along the corridor. For example, the slowest speeds through the corridor are observed through Roslindale Square and there are stretches of Belgrade Avenue where a bus can travel at higher speeds than in other locations along the corridor. As such, we used this type of data to determine the relative hot spots through the corridor.

APC data was used to determine bus stops that are candidates for consolidation and to understand the characteristics of bus loads. A representative chart showing the loading profile of the Route 36 bus through the study corridor is presented in Exhibit 13.

**Exhibit 13 Loading Profile (Route 36 Inbound Morning Peak)**
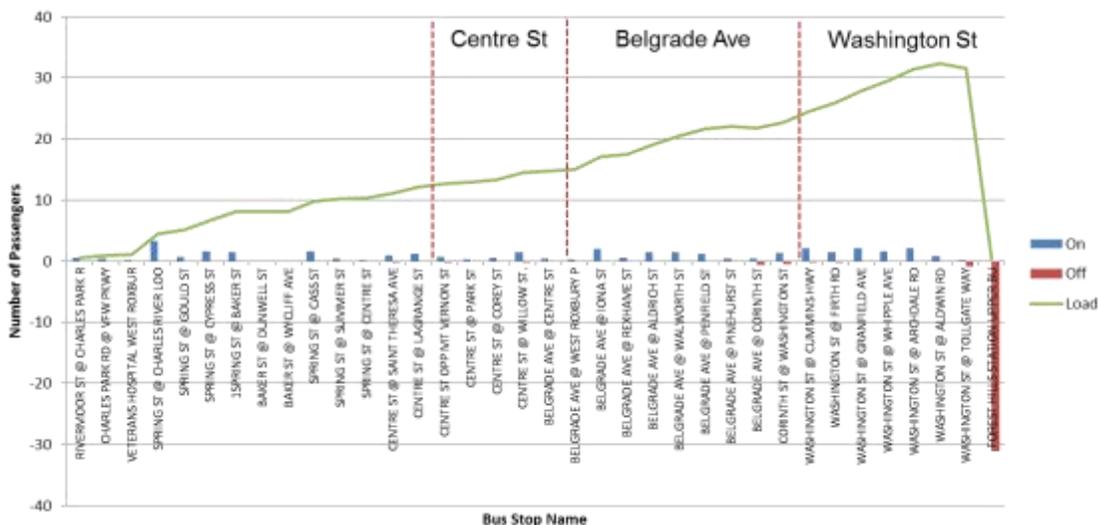
Potential improvements considered for the plan are presented below in Exhibit 14. It should be noted that bus lanes were considered through this corridor however deemed infeasible due to the constrained right-of-way and roadway capacity needs. Additional information on these bus priority measures is presented in the Phase A report of this study.

Exhibit 14 Candidate Bus Priority Measures

Bus Priority Measure	General Effect
Bus Stop Modifications	
Consolidation/Elimination	• Shortens trip times • Improves reliability
Near/Far-Side Stops	• Use far-side stops at all TSP-enabled intersections • Use near side stops at intersections with high volumes of cross-traffic (and no TSP)
Bus Curb Extensions	• Improves bus operations • Enhances customer experience
Traffic Signal Treatments	
Transit Signal Priority (TSP)	• Can provide bus with extended/advanced green • Implemented only at central computer controlled intersections
Bus Advance Signal	• Less complex to implement than TSP • Provides dedicated phase for bus in advance of regular traffic
Bus Lanes/Queue Jumps	
Queue Jump	• Enable bus to bypass queues at intersections • Minimal impact to traffic operations/parking
Other Improvements	
Bus Reroutes	• Reroute service to more optimal streets for operations
Boarding Changes	• Implement all door boarding to improve dwell times

The bus priority improvement selection process, presented in Exhibit 15, describes the process and data inputs used to determine potential bus priorities.

Exhibit 15 Improvement Selection Process
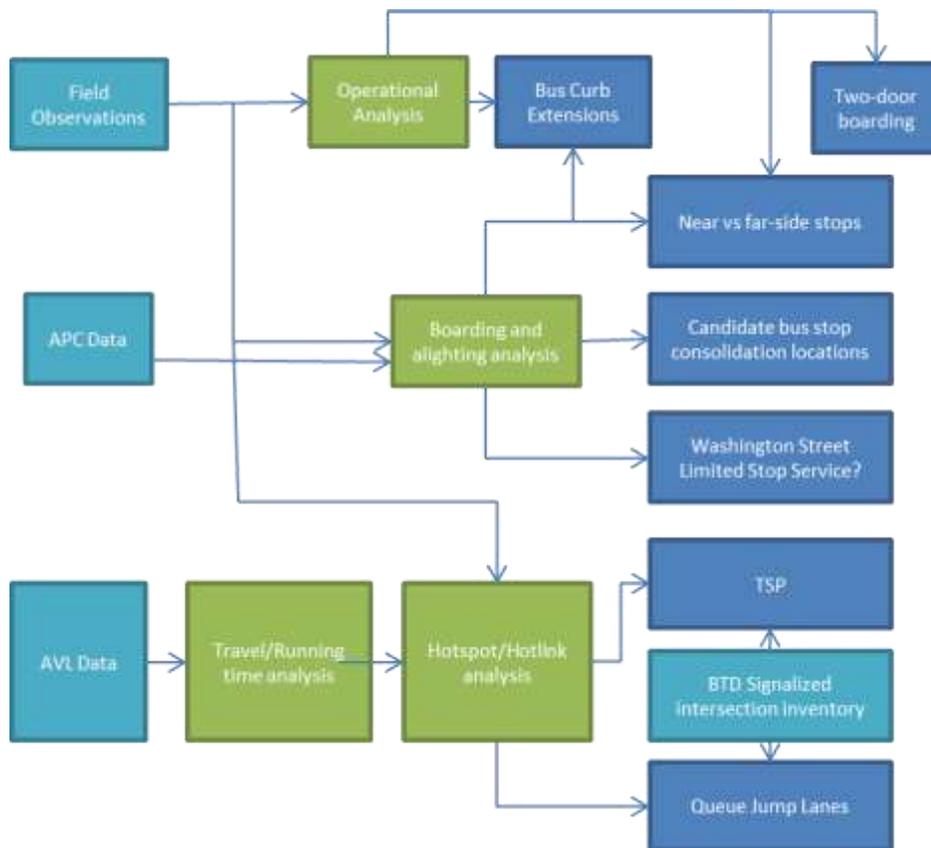
Based on the process outline in Exhibit 15, the bus priority treatments the following bus priority measures were selected for the corridors listed below:

Washington Street

- Bus stop consolidations
- Queue Jumps
- Traffic Signal Priority
- Potential Bus Lanes
- Improvements at Forest Hills Station
- Reroute along South Street

Belgrade Avenue

- Bus stop consolidations
- Change from near to far-side at Walworth Street
- Potential bus re-route

Centre Street

- Bus stop improvements
- Install/improve bus bulbs
- Consolidate select bus stops

Exhibits 17, 18 and 20 present the location of the bus priority improvements along each section of corridor.

After field observations at Forest Hills, it is suggested that the Forest Hills Upper Bus Turn Around is a good candidate for a fare paid zone. A fare paid zone is a restricted area for passengers who have already paid their fare, either at a gate, turnstile, or hold a monthly transit pass. A fare paid zone allows for quick boarding of buses since passengers do no have to queue to pay their fare onboard. One issue with fare-paid zones is enforcement. In some cases, fare-paid zones are restricted areas using gates and turnstiles to prevent fare evasion. In other cases, agencies use a proof of payment method and levy steep fines on those who are found to have not paid their fare.

Exhibit 16 Fare Paid Zone in Toronto, Ontario, Canada

Exhibit 17 Washington Street Corridor Improvements

Date: March 28, 2014
Project No.: 12050.00

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# Stops	IB	OB
Existing	8	7
Change	-3	-2
Net	5	5

Intersection Applications	#
TSP	4
Queue Jump	2
Bus Advance Signal	0
Net	6

Curb Extension	#
New	0
Enhanced	0
Net	0

Key
- Existing Signal
- Existing Signal (CC
- Existing Bus Stop
- New/Relocated Stop
- Bus Stop Eliminated
- TSP Application
- Queue Jump Application
- TSP and Queue Jump Application
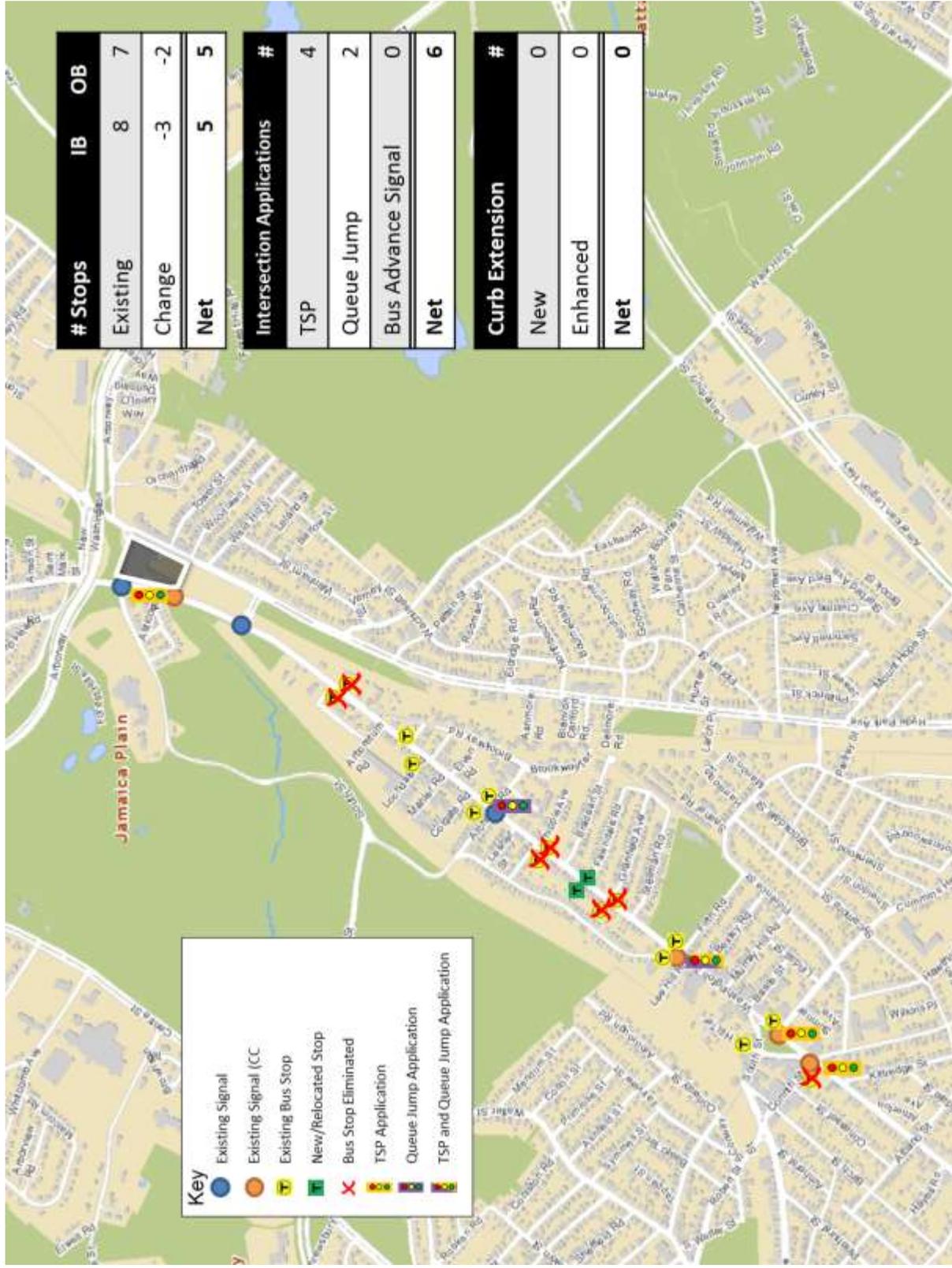
Exhibit 18 Belgrade Avenue Corridor Improvements

# Stops	IB	OB
Existing	8	9
Change	-2	-2
Net	6	7

Intersection Applications	#
TSP	1
Queue Jump	1
Bus Advance Signal	0
Net	2

Curb Extension	#
New	0
Enhanced	0
Net	0

Key
- Existing Signal
- Existing Signal (CC
- Existing Bus Stop
- New/Relocated Stop
- Bus Stop Eliminated
- TSP Application
- Queue Jump Application
- TSP and Queue Jump Application
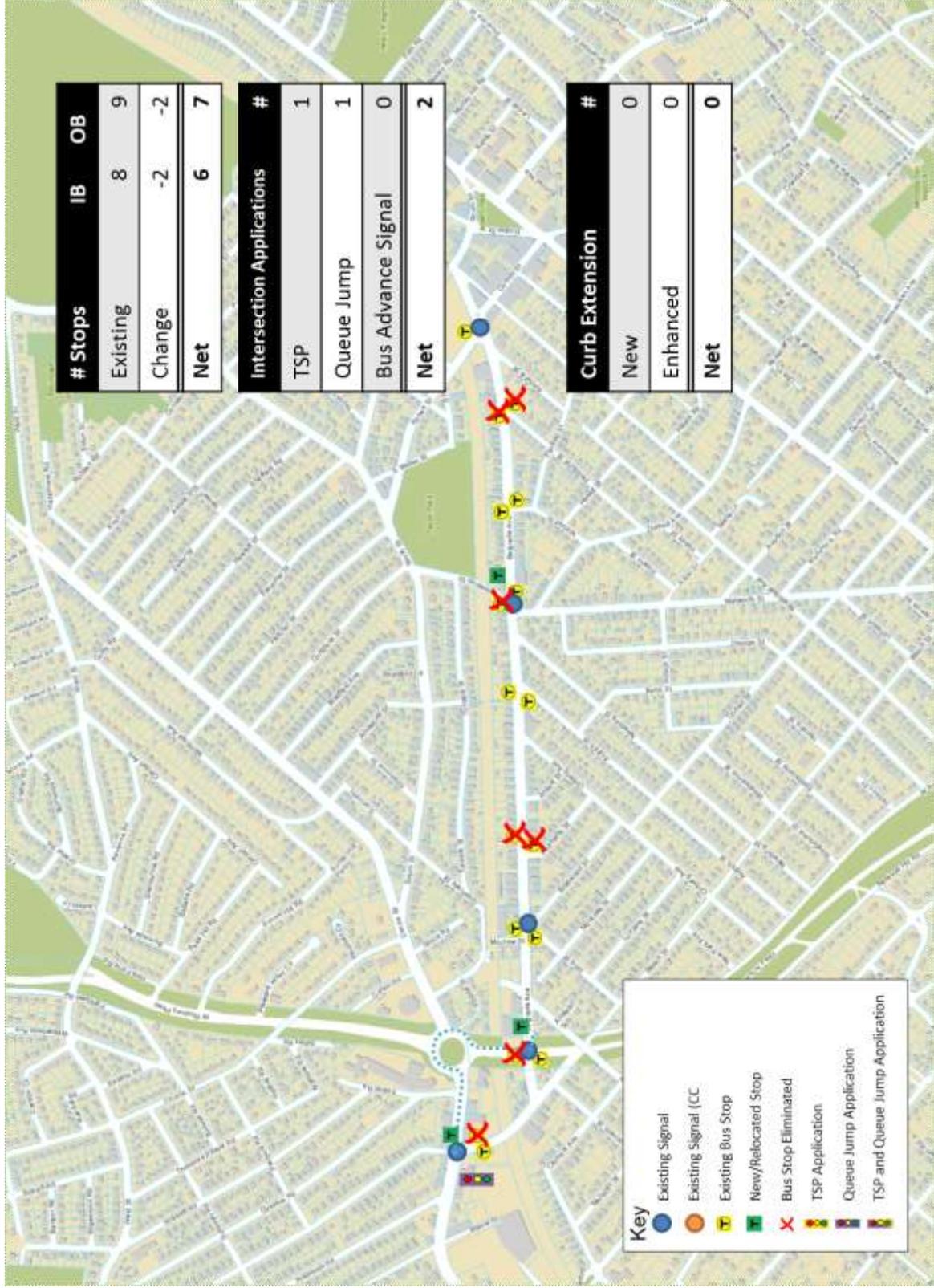
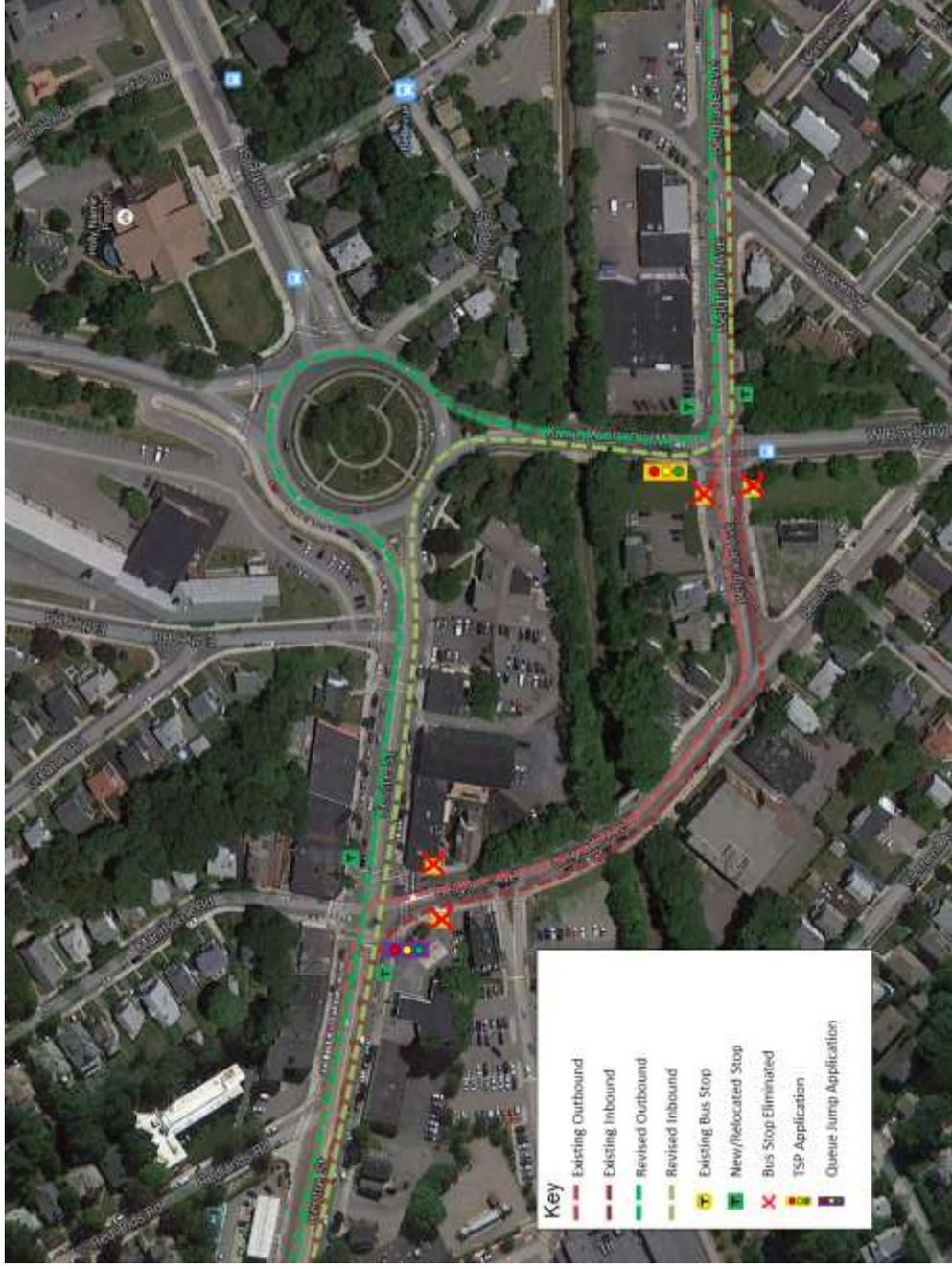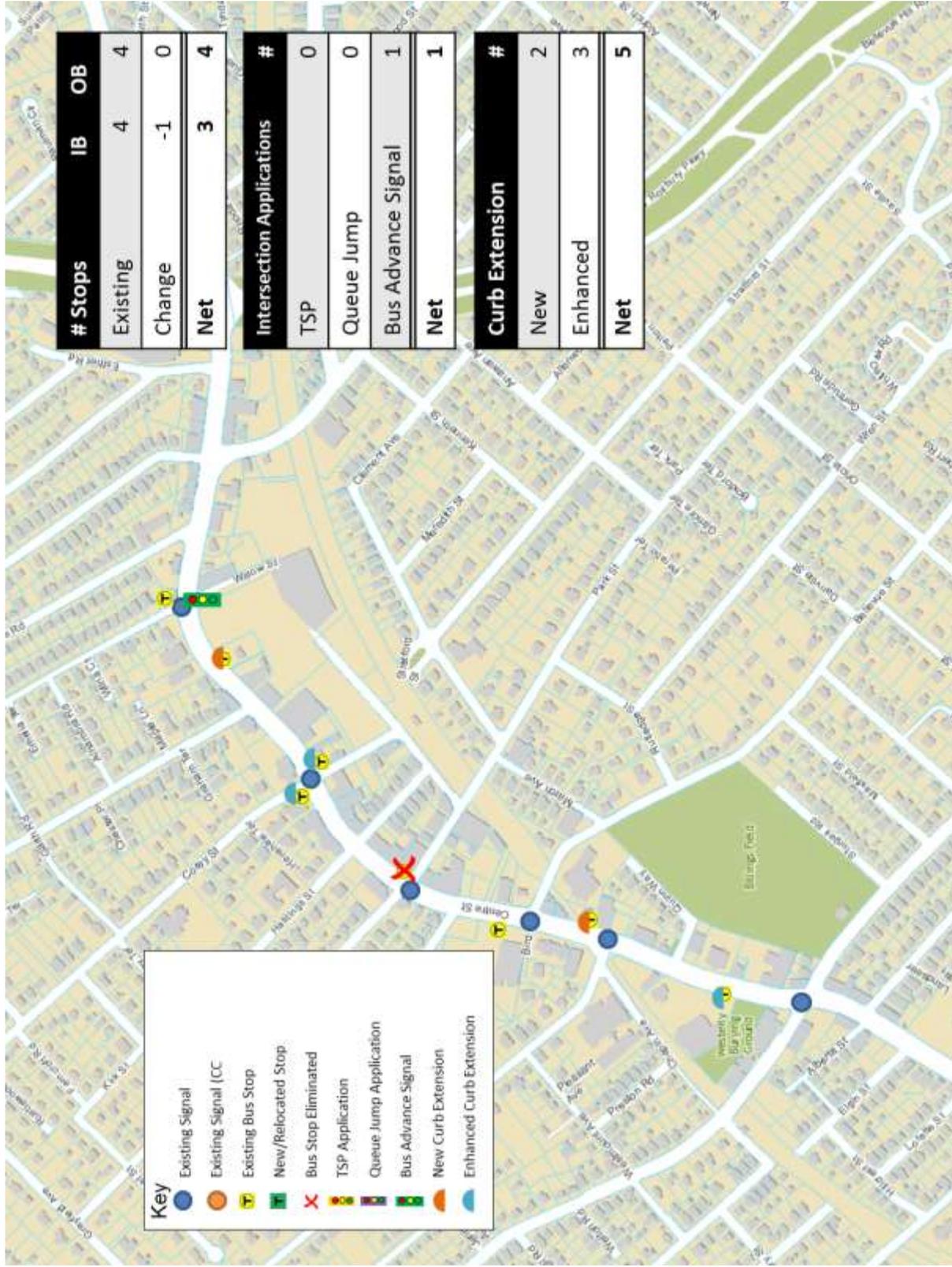**Exhibit 19 Potential Rerouting at Centre Street and Belgrade Avenue**

Exhibit 19 presents a potential rerouting of the bus routes to utilize the rotary at the intersection of Centre Street and West Roxbury Parkway. In the outbound direction, the bus would make a right at West Roxbury Parkway, travel around the rotary and exit onto Centre Street. In the outbound direction, the bus stop at Belgrade Avenue and West Roxbury Parkway would be relocated to become a near-side stop and the bus stop at intersection of Belgrade Avenue at Centre Street is moved to the northeast corner of the intersection. This eliminates a left turn from the route. The inbound route could remain unchanged (right from Centre Street to Belgrade Avenue) or could continue straight on Centre Street to the rotary, exit rotary at West Roxbury Parkway and then a left turn onto Belgrade Avenue. In the inbound direction, the original routing is preferred.

Exhibit 20 Centre Street Corridor Improvements

# Stops	IB	OB
Existing	4	4
Change	-1	0
Net	**3**	**4**

Intersection Applications	#
TSP	0
Queue Jump	0
Bus Advance Signal	1
Net	**1**

Curb Extension	#
New	2
Enhanced	3
Net	**5**

Key
- Existing Signal
- Existing Signal (CC
- Existing Bus Stop
- New/Relocated Stop
- Bus Stop Eliminated
- TSP Application
- Queue Jump Application
- Bus Advance Signal
- New Curb Extension
- Enhanced Curb Extension

Model Development

VHB developed a mathematical model based on calculated existing bus running time values derived from APC and/or AVL data provided by the MBTA and on time-saving factors for each proposed improvement based on research conducted during Phase A of this project. For the purposes of this exercise, the running times for Route 36 will serve as a proxy for the entire corridor:

Three models were developed for two time periods representing the critical movements during peak periods of bus operations. The three models depict three schematic design packages representing three degrees of bus improvements within the corridor: limited, moderate and major improvements. The schematic design and specific improvements within each package were vetted with ABC prior to development of the model. The following list presents the three models, the critical analysis periods and direction of analysis for those respective periods.

Exhibit 21 Improvement Packages

Limited Improvements –

- Require minimal capital improvements
- Implemented with minimal cost and delay

Periods and direction

- AM Peak Hour – inbound direction
- PM Peak Hour – outbound direction

Moderate Improvements

- Require some capital improvements
- Implemented in a short-medium time-frame.
- Include all of the changes in the "low" category, as well as queue jumps and curb extensions, and advance signals.

Periods and direction

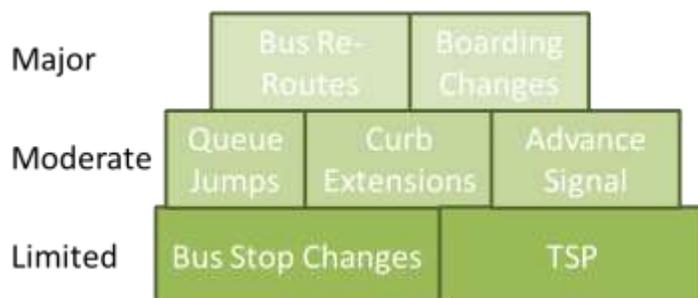- AM Peak Hour – inbound direction
- PM Peak Hour – outbound direction

Major Improvements

- Relatively high capital cost
- May require some policy alterations or additional inter-agency coordination
- Includes all bus priority treatments.

Periods and direction

- AM Peak Hour – inbound direction
- PM Peak Hour – outbound direction

Existing Conditions:

Existing stop-to-stop running times and dwell times throughout the corridor were based on MBTA provided data and calculated travel times. Existing travel times were developed based on a straight line factoring of the published scheduled running time and the distance between stops.

Future Conditions:

Future conditions are based on a five-year outlook on bus activity within the corridor. Future conditions analysis included a "growth factor" of one percent per year increase for five years in travel time due to increased roadway traffic and congestion, increased boardings and alightings, and other factors that may contribute to increased travel time. A "no-build" condition is analyzed, without any application of bus priority measures. Time saving factors were developed for six separate types of improvements (Changes to the number of bus stops (bus stop consolidation), bus stop configuration alterations (near-side vs far-side, curb extensions), queue jumps, TSP/signal alterations, bus rerouting and boarding/alighting configuration changes). These factors were based on published literature, wherever possible. If there were no factors available that would be applicable to this corridor, professional judgment were used to develop them.

The time saving factors were used to calculate changes in running time for the corridor, using a subtractive approach.

Passenger Minute Savings

Using the maximum loads per route in the corridor, the time savings were used to develop a metric of the number of passenger minutes saved. This metric is useful in conveying to the public the cumulative impact of the proposed improvements.

Travel Time Reduction Assumptions

The model was built upon the travel time savings per applied bus priority improvement presented in Exhibit 22.
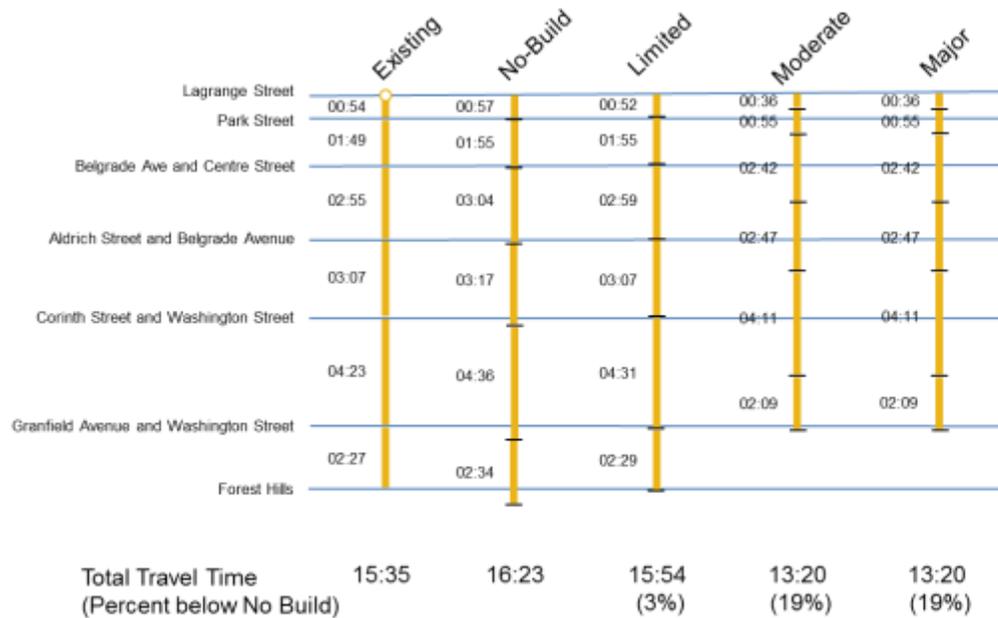
Exhibit 22 Travel Time Saving Assumptions

Bus Priority Improvement	Travel Time Savings	Source/Notes
TSP	0:00:00	Assume no savings, reliability only
Queue Jumps	0:00:10	BRT Practitioners Guide TCRP, P 4-40
Bus Advance Signal	0:00:30	
Curb Extension	0:00:15	BRT Practitioners Guide TCRP, P 4-43
Bus Stop Consolidation	0:00:15	Similar to curb extension; pull-in pull-out savings only

Modeling Results

The modeling results based on existing running times, no-build condition with applied growth factor without improvements and a build condition with applied growth factor and three improvement packages. Exhibit 23 and Exhibit 24 present the running time and travel time savings, respectively, for the inbound morning peak period. Exhibit 25 and Exhibit 26 present the running time and travel time savings, respectively, for the outbound evening peak period.

Exhibit 23 Inbound AM Peak Running Times

As shown in Exhibit 23, the no-build condition increases the travel time by approximately 50 seconds over the existing running time between Lagrange Street and Forest Hills. The Limited package reduces the travel time by 3 percent compared to the no-build condition. The Moderate and Major Improvement packages decrease the travel time by 2 minutes (or 19 percent) when compared to the no-build conditions.

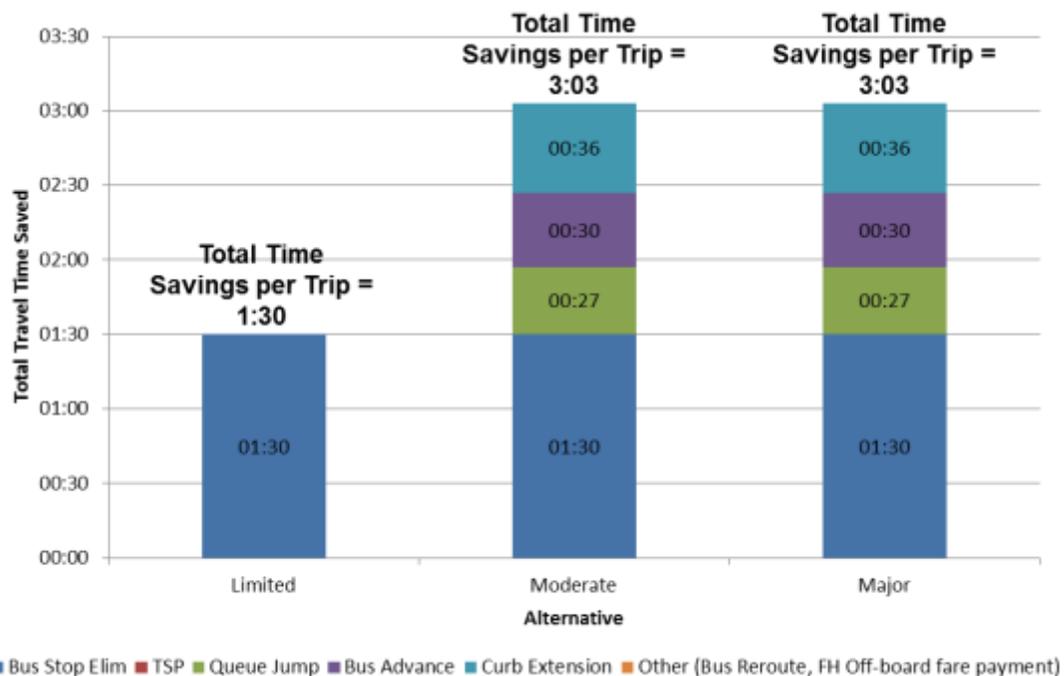**Exhibit 24 Inbound AM Peak Time Savings**

Exhibit 24 shows that all of the travel time savings in the Limited improvement package is due to the consolidation of bus stops. The travel time savings is twice as much for the moderate and major improvement packages compared to the Limited improvement package. The moderate and major improvement package offer the same treatments in the inbound direction. As such, these packages result in the same travel time savings.

Exhibit 25 Outbound PM Peak Running Times
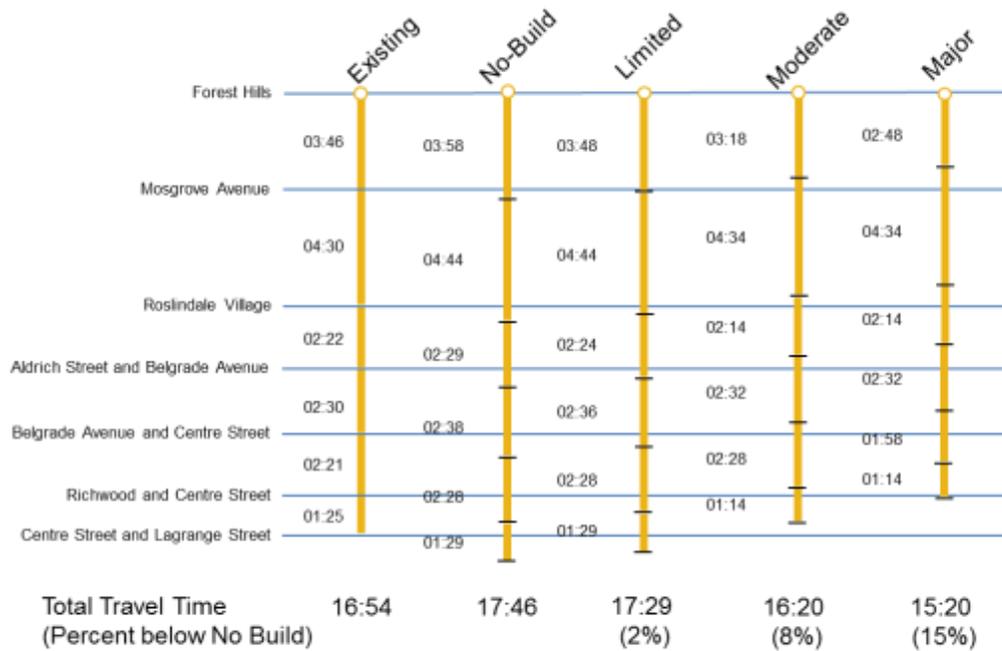
"No-Build" assumes 1% increase in travel time per year for five years

Travel times for Low, Medium and High represent the high range of travel times

Exhibit 25 shows that the limited improvement package decreases the running time by 2 percent compared to the no-build condition but does not bring the travel time back to existing conditions. The moderate and major improvement packages reduce travel time by 8 percent and 15 percent respectively compared to the no-build condition. As shown in Exhibit 26, the additional time savings is due to bus rerouting and off-board fare payment at Forest Hill Station.

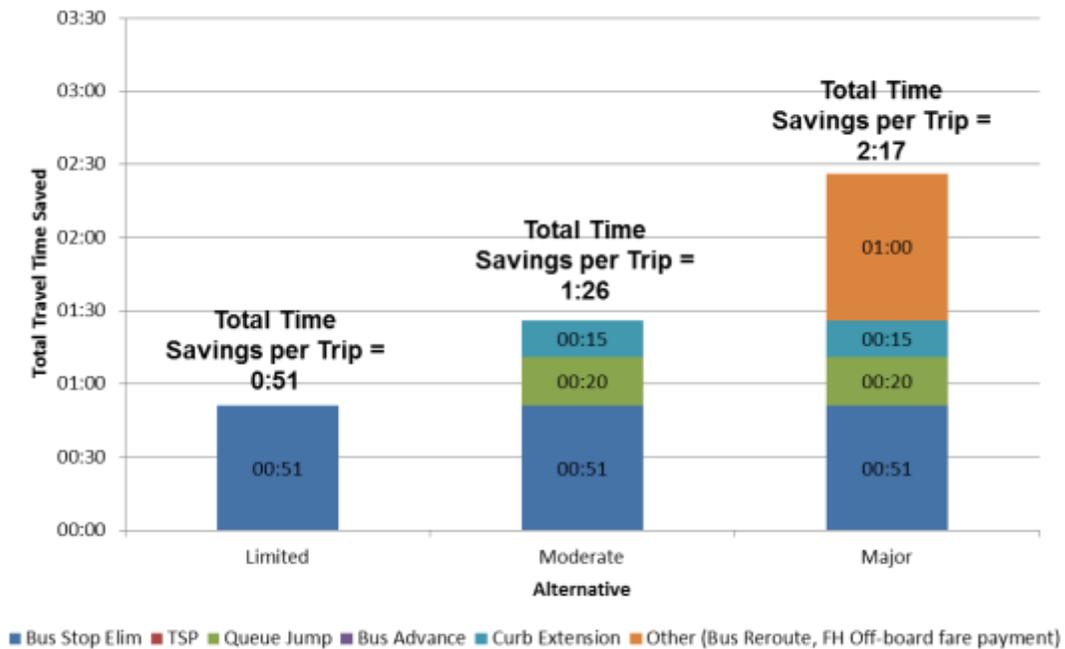**Exhibit 26 Outbound PM Peak Time Savings**

Exhibit 27 presents a chart which depicts the degree of secondary impact based on levels of travel time reduction. The results of the model show travel time savings range of just under one minute to approximately three minutes. As such, implementing these improvement packages would most likely yield passenger time savings and increased reliability. Exhibit 28 presents the total daily travel time savings for passengers on Routes 35, 36, and 37. This value was calculated using the cumulative link passenger load multiplied by the time savings on that link.

Exhibit 27 Potential Secondary Impact
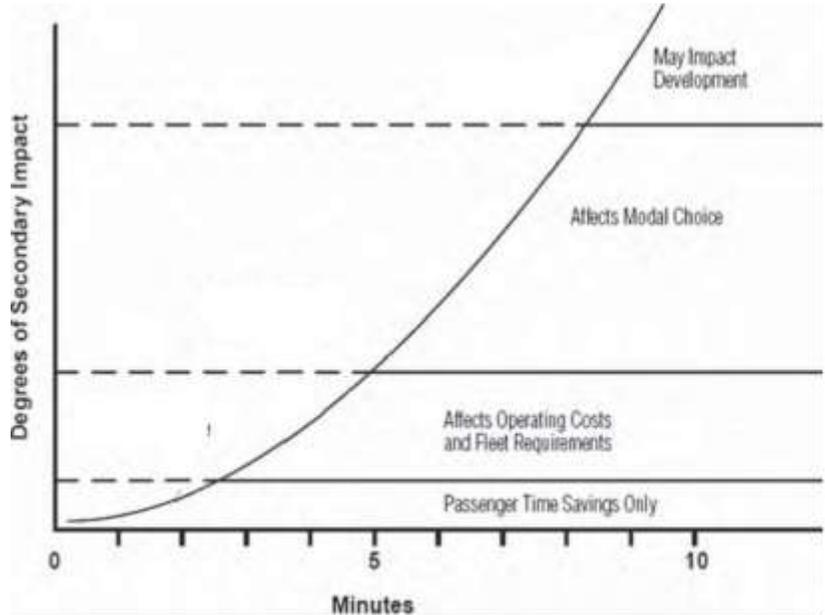
Source: TCRP Report 26

Exhibit 28 Passenger Hour Savings
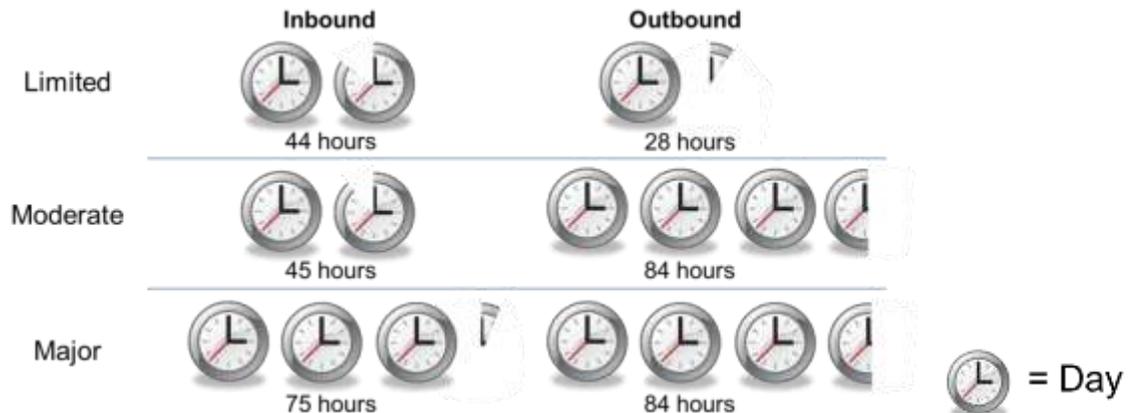
As shown in Exhibit 28, the limited improvement package yields a total of three days worth of passenger travel time savings while the major improvement package can potentially save approximately one week of passenger travel time savings every day.

Cost-Effectiveness Calculation

A cost-effectiveness analysis was completed to compare each of the improvement packages with one another and against previous Federal Transit Agency (FTA) criteria. As a rule of thumb, a cost per hour saved under $20 is considered "good" by FTA standards based on previous new starts cost-effectiveness criteria. Cost-effectiveness is calculated based on the estimated capital cost of the improvement package and the estimated passenger hour savings for each package.

Exhibit 29 Cost-effectiveness Calculation for Improvement Packages

Major	A	Capital Cost	$690,000
	B	Daily PAX-hr Saved	160 hours
	C	Annualization Factor	252 day/year
	D	Annual PAX-hr Saved	40,068 hours
	E	Cost per hour saved (E=A/D)	$17.22
Moderate	A	Capital Cost	$435,000
	B	Daily PAX-hr Saved	129 hours
	C	Annualization Factor	252 day/year
	D	Annual PAX-hr Saved	32,508 hours
	E	Cost per hour saved (E=A/D)	$13.38
Limited	A	Capital Cost	$25,000
	B	Daily PAX-hr Saved	24 hours
	C	Annualization Factor	252 day/year
	D	Annual PAX-hr Saved	6,048 hours
	E	Cost per hour saved (E=A/D)	$8.20

As shown in Exhibit 29, each improvement package can be considered cost effective based on FTA criteria, the limited improvement package is the most cost effective.

Conclusions

This memorandum provides an overview of the results from Phase B of the Boston Surface Transportation Optimization Pilot Study. The WBC corridor was selected using a unique set of selection criteria including choosing a study corridor that includes multiple routes in order to provide benefits and improved travel time on several routes.

The evaluation of several improvement packages, introducing several groupings of bus priority measures to the corridor, demonstrated that the introduction of bus priority measures is cost effective and has the potential of providing bus passengers between 3 to 19 percent travel time savings in the morning peak inbound direction and 2 to 15 percent travel time savings in the evening peak outbound direction.

Bus priority measures also have the capability of improving the character of a corridor. Introduction of curb extensions provides additional space to install bus shelters, benches, and other amenities for passengers. Additionally, they move waiting passengers off of the sidewalk, providing additional room for pedestrians.

Overall, this study, along with the MBTA Key Bus Routes Program, demonstrates that bus priority measures have benefits within Boston's urban context. While full BRT systems have the potential to transform the character of corridors, improve travel times, increase ridership, and increase economic development in the area, gold standard BRT systems are not always practical or feasible in all contexts. Bus priority measures can improve reliability for customers and operators without the same financial or political barriers of full scale BRT systems.

Next Steps

The following are a series of recommended next steps to continue the pursuit of bus priority measures for the WBC corridor.

- Engage community and present draft conceptual design
    - Vet suggested improvements/packages in pubic process
- Revise conceptual design and work with MBTA to develop pilot program
- Determine capital costs of improvement
- Work with MBTA to determine possible pilot funding mechanism(s)
- Pursue funding for improvements