TASK ORDER PUBLIC TRANSPORTATION SERVICES

CORE ID. No. 15DOT0090AA

Route 1 Bus Rapid Transit Feasibility Study

STATE PROJECT NO. 173-471

DRAFT

Task 7.2 Technical Memorandum: Corridor Prioritization and Recommendation

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1. Introduction

This Technical Memorandum was developed under Task 7.2 of the Route 1 Bus Rapid Transit Feasibility Study. Under Task 6, several technical memoranda were developed, focusing on specific categories of Bus Rapid Transit (BRT) improvement strategies for the Route 1 corridor. Under Task 7.1, all of the improvement strategies were combined into a single program of improvements for each of the five Route 1 corridor segments.

In October 2016, the program of improvements for each corridor segment was reviewed at two meetings of the expanded Technical Advisory Committee (TAC) for the project. The expanded committee included not only the initial representatives from CTDOT, the five bus operating divisions, and the three Councils of Governments, but also representatives from the impacted municipalities. All twelve municipalities were invited to participate. Representatives attended from the municipalities of Greenwich, Stamford, Darien, Norwalk, Westport, Stratford, Milford, West Haven and New Haven. Meeting attendees provided feedback on the proposed corridor program elements as well as an indication of both the consistency of the proposals with local transit initiatives and the level of support for BRT enhancements in each municipality.

This technical memorandum presents a summary of the impacts on running time, ridership, and cost of each of the corridor programs, followed by a comparison of the five corridor segments and also four possible corridor combinations. A set of evaluation criteria is presented and applied to each corridor and corridor combination and recommendations are made for next steps in developing BRT in the corridor. The improvement program for the preferred initial corridor is described, including a breakdown of improvements by municipality in the preferred initial corridor and a discussion of implementation issues to be resolved before BRT service can be implemented.

2. Corridor Comparison and Evaluation

2.1 Comparison of Corridors

Table 1 contains a summary of the technical analysis of potential BRT service conducted for each of the five corridor segments. The table shows the headways assumed for each limited stop BRT service, which are equivalent to the headways on the existing local service that currently operates in each corridor segment. The table also shows the current running times on the local service and the estimated running time saved by the limited stop BRT service.

The Ridership section shows the “potential ridership” for limited stop service. “Potential ridership” is based on the current ridership at proposed limited stops plus half the ridership at the two adjacent stops, adjusted to estimate the number of riders who could both board and alight at the limited BRT stops. Current corridor ridership, estimated revised corridor ridership with BRT service, and estimated ridership on just the limited stop BRT service are also shown, along with the estimated corridor ridership increase over current levels.

The Capital Cost section shows some of the figures on which capital costs are based. It includes the total number of stations to be constructed, as well as the number of stations with more complex needs, such as those that would be located at a different corner of the intersection from the current bus stop, and those requiring construction of curb ramps, additional sections of sidewalk, or curb extensions. The number of buses to be procured includes the number of buses required for the limited stop BRT service,

Table 1: Comparison of Corridors

	311	341	CL West	CL East	O
Service Frequency					
Peak Period Headway	20	20	20	20	15
Midday Headway	30	30	60	60	20
Running Time					
Current Average Route Running Time	50.7	45.5	59.2	51.3	43.7
BRT Average Running Time Savings	12.0	5.8	5.1	3.9	11.1
Percent BRT Running Time Savings	24%	13%	9%	8%	25%
Ridership					
Potential BRT Ridership Share	45%	65%	65%	66%	56%
Current Weekday Daily Corridor Ridership	2,447	2,470	2,318	1,435	2,556
Estimated Revised Corridor Ridership	3,132	3,253	3,023	1,869	3,474
Estimated BRT Service Ridership	1,334	1,449	1,332	832	1,788
BRT Service Ridership Share	43%	45%	44%	44%	51%
Weekday Corridor Ridership Increase	685	783	705	434	918
Percent Corridor Ridership Increase	28%	32%	30%	30%	36%
Annual Corridor Ridership Increase (000)	175	200	180	111	234
Capital Costs					
Total Stations Constructed	22	23	44	33	32
Stations Relocated	5	4	4	1	4
Stations with Additional Construction	4	2	6	3	16
Additional Buses	6	7	8	7	8
Station Cost ($000)	$895	$1,184	$1,703	$1,075	$1,712
Intersection Improvement Cost ($000)	$131	$23	$59	$161	$64
Bus Procurement Cost ($000)	$2,550	$2,975	$3,400	$2,975	$3,400
Transit Agency TSP Cost ($000)	$88	$98	$123	$119	$119
Total Capital Cost ($000)	$3,664	$4,280	$5,285	$4,330	$5,295
Annualized Capital Cost ($000)	$327	$384	$469	$386	$470
Operating Costs					
Annual Operating Cost ($000)	$955	$1,105	$1,287	$1,102	$1,413
Estimated Revenue Increase ($000)	$214	$244	$180	$111	$211
Net Annual Operating Cost ($000)	$742	$861	$1,107	$991	$1,202
Net Operating Cost per New Rider	$4.24	$4.31	$6.15	$8.92	$5.14
Total Costs					
Net Annual Total Cost ($000)	$1,069	$1,245	$1,576	$1,377	$1,672
Net Total Cost per New Rider	$6.11	$6.23	$8.75	$12.40	$7.14

plus spares. In addition to station costs and bus procurement costs, the costs of intersection improvements (primarily signalization improvements for transit signal priority - TSP) and the cost to transit operators for signal priority equipment are shown.

The Operating Costs section shows the total and net annual operating cost for the limited stop BRT service that would be borne by the bus operators, and also shows the estimated net additional operating cost per new rider. The Total Cost section factors in the annualized capital cost and shows net additional total cost per new rider.

In developing recommendations for Route 1 BRT service and in discussions with the expanded TAC, the idea of a limited stop BRT route spanning two adjacent corridors was considered. To evaluate this possibility, the same summary analysis was prepared for the four possible combinations of adjacent corridor segments, and is shown in Table 2. In developing the summary, it was noted that the proposed headways differ for two of the pairs of segments (341+CLW and CLE+O). In those two cases, the entire combined segment service was assumed to operate at the more frequent headway, as indicated in the Service Frequency section of the table. This resulted in some measures, such as ridership, bus procurement costs, and operating costs, being higher than for the total of the two segments separately. For the other two combination segments, proposed headways on the two corridors are equal, so the impacts of combined service are equal to the sum of the impacts on the two individual segments.

It should be noted that no increases in ridership were assumed to result from the actual combining of adjacent corridors. However, while the 2012 Coastal Corridor Study survey showed little evidence of need for such service among current riders, members of the expanded TAC felt that the unmet need exists in some cases and such a service is worth considering.

2.1 Evaluation Criteria

One of the goals of the Route 1 Bus Rapid Transit Feasibility Study is to "determine where *the best locations* are for potential BRT enhancements to increase the effectiveness of bus services and improve operations." Therefore, an evaluation and prioritization process was needed to determine which corridor segment poses the best opportunity for successful implementation of an initial BRT service. Any evaluation and ranking of the corridor programs should be based on a series of measures resulting from questions that can be answered with either quantitative or qualitative information. Quantitative data can be used to assess the overall cost effectiveness and value proposition for the improvement plan, while a qualitative assessment is needed to consider less quantifiable measures, such as other ongoing complementary initiatives that could facilitate a successful implementation and also the degree of complexity of the implementation, in terms of construction, technology integration, and governance.

Working with CTDOT, the study team developed the following evaluation questions that can be answered quantitatively for each corridor segment using the data in Table 1 or Table 2:

- How many customers are served today?
- What would be the potential travel time savings versus the existing service?
- What would be the anticipated corridor ridership growth?
- How large a share of corridor riders would a limited stop BRT service attract?
- What would be the total capital cost associated with the improvements?
- What would be the total annual operating cost associated with the improvements?
- What would be the net cost per new rider?

Table 2: Comparison of Combination Corridors

	311+341	341+ CLW	CLW+CLE	CLE+O
Service Frequency				
Peak Period Headway	20	20	20	15
Midday Headway	30	30	60	20
Running Time				
Current Average Route Running Time	96.2	104.7	110.5	95.0
BRT Average Running Time Savings	17.8	10.7	9.0	14.7
Percent BRT Running Time Savings	19%	10%	8%	15%
Ridership				
Potential BRT Ridership Share		0		0
Current Weekday Daily Corridor Ridership	4,917	4,788	3,753	3,991
Estimated Revised Corridor Ridership	6,385	6,429	4,892	5,497
Estimated BRT Service Ridership	2,783	2,876	2,164	2,715
BRT Service Ridership Share	44%	45%	44%	49%
Weekday Corridor Ridership Increase	1,468	1,641	1,139	1,506
Percent Corridor Ridership Increase	30%	34%	30%	38%
Annual Corridor Ridership Increase (000)	375	418	291	384
Capital Costs				
Total Stations Constructed	45	67	77	65
Stations Relocated	9	8	5	5
Stations with Additional Construction	6	8	9	19
Additional Buses	13	15	15	18
Station Cost ($000)	$2,079	$2,887	$2,778	$2,787
Intersection Improvement Cost ($000)	$154	$82	$220	$226
Bus Procurement Cost ($000)	$5,525	$6,375	$6,375	$7,650
Transit Agency TSP Cost ($000)	$186	$221	$242	$252
Total Capital Cost ($000)	$7,944	$9,565	$9,615	$10,915
Annualized Capital Cost ($000)	$711	$853	$855	$978
Operating Costs				
Annual Operating Cost ($000)	$2,060	$2,705	$2,388	$3,049
Estimated Revenue Increase ($000)	$458	$464	$291	$361
Net Annual Operating Cost ($000)	$1,603	$2,241	$2,097	$2,689
Net Operating Cost per New Rider	$4.27	$5.36	$7.21	$7.00
Total Costs				
Net Annual Total Cost ($000)	$2,314	$3,094	$2,952	$3,667
Net Total Cost per New Rider	$6.17	$7.40	$10.15	$9.55

To consider the ease and complexity of implementation in each corridor, the following qualitative questions were posed:

- Are there ongoing complementary initiatives in the corridor that could facilitate a successful implementation and is there support among the local municipalities and transit operators?
- Would the improvement plan involve creation of a new one-seat connection?
- Would the plan require governance changes relative to the current service(s)?
- What would be the scale and complexity of construction activities?
- How complex would the integration of technology be for real time information and transit signal priority applications?

To address these more qualitative questions, a numeric rating along a scale of 1 (least favorable) to 5 (most favorable) was given to each corridor for each question. Complementary initiatives and local support were judged primarily using input from the expanded TAC meeting. New one-seat connections are provided by some of the combination corridors, whereas the existing corridors provide no new connections. Governance issues arise for any new service in the Coastal Link corridor (where three operators now share control), as well as any combination corridor that combines corridors now served by different operators. Scale and complexity of construction was judged based on how many stations are needed and how many stations would require more complex construction and coordination. Complexity of technology integration was based on an estimate of the complexity of integrating transit Automatic Vehicle Location (AVL) systems for the operator(s) on each segment, or combination, with the signal systems on that segment.

2.2 Corridor Evaluation

From the evaluation questions, a matrix was developed and populated with empirical data for the quantitative measures, and with the study team's judgment concerning the more qualitative measures. Separate matrices were prepared for the five corridor segments (Table 3) and for the four combination corridors (Table 4). The tables use a color scale to indicate the relative ratings for each measure, with green indicating the most favorable and red the least favorable values for each measure. The colors for intermediate values are scaled along a gradient between green and red based on where the data lies along the range between the most and least favorable values. Data for the quantitative measures was taken from the above tables while the study team's reasoning behind the ratings given for the qualitative measures are discussed below.

Complementary Initiatives and Local Support

The municipal representatives at the expanded TAC meetings expressed considerable general support for improved bus service in the corridor. Representatives from Stamford, Darien, Norwalk, Westport, Stratford, West Haven and New Haven were supportive of service in their communities, as were representatives from Greater Bridgeport Transit, Norwalk Transit District and CT*transit*. Representatives from the Cities of New Haven and Stamford provided information about the ongoing transit studies in their respective cities and noted possible synergies between the proposed BRT improvements and improvements being considered as part of the New Haven Alternatives Analysis and the Stamford Bus and Shuttle Study. As a result, the O Route 1 and 341 corridors were rated most highly. The two Coastal Link corridors were also rated highly. Bridgeport Transit noted proposed improvements from its Long Range Transit Plan, including an alternative Coastal Link routing, although implementation of that

Table 3: Evaluation of Corridors

	311	341	CL West	CL East	O
Running Time					
Percent BRT Running Time Savings	24%	13%	9%	8%	25%
Ridership					
Current Weekday Daily Corridor Ridership	2,447	2,470	2,318	1,435	2,556
BRT Service Ridership Share	43%	45%	44%	44%	51%
Percent Corridor Ridership Increase	28%	32%	30%	30%	36%
Costs					
Total Capital Cost ($000)	$3,664	$4,280	$5,285	$4,330	$5,295
Annual Operating Cost ($000)	$955	$1,105	$1,287	$1,102	$1,413
Net Total Cost per New Rider	$6.11	$6.23	$8.75	$12.40	$7.14
Ease of Implementation					
Complementary Initiatives and Local Support	3	5	4	4	5
Creation of New One-Seat Connection	1	1	1	1	1
Scale of Governance Change Required	5	5	3	3	5
Construction Scale and Complexity	4	4	2	3	2
Complexity of Technology Integration	4	4	2	2	5

Table 4: Evaluation of Combination Corridors

	311+341	341+ CLW	CLW+CLE	CLE+O
Running Time				
Percent BRT Running Time Savings	19%	10%	8%	15%
Ridership				
Current Weekday Daily Corridor Ridership	4,917	4,788	3,753	3,991
BRT Service Ridership Share	44%	45%	44%	49%
Percent Corridor Ridership Increase	30%	34%	30%	38%
Costs				
Total Capital Cost ($000)	$7,944	$9,565	$9,615	$10,915
Annual Operating Cost ($000)	$2,060	$2,705	$2,388	$3,049
Net Total Cost per New Rider	$6.17	$7.40	$10.15	$9.55
Ease of Implementation				
Complementary Initiatives and Local Support	4	4.5	4	4.5
Creation of New One-Seat Connection	2	5	1	5
Scale of Governance Change Required	5	2	4	2
Construction Scale and Complexity	4	3	2.5	2.5
Complexity of Technology Integration	4	2	2	2

proposal is at least several years away. Milford Transit was less supportive of changes in the Coastal Link corridor. The Route 311 corridor was rated less highly primarily due to concerns expressed about past lack of support for bus service in both Greenwich and Port Chester. For the four combination corridors the individual corridor ratings were averaged.

Creation of New One-Seat Connection

Only two of the combination corridors (341+CLW and CLE+O) would create new one-seat connections, while none of the single corridors, nor the combination of Coastal Link East and West, would do so. Routes 311 and 341 already operate much like a single service, but the combination would be a slight improvement with a single route identity and most likely a more direct through-routing in Stamford, so that combination was given a slightly higher rating.

Scale of Governance Change Required

Issues of governance revolve around the number of different operating agencies that would be responsible for providing the service and how the operations, supervision, costs and revenues would be divided among them. The details of governance cannot be fully answered in the process of this evaluation, although it is clear that the 311, 341 and O Route 1 corridors could each be operated by the local CT*transit* Division alone. A new BRT service in one or both Coastal Link corridors would require an agreement concerning operations, supervision, costs and revenues of the BRT service and could result in revisions to the agreement between the three operators governing the existing local Coastal Link service. Having a single operator for the BRT service would make implementation of Transit Signal Priority (TSP) and real-time information far less complex, but could raise questions impacting the existing governance structure. Combining one of the Coastal Link segments with one of the CT*transit* segments would add a fourth transit operator to the mix, further complicating governance.

Construction Scale and Complexity

The Route 311 and Route 341 corridors would have the fewest stations to construct and the areas served generally have the best pedestrian connections requiring the least construction of additional pedestrian improvements. The Coastal Link East and O Route 1 would have more stations to construct, but the O Route 1 corridor has by far the most need for construction of additional sidewalks and curb ramps. The Coastal Link West is the longest segment and would involve construction of the most stations. For the combination corridors the individual corridor ratings were averaged.

Complexity of Technology Integration

The CT*transit* New Haven Division, operator of O Route 1, is installing the current version of the Trapeze AVL system, which is designed to support both real-time information dissemination and TSP. The older Xerox AVL system operated by the Stamford Division in the 311 and 341 corridors has less proven ability to support the two technologies. Implementing the two technologies on all or part of the Coastal Link corridor would involve three different operators with three different AVL systems, each with different levels of capability and different procedures for integration. Adding either of the adjacent CT*transit* divisions to Coastal Link service would add a fourth operator and a fourth AVL system to the mix. The feasibility of supporting the two technologies with multiple AVL systems is not known but limiting the operation to one operator would raise governance issues.

3. Recommendations for BRT in the Route 1 Corridor

The evaluation shown in the tables in the previous section illustrates that each of the five corridors has advantages and disadvantages. The Route 311 and O Route 1 corridors could provide the biggest travel time savings. The O Route 1 corridor could also provide the most ridership benefits, albeit at the highest costs, while the Route 311 corridor has the lowest costs and least ridership benefits. The Route 341 corridor has a slight advantage over the O Route and the 311 in ease of implementation, along with ridership, travel time, and costs that lie in the middle of the pack. The Coastal Link corridors would have the lowest travel time benefit and the most implementation challenges, due to the complexity of the existing operation.

On the whole, however, by most measures, the differences between the corridors are not large. There are clear, albeit modest, benefits that can be realized in each corridor and therefore there is little reason to exclude any one outright from consideration for eventual BRT service. Ultimately, there could be BRT service throughout the entire corridor, most likely using a number of routes rather than one single long service, but possibly using as few as two or three long routes, each covering one or two segments.

Keeping in mind that one of the goals of this project was to "determine where *the best locations* are for potential BRT enhancements to increase effectiveness of bus services and improve operations," it is essential that this project identify which location, or which corridor segment, poses the best opportunity for successful implementation of an initial BRT service. Implementation in one corridor segment would also be less of an undertaking than a corridor-wide program and an initial successful example in one segment can provide the impetus for services on additional segments, or extension of the initial service to cover a second segment. Therefore, while all corridor segments could benefit from BRT improvements, an initial segment has to be identified at this time.

The other goal of this project was to "develop alternatives and assess their viability in improving bus travel time and increasing bus ridership in targeted corridors." This emphasis on travel time improvements and increasing ridership indicates that the most emphasis in selecting an initial corridor segment for BRT implementation should be placed on travel time and ridership measures. Taking this into account, but considering all of the evaluation measures evaluated above, the recommendation of this study is that the O Route 1 corridor segment presents the best opportunity for a successful initial BRT service, due to the potential for travel time savings, estimated ridership increases, and consistency with the city's plans for bus service improvements. While the cost of implementation in this corridor may be slightly higher than the others, the cost per new rider is not far above that of the lowest cost corridor segments.

The Route 341 segment appears to present the second best opportunity and could be considered for a second phase, given the ease of implementation, low cost, and moderate travel time and ridership benefits. BRT service could also eventually be introduced on the Route 311 segment, either as a separate service or as an extension of Route 341 service, but only if support among all affected municipalities is evident.

The Coastal Link Corridor has numerous governance and technological issues to be resolved. It has also been recently made clear that there are schedule and performance issues that must be given higher priority and there is a need to improve the reliability, and possibly the frequency, of service on the existing route, before considering BRT service in the corridor. Separate BRT service could be

implemented at a later date in the Coastal Link corridor, or there could eventually be extensions of both the O Route 1 and 341 BRT services to Bridgeport, provided governance issues can be resolved.

The above findings and recommendations are summarized in Table 5.

Table 5: Route 1 Bus Rapid Transit Feasibility Study Findings and Recommendations

• All Route 1 corridor segments could benefit from BRT improvements.
• There could ultimately be BRT service throughout the entire Route 1 corridor using multiple BRT routes.
• The O Route 1 segment presents the best opportunity for a successful initial BRT service.
• The Route 341 segment presents the second best initial opportunity.
• BRT service could eventually be introduced on the Route 311 segment, either as a separate service or as an extension of Route 341 service, but only if support among all affected municipalities is evident.
• The priority on the Coastal Link corridor should be improving the reliability and performance of the existing local service first, before adding BRT. BRT service could eventually be implemented possibly as extensions of the O Route 1 and 341 BRT services to Bridgeport, provided governance issues can be resolved.

4. O Route 1 Corridor BRT Program

The O Route 1 corridor BRT improvement program consists of a new bus route operating as a limited stop BRT service along a similar alignment to CT*transit* O Route 1. It would have fewer stops than the O Route, but the stops it would serve would be enhanced with new shelters and other passenger amenities. Improvements would also be made to several of the most congested intersections by implementing TSP to reduce delays and improve on-time performance.

4.1 Service Plan

4.1.1 *Route and Stations*

A limited stop BRT service would be overlaid on the western half (the O Route 1 half) of the CT*transit* New Haven Division O Route, but would differ from the local O Route 1 in two locations. As shown in Figure 1, the proposed limited stop BRT overlay route would stay on Route 1 in West Haven, skipping the diversion along Meloy and Canton Streets. In New Haven, instead of using Sylvan Avenue, the BRT route would follow a more direct route to the New Haven Green. Several routing alternatives are possible in New Haven. The preliminary route evaluated in this study would follow Congress Avenue, South Frontage Road and Church Street inbound to the New Haven Green. Outbound, the route would use Temple Street (including a planned new crossing of the Route 34 corridor) directly to Congress Avenue. Buses would turn around using Trumbull Street.

The City of Haven is currently evaluating transit and traffic circulation alternatives in the city and has suggested several possible alternate routes that could take advantage of traffic circulation changes, provide service closer to Union Station, and include a more convenient way to turn buses around at the end of the route. A final routing decision would have to be developed in conjunction with the city before

BRT service could be implemented in the corridor. Regardless of the final routing, the limited stop route would provide a faster, more direct service between the CT Post Mall, businesses on Route 1, and New Haven. (No changes would be made to the routing of the existing local route, O Route 1.)

The locations of the proposed BRT stations in this corridor are shown in Figure 1. The 34 proposed stations (17 in each direction) are listed in Table 6 along with the estimated potential weekday daily boardings and proposed station type. The 17 stations in each direction are far fewer than the 69 possible stops on the current O Route 1, although the O Route averages only between 18 and 26 actual stops made per trip, depending on the direction and time of day.

Stations were categorized into Major, Standard and Minor Stations based on boarding ridership and site restrictions, as follows:

- Major Station – high ridership locations and transfer points
- Standard Station – most locations - where space permits a shelter to be installed
- Minor Station – locations with few boardings (but may have many alightings) or locations that lack the space to include a shelter

Major and Standard Stations would include specially branded shelters with larger shelters at the Major Stations. All would have a route and system map, as well as a standalone wireless real-time information display. Major Stations would have additional features, such as lighting, a bike rack, a second bench, and a trash receptacle. Each would have a connection constructed to the nearest sidewalk, if needed. The amenities included for each station type in developing station costs are shown in Table 7.

Two of the proposed stations (one in each direction) would be the existing hub at the CT Post Mall, which would not need any improvements. Of the remaining 32 stations, two are proposed to be Major Stations, 22 are proposed to be Standard Stations, and eight would be Minor Stations.

4.1.2 *Frequency and Span of Service*

Proposed service frequencies are shown in Table 8. The limited stop BRT route would operate at the same frequency as O Route 1, effectively doubling service between the CT Post Mall and New Haven. Limited stop BRT service would operate approximately 14 hours per day. The limited stop route is expected to require seven buses to operate in the weekday peak periods. No changes would be made to the existing O Route schedule.

4.1.3 *Running Times and Reliability*

Several factors would combine to reduce the end-to-end running time on the limited stop BRT route versus the current O Route 1. The biggest factor would simply be the more direct routing. Other important factors include fewer planned stops, use of smart cards for fare payment, TSP, and fewer passengers per trip (resulting from the increased frequency in the corridor). Table 9 shows the combined effect of all of the proposed strategies. Overall, the combined strategies are estimated to result in an average 11 minute running time savings over the current O Route 1, or a savings of about 25%.

While sufficient detailed data is not available to estimate current on-time performance as a measure of service reliability in the corridor, introduction of enhanced service in the corridor will highlight the need for reliable on-time service in order to both attract and retain ridership. TSP will reduce intersection

Figure 1: O Route 1 Corridor Proposed Stations and Improvements

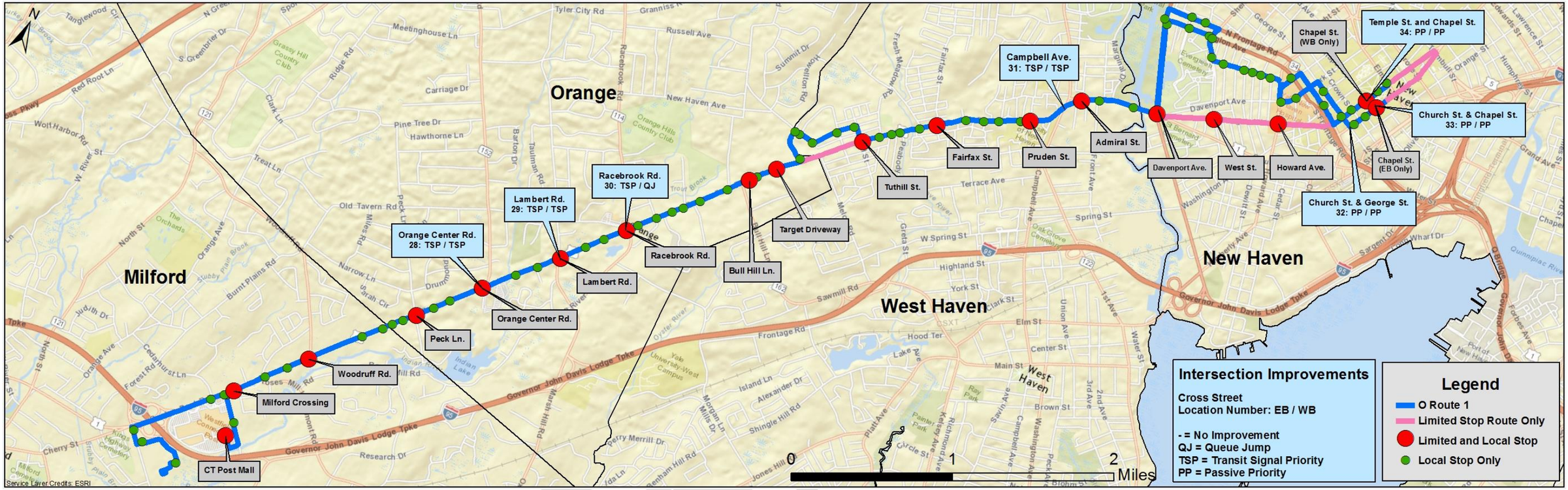

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Table 6: O Route 1 Corridor Proposed Stations

Stop Name	Potential Daily Boardings	Station Type
Eastbound		
CT POST MALL AT TRANSIT HUB	399	Existing
BOSTON POST RD & MILFORD CROSSING	106	Standard
BOSTON POST RD & WOODRUFF RD	11	Standard
BOSTON POST RD & PECK LN	25	Standard
BOSTON POST RD & ORANGE CENTER RD	23	Standard
BOSTON POST RD & S LAMBERT RD	23	Standard
BOSTON POST RD & RACEBROOK RD	23	Standard
BOSTON POST RD & BULL HILL LN	64	Standard
BOSTON POST RD & WALGREENS	45	Standard
ORANGE AVE & TUTHILL ST	35	Standard
ORANGE AVE & OPP FAIRFAX ST	33	Minor
ORANGE AVE & OPP PRUDEN ST	38	Standard
ORANGE AVE & OPP ADMIRAL ST	41	Standard
CONGRESS AVE & DAVENPORT AVE	17	Standard
CONGRESS AVE & WEST ST	56	Standard
CONGRESS AVE & HOWARD ST	59	Standard
CHURCH ST & CHAPEL ST		Minor
Westbound		
TEMPLE ST & CHAPEL ST	726	Major
CONGRESS AVE & HOWARD ST	39	Standard
CONGRESS AVE & WEST ST	48	Standard
CONGRESS AVE & DAVENPORT AVE	25	Standard
ORANGE AVE & ADMIRAL ST	140	Major
ORANGE AVE & PRUDEN ST	45	Standard
ORANGE AVE & FAIRFAX ST	13	Standard
ORANGE AVE & TUTHILL ST	6	Minor
BOSTON POST RD & McDONALD'S	20	Standard
BOSTON POST RD & BULL HILL LN	28	Standard
BOSTON POST RD & RACEBROOK RD	9	Minor
BOSTON POST RD & LAMBERT RD	4	Minor
BOSTON POST RD & ORANGE CENTER RD	6	Minor
BOSTON POST RD & PECK LANE	2	Minor
BOSTON POST RD & WOODRUFF RD	1	Minor
BOSTON POST RD & TURNPIKE SQUARE	4	Minor
WESTFIELD CONNECTICUT POST MALL		Existing
Sub-Total		
TOTAL	**2,144**	

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Table 7: Station Features by Category

	Major Station	Standard Station	Minor Station
Boarding Area	✓	✓	✓
Bus Stop Sign	✓	✓	✓
Large Branded Shelter with Bench	✓		
Branded Shelter with Bench		✓	
Standalone Bench	✓		✓
Standard Shelter			
Real time Information	✓	✓	✓
System Information	✓	✓	✓
Lighting	✓		
Trash Receptacle	✓		
Bike Rack	✓		
Sidewalk Connections and Curb Ramps	as needed	as needed	as needed

Table 8: O Route 1 Corridor Service Headway and Daily Trips

	O Route 1		0 Route 1 Limited	
	EB	WB	EB	WB
AM Peak	20	20	20	20
Midday	20	20	20	20
PM Peak	15	15	15	15
Evening	35	30		
Saturday	20	20		
Sunday	40	60		
Weekday Trips	50	50	43	45
Saturday Trips	41	40		
Sunday Trips	14	15		

Headway in minutes.

Table 9: O Route 1 Corridor Estimated Limited Stop Running Times

	Eastbound			Westbound			Average
	AM	Mid	PM	AM	Mid	PM	
Current Route Running Time	39.4	43.9	48.7	38.5	44.5	47.3	43.7
Estimated Limited Stop Running Time	30.3	32.5	36.4	28.3	31.5	36.3	32.6
Running Time Saved	9.1	11.4	12.3	10.2	13.0	11.0	11.1
Percent Running Time Saved	23.1%	25.9%	25.2%	26.4%	29.2%	23.2%	25.5%

delays to late buses and limited stop service will result in a more consistent number of stops made per trip, as well as more consistent dwell times, both of which can result in improvements to on-time performance.

4.1.4 *Ridership*

Several factors would combine to increase ridership in the corridor. The biggest impact would be from the overall increase in frequency of service in the corridor. The increased availability of service would encourage increased ridership, as would the reduced travel times. The installation of more substantial station amenities would have a positive impact on ridership as well. Table 10 shows the combined effect of all of the proposed strategies. Overall, the combined strategies are estimated to result in a 36% increase in ridership in the corridor over the current O Route 1, almost 920 additional daily trips, or about 234,000 trips annually.

Table 10: O Route 1 Corridor Estimated Weekday Ridership

Route	Current	Proposed	Change
O Route 1	2,556	1,686	-870
Limited Stop Route	-	1,788	1,788
Total	**2,556**	**3,474**	**918**
Percent Increase			36%

4.1.5 *Operating Cost*

The limited stop service is estimated to require approximately 75 additional vehicle-revenue-hours of service per weekday. Assuming the current CT*transit* hourly operating cost of $72.72, the additional annual operating cost would be approximately $1.404 million. Maintenance of the on-board emitters for TSP is expected to add about another $9,000, for a total of $1.413 million.

4.2 Capital Plan

Capital improvements to support the BRT service in the O Route 1 corridor would include the 32 stations, plus emitters for TSP on-board buses and intersection signalization improvements to implement TSP. The proposed stations and intersection improvements are listed in the following sections by the municipality in which they are located, although many improvements would be within the state-owned right-of-way and involve state-owned traffic signals not under local control.

Each of the stations would be constructed to meet current accessibility guidelines under the Americans with Disabilities Act (ADA) and require construction of a firm, level boarding and alighting area and an accessible connection to the nearest sidewalk. In addition, each station would include a specialized sign designating it as a station on the limited stop BRT service. With the exception of Minor Stations, all would include specially branded shelters, with larger branded shelters for the Major Stations. All stations would have a route and system map, as well as a standalone wireless real-time information display. Major Stations would have additional features, such as lighting, a bike rack, a second bench, and a trash receptacle. Costs were estimated for each generic station type, with additional station-specific costs estimated for additional pedestrian sidewalk and curb ramp connections.

For this particular TSP implementation (at a limited number of intersections in a single corridor) it is recommended that a distributed system involving direct communication between a bus and a particular

traffic signal controller would be most appropriate (as opposed to one operating through a centralized traffic control system). Priority would only be granted on a conditional basis, when a bus is behind schedule, rather than unconditionally. TSP would require integration with CT*transit*'s Trapeze AVL system and the addition of emitters on board all buses serving the corridor.

The intersections identified for TSP implementation in each municipality represent only those that were identified through the bus travel time data collected for this study as the locations causing the most significant delays for buses. Other locations may exhibit less consistent delays but may, over time, begin to experience more significant delays. In the future TSP could be implemented at those additional locations, as needed, at relatively low additional cost.

4.2.1 *Milford*

The proposed BRT stations in Milford are listed in Table 11. All of the proposed stations in Milford would be existing bus stops, although the eastbound stop on Route 1 at Woodruff Road could be moved to the far side of the intersection to provide for a better pedestrian connection to existing sidewalks in the area. The westbound stop on Route 1 at Woodruff Road also has no existing sidewalk and would require construction of a connection to the sidewalk on the east side of Woodruff Road.

Table 11: Milford Capital Improvements

Station Location	Station Type	Notes	Est. Station Cost	Pedestrian Improvement Est. Cost
Eastbound Stations				
CT POST MALL AT TRANSIT HUB	Existing	Existing Transit Center	$0	$0
BOSTON POST RD & MILFORD CROSSING	Standard		$45,000	$0
BOSTON POST RD & WOODRUFF RD	Standard	Move to far side for better sidewalk connection	$45,000	$0
Westbound Stations				
BOSTON POST RD & WOODRUFF RD	Minor		$20,000	$52,500
BOSTON POST RD & TURNPIKE SQUARE	Minor		$20,000	$0
WESTFIELD CONNECTICUT POST MALL	Existing	Existing Transit Center	$0	$0

The station at the CT Post Mall would use the existing bus stop facility there which would not need to be upgraded. The two eastbound stations on Route 1 would be standard stations, while the two westbound stations have very few boardings and would be minor stations with no shelter.

There are no intersections proposed for TSP along the route in Milford.

4.2.2 *Orange*

The proposed BRT stations in Orange are listed in Table 12. All of the proposed stations in Orange would be existing bus stops, although the eastbound stop on Route 1 at Lambert Road would need to be moved further east to avoid a driveway. More importantly, 11 of the 12 station locations have no adjacent sidewalks. As a result, additional pedestrian improvements, such as extended sidewalks and curb ramps, would need to be constructed to make those stations accessible. The station locations at Peck Lane and Racebrook Road do not even have nearby sidewalks to connect to, so a connection can be made only to the nearest intersection. This is indicative of the significant needs, beyond those identified

Table 12: Orange Capital Improvements

Station Location	Station Type	Notes	Est. Station Cost	Pedestrian Improvement Est. Cost
Eastbound Stations				
BOSTON POST RD & PECK LN	Standard	No nearby sidewalk to connect to	$45,000	$0
BOSTON POST RD & ORANGE CENTER RD	Standard		$45,000	$19,100
BOSTON POST RD & S LAMBERT RD	Standard	Move eastward past driveways	$45,000	$61,250
BOSTON POST RD & RACEBROOK RD	Standard	No nearby sidewalk to connect to	$45,000	$10,350
BOSTON POST RD & BULL HILL LN	Standard		$45,000	$22,600
BOSTON POST RD & WALGREENS	Standard	Connect to Walgreens and nearest intersection	$45,000	$45,350
Westbound Stations				
BOSTON POST RD & McDONALD'S	Standard	Connect to nearest intersection	$45,000	$71,600
BOSTON POST RD & BULL HILL LN	Standard		$45,000	$22,600
BOSTON POST RD & RACEBROOK RD	Minor	No nearby sidewalk to connect to	$20,000	$10,350
BOSTON POST RD & LAMBERT RD	Minor		$20,000	$8,750
BOSTON POST RD & ORANGE CENTER RD	Minor		$20,000	$19,100
BOSTON POST RD & PECK LANE	Minor	No nearby sidewalk to connect to	$20,000	$27,850
Intersection Improvements	**Signal Owner**	**Notes**	**Est. Cost**	
Boston Post Rd and Orange Center Rd	CTDOT	Transit Signal Priority	$12,740	
Boston Post Rd and Lambert Rd	CTDOT	Transit Signal Priority	$12,740	
Boston Post Rd and Racebrook Rd	CTDOT	Transit Signal Priority (possible WB queue jump)	$17,640	

here, for improvements to the pedestrian environment along Route 1 in Orange, as sidewalks are not continuous and crosswalks are often lacking.

All of the eastbound stations and two of the westbound stations in Orange would be standard stations, while the four westbound stations closest to the CT Post Mall are expected to have very few boardings and would be minor stations with no shelter.

The three intersections in Orange proposed for TSP are also listed in Table 12. At the Racebrook Road intersection, it may be feasible to implement a bus queue jump instead utilizing the existing right turn lane. There buses could use the right-turn-only lane and receive an advanced green signal to proceed through the intersection ahead of general traffic. A new signal head and modifications to signage and pavement markings would be needed.

4.2.3 *West Haven*

The proposed BRT stations in West Haven are listed in Table 13. All of the proposed stations in West Haven would be existing bus stops, although the westbound stop on Route 1 at Admiral Street would need to be moved farther east to make room for the larger shelter and station amenities that the

Table 13: West Haven Capital Improvements

Station Location	Station Type	Notes	Est. Station Cost	Pedestrian Improvement Est. Cost
Eastbound Stations				
ORANGE AVE & TUTHILL ST	Standard		$45,000	$15,600
ORANGE AVE & OPP FAIRFAX ST	Minor	No room for shelter	$20,000	$10,350
ORANGE AVE & OPP PRUDEN ST	Standard		$45,000	$0
ORANGE AVE & OPP ADMIRAL ST	Standard		$45,000	$0
Westbound Stations				
ORANGE AVE & ADMIRAL ST	Major	Move 100' east to make room for shelter	$88,000	$0
ORANGE AVE & PRUDEN ST	Standard	Move to far side	$45,000	$1,600
ORANGE AVE & FAIRFAX ST	Standard		$45,000	$0
ORANGE AVE & TUTHILL ST	Minor		$20,000	$12,100
Intersection Improvements	**Signal Owner**	**Notes**	**Est. Cost**	
Boston Post Rd and Campbell Ave	CTDOT	Transit Signal Priority	$12,740	

ridership at this location warrants, and the westbound stop on Route 1 at Pruden Street would need to be moved to the far side where there is more space for a shelter. Four of the eight station locations have no adjacent sidewalks, so pedestrian improvements, such as extended sidewalks and curb ramps, would need to be constructed to make those stations accessible.

The westbound station at Admiral Street currently attracts a significant number of boarding passengers and therefore is proposed to be a major station with a larger shelter and additional features, such as lighting, a bike rack, a second bench, and a trash receptacle. All of the eastbound stations and all but one of the westbound stations attract sufficient boarding ridership to be standard stations, however, the location on Route 1 opposite Fairfax Street does not appear to have room for a shelter and would therefore be a Minor Station. The eastbound stop on Route 1 at Tuthill Street is proposed to be Minor Stations with no shelter, due to low ridership, but could be upgraded to a Standard Station if pedestrian improvements can be made to attract riders from the adjacent neighborhood around Meloy and Canton Streets.

The one intersection in West Haven proposed for TSP, Route 1 at Campbell Avenue, is also listed in Table 13.

4.2.4 *New Haven*

The proposed BRT stations in New Haven are listed in Table 14. All of the proposed stations in New Haven would be existing bus stops, none of which would need to be moved. All eight station locations in New Haven are on existing sidewalks, so no additional pedestrian improvements would be needed.

The eastbound station on Church Street at Chapel Street is assumed to be the end of the eastbound route where all riders would be expected to alight. Therefore, that location is designated as a Minor Station with no need for a new branded shelter. Conversely, the westbound station on Temple Street at Chapel Street (on the New Haven Green) would be the beginning of the westbound route and would be a Major Station with a larger shelter and additional features, such as lighting, a bike rack, a second bench, and a trash receptacle. The other six stations in New Haven would be Standard Stations.

Table 14: New Haven Capital Improvements

Station Location	Station Type	Notes	Est. Station Cost
Eastbound Stations			
CONGRESS AVE & DAVENPORT AVE	Standard		$45,000
CONGRESS AVE & WEST ST	Standard		$45,000
CONGRESS AVE & HOWARD ST	Standard		$45,000
CHURCH ST & CHAPEL ST	Minor		$20,000
Westbound Stations			
TEMPLE ST & CHAPEL ST	Major		$88,000
CONGRESS AVE & HOWARD ST	Standard		$45,000
CONGRESS AVE & WEST ST	Standard		$45,000
CONGRESS AVE & DAVENPORT AVE	Standard		$45,000
Intersection Improvements	**Signal Owner**	**Notes**	**Est. Cost**
Church St and George St	New Haven	Transit Signal Priority (by City of New Haven)	$0
Church St and Chapel St	New Haven	Transit Signal Priority (by City of New Haven)	$0
Temple St and Chapel St	New Haven	Transit Signal Priority (by City of New Haven)	$0

The three intersections listed in Table 14 were identified as candidates for improvements. The City of New Haven is currently undertaking a project to replace traffic signal equipment, improve coordination timing, and implement TSP throughout the downtown area. While the improvements are expected to reduce bus travel times and delays in the downtown, the cost of these planned improvements are assumed borne by the city and therefore are not included in cost estimates for this project.

4.2.5 *CTtransit New Haven Division*

The proposed limited stop BRT route in the corridor would require seven buses to operate during peak periods. Providing one spare bus means that eight additional buses would have to be added to the fleet at a typical cost of $450,000 per bus, including all standard CT*transit* add-on bus features (such as fareboxes, vehicle location system, radio, etc.).

The only other capital equipment that CT*transit* would need would be the emitters for communicating with the traffic signals to receive priority. At a minimum, the eight buses on the limited stop BRT route would have to be equipped. In addition, it was assumed that all buses operating in the corridor would also be equipped with emitters and be able to take advantage of TSP when needed. CT*transit* currently schedules 19 different vehicle blocks on the local O Route 1, so as many as 19 local buses may have to be equipped. Adding the eight buses for the proposed limited stop BRT route would increase the total to as many as 27. A further 25% contingency was assumed to allow CT*transit* some flexibility in vehicle assignment, for a total of 34 TSP-equipped buses. While 34 TSP-equipped buses was assumed for estimation of costs for the corridor, in reality CT*transit* may want to consider equipping the entire New Haven Division fleet in anticipation of a more widespread implementation of TSP in the New Haven region.

4.2.6 *Capital Cost Summary*

The capital costs associated with instituting limited stop BRT service with enhanced stations and TSP capability in the O Route 1 corridor are summarized in Table 15. The table includes the costs, detailed above, for stations and intersection improvements, plus capital costs for additional buses and for equipping all buses in the O Route 1 corridor to support conditional TSP. Capital costs were annualized assuming a useful life of 12 years for buses and TSP emitters, 15 years for stations, and 20 years for intersection improvements, all assuming a 2% discount rate, per FTA guidance.

Table 15: O Route 1 Corridor Summary of Estimated Capital Cost

Cost Category	Capital Cost*	Annualized Cost
Stations	$1,712,000	$133,237
Intersection Improvements	$64,000	$3,914
Buses (8)	$3,400,000	$321,503
TSP emitters (34)	$119,000	$11,253
TOTAL	**$5,295,000**	**$469,907**

*In 2016 dollars

4.3 Implementation Challenges

Implementation of a limited stop BRT overlay service with enhanced stations and intersection improvements that would reduce travel times, improve service reliability, and increase ridership in the O Route 1 corridor would require a significant amount of time for planning, design, procurement, and construction. Further planning is needed, including a detailed implementation plan that identifies a feasible timeline. Several factors that could influence the timing of implementation are listed here.

4.3.1 *New Haven Routing*

The routing in the City of New Haven was discussed at the expanded TAC meeting. The City of New Haven is currently evaluating transit and traffic circulation alternatives in the city and has suggested several possible alternate routes that could take advantage of proposed traffic circulation changes and provide service closer to Union Station, as well as provide for a more efficient routing to turn around at the New Haven end of the line. A final routing decision would have to be developed in conjunction with the city and any necessary changes to the street network made before BRT service could be implemented in this corridor.

4.3.2 *Station Development*

The 32 stations to be improved in the O Route 1 corridor would be constructed at existing bus stops within the existing city or state-owned right-of way. However, there are many cases of stations where construction would be complicated by a need to relocate the stop or to complete additional construction to make them fully accessible. Four stations are proposed to be relocated to the opposite side of the intersection and the new location would need to be reviewed for impacts on traffic and on abutting properties. Sixteen stations would require additional construction of sidewalks and/or curb ramps. Construction of all stations and sidewalk improvements will require design, procurement of shelters and information displays, contractor procurement, and a phased construction schedule.

Construction of stations will require coordination among CTDOT, CT*transit* (New Haven Division), and the four municipalities. While local municipal involvement is expected in the final siting of stations, most

stations would be located on state-owned right-of-way. However, local public works departments will need to be involved for any stations being installed on city-owned property.

4.3.3 *Signalization Upgrades to Support TSP*

The lead time for implementation of signalization upgrades for TSP would need to be determined. Upgrades needed for the O Route 1 corridor that could involve various lead times include:

- Controller replacement and addition of detectors at four CTDOT-owned signals
- Addition of a new signal head and modifications to signage and pavement markings to accommodate a possible queue jump at Racebrook Road
- Implementation of City of New Haven proposals for signal improvements, possibly including TSP, as well as changes to traffic circulation

Each of the seven intersections where improvements are proposed would require an intersection operational analysis to determine the impact on traffic and to develop optimal signal timings. Proposed improvements would also require approvals from the Office of State Traffic Administration (OSTA) and from CTDOT Highway Operations. Implementation of TSP will also require coordination among CTDOT, City of New Haven, and CT*transit* (New Haven Division).

4.3.4 *Bus Procurement*

Even implementing just the service elements, operating the limited stop service with no station or intersection improvements, would still require the purchase of additional buses. Bus procurement, following mandated federal procedures, can take up to 18 months once funding has been identified.

4.3.5 *Implementation of AVL*

CTtransit New Haven Division is still in the early stages of implementing the Trapeze AVL System. A working AVL system is essential for implementing the real-time information aspects of a BRT project, as well as implementing TSP.

4.3.6 *Integration of CTtransit AVL with TSP*

In order to take advantage of the TSP at selected intersections, CT*transit* will need to equip a sufficient number of buses with emitters and integrate the emitters with their Trapeze AVL system. That system is capable of supporting TSP although the level of effort and time needed to activate the system for conditional TSP still needs to be determined. Emitters will require procurement and installation.

4.3.7 *Maintenance Responsibilities*

Several elements of the improvements would require occasional ongoing maintenance. CT*transit* would be responsible for maintaining the buses and the on-board emitters. At CTDOT-owned signals CTDOT maintains the signals but the municipality maintains the optical detectors and phase selectors. CT*transit* operations would be dependent on the city and state maintaining the system at each intersection. Responsible parties for cleaning and maintaining the stations, including real-time information displays, would also need to be identified.

4.3.8 *Funding*

Funding sources would need to be identified for both the capital and operating costs of the improvements. Timing of implementation would have to take into account application schedules for various potential funding sources as well as state and local budget cycles.