To: Andrew McFarland, MBTA
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From: Adam Prichard
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Date: December 11, 2020

Project #: 15050.00

Re: Gateway East – Transit Improvements
Traffic Design Implications

Memorandum

Introduction

In support of the potential to provided dedicated bus lanes along a key bus route corridor, VHB has reviewed three concepts developed by the MBTA that attempt to improve transit operations along the Route 9 corridor (known as Gateway East) in Brookline, Massachusetts. This memo details the methodology and analysis of the associated traffic review and provides suggestions for the MBTA and the Town's consideration. Physical implications to the ongoing construction project (MassDOT's Tip Project 605110) in the area are covered in a separate memorandum. The MBTA has identified this corridor as a critical transit area and has an opportunity to improve transit ridership by making lane configuration modifications. These modifications are illustrated in concepts provided by the MBTA and are included in the attachments.

The study area consists of three signalized intersections: Boylston Street/ Washington Street (Route 9) at Washington Street/ High Street; Washington Street (Route 9) at Pearl Street/ Walnut Street; and Washington Street (Route 9) at Brookline Avenue.

Methodology

The analysis prepared for this evaluation focuses on impacts to traffic operations with and without the proposed dedicated transit lanes, as measured against the benefits/impacts to transit users within the system. With the goal to improve transit schedules/headways and encourage ridership, it was determined that person-trip comparisons along this busy transit corridor would be a preferred comparison to evaluating benefits versus impacts. This is accomplished by using the MassDOT Project 605110 Synchro model and MBTA ridership data for the Route 65 and 66 buses. With the synchro model as a baseline condition, each concept was compared to determine overall vehicle impacts.

Ridership Data

MBTA ridership data was evaluated to understand the peak hour impacts to total persons along the corridor. The ridership data consisted of a composite day during 2019 of the number of buses and riders, which highlights peak hour buses and riders for both inbound and outbound routes. Use of the composite day allows the analysis to consider seasonal factors that may affect ridership or schedule adherence and also eliminates any impact COVID 19 is currently having on ridership. Table 1 shows the ridership statistics for the 65 and 66 Routes during the typical weekday peak hours at the study area.

Table 1 Ridership Data

		Weekday Morning Peak Hour		Weekday Evening Peak Hour	
Route	Direction	Buses	Riders	Buses	Riders
65	Inbound	6	322	3	30
	Outbound	3	19	5	223
66	Inbound	7	283	6	214
	Outbound	8	212	6	233

Table 1 shows that during a typical peak hour, there are 605 morning peak hour riders on 13 buses and 456 evening peak hour riders on 11 buses. Route 65 provides service up Washington Street to the west and Brookline Avenue to the east of the study area. Route 66 provides service up Harvard Street to the west and continues along Huntington Avenue to the east of the study area. While Route 60 does travel through the study area, the bus would not utilize the proposed dedicated bus lanes, so Route 60 ridership data was not analyzed. Route composite data is included in the Attachments to this memorandum. The MBTA has anecdotal data that suggest ridership on the Route 65 and 66 buses may increase by as much as five percent during peak hours if dedicated bus lanes were in place. This would increase ridership to 635 morning and 478 evening riders on the two services and potentially eliminate 20 to 30 vehicle that currently transport these riders. The MBTA also has anecdotal data that dedicated bus lanes decrease traffic volumes along the route by 10 to 20 percent. This is discussed further below (see reduced/diverted demand).

Traffic Operations Analysis

The first step in understanding the benefits and impacts of the dedicated bus lane concepts is to assess the impacts to roadway capacity that would be realized for each option. Under each concept being evaluated, Route 9 eastbound would essentially be reduced to one through lane and Route 9 westbound would be reduced to two through lanes, with only a single turn lane to/from Washington Street and the Brookline Village area. Intersection capacity analyses were conducted with respect to full build traffic volume conditions expected once the MassDOT construction is complete. Capacity analyses provide an indication of how well the roadway facilities serve the traffic demands placed upon them. Roadway operating conditions are classified by calculated levels-of-service. The build traffic volumes do not take into account reduction in traffic due to the COVID-19 pandemic, however, it is estimated that traffic volumes in the area are currently about 40 percent lower than pre-pandemic conditions. The volumes also do not reflect a reduction in corridor traffic due to the provision of dedicated bus lanes. This is discussed further in the section below on reduced/diverted demand.

Level of Service Criteria

Level–of-service (LOS) is the term used to denote the different operating conditions that occur on a given roadway segment under various traffic volume loads. It is a qualitative measure that considers a number of factors including roadway geometry, speed, travel delay, freedom to maneuver, and safety. Level-of-service provides an index to operational qualities of a roadway segment or an intersection. Level-of-service designations range from A to F, with LOS A representing the best operating conditions and LOS F representing the worst operating conditions.

For this study, capacity analyses were completed for the signalized intersections within the study area using Synchro traffic analysis software. The evaluation criteria used to analyze the signalized study area intersections is based on the *2010 Highway Capacity Manual* (HCM)[1].

Intersection Capacity Analysis

Table 2 summarizes the capacity analyses for the three signalized intersections under each concept. Operationally, Concepts 2 and 3 would provide the same traffic delays and levels of service. Therefore, these results are combined in the tables below. It is noted that moving the bus stop to the far side (Concept 3) will have some improved effect in traffic flow through the intersection, as there would be no need for vehicles to move around waiting buses. However, these effects cannot be reasonably modeled in Synchro. The capacity analyses worksheets are included in the Attachments to this memorandum.

In addition to the intersection capacity analysis summary tables, queue diagrams illustrating the 95th-percentile queue for each movement were developed for each intersection. Queue diagrams were developed for the weekday morning peak hour of operations at the intersections of Route 9 at Washington Street / High Street and Route 9 at Walnut Street / Pearl Street and for the weekday evening peak hour of operations at the intersection of Route 9 at Brookline Avenue, representing the peak hours with the largest queues at each intersection. The queue diagrams are included in the Attachments to this memorandum.

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1 Highway Capacity Manual, Transportation Research Board, Washington D.C., 2010.

Table 2 Signalized Intersection Capacity Analysis

Location / Movement	Storage	2020 Design Conditions					2020 Concept 1 Conditions					2020 Concept 2 Conditions				
		v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q
1: Route 9 at Washington Street/ High Street																
Weekday Morning																
EB T*/R	2,200	1.14	113	F	~774	#914	1.18	>120	F	~1610	#1875	1.12	106	F	~1432	#1698
EB R*	2,200	-	-	-	-	-	0.04	31	C	14	35	0.04	27	C	12	33
WB T	250	0.85	20	B	108	144	0.89	41	D	300	#517	0.85	19	B	137	m124
WB R	**250**	**1.10**	**106**	**F**	**~286**	**m#405**	**>1.20**	**>120**	**F**	**~592**	**#817**	**>1.20**	**>120**	**F**	**~686**	**m#603**
NB L/T/R	75	>1.20	>120	F	~453	#581	>1.20	>120	F	~489	#619	>1.20	>120	F	~453	#580
SB L	**200**	**0.85**	**66**	**E**	**209**	**#294**	**1.06**	**107**	**F**	**~489**	**#710**	**>1.20**	**>120**	**F**	**~600**	**#817**
SB T/R	200	1.08	>120	F	~281	#465	0.69	49	D	245	355	1.08	>120	F	~281	#465
Total		1.11	99	F			>1.20	118	F			>1.20	>120	F		
Weekday Evening																
EB T*/R	2,200	0.83	39	D	412	504	0.78	44	D	969	1149	0.80	37	D	774	951
EB R*	2,200	-	-	-	-	-	0.08	29	C	28	57	0.08	24	C	23	49
WB T	250	0.97	21	C	133	m138	1.01	49	D	~641	#857	1.03	33	C	~152	m101
WB R	**250**	**0.85**	**44**	**D**	**237**	**m240**	**1.01**	**88**	**F**	**~531**	**m#665**	**>1.20**	**>120**	**F**	**~578**	**m#362**
NB L/T/R	75	0.98	98	F	186	#272	>1.20	>120	F	~271	#361	0.98	98	F	185	#272
SB L	**200**	**0.76**	**52**	**D**	**208**	**261**	**0.99**	**83**	**F**	**537**	**#741**	**>1.20**	**>120**	**F**	**~606**	**#788**
SB T/R	200	>1.20	>120	F	~461	#637	0.90	65	E	437	#606	>1.20	>120	F	~491	#667
Total		1.02	58	E			1.07	72	E			1.14	>120	F		

BOLD – Movement altered by bus lane.
* 2020 Design Conditions – EB T and EB T/R; Concepts 1 and 2/3 – EB T and EB R

Table 2 Signalized Intersection Capacity Analysis (continued)

Location /		2020 Design Conditions					2020 Concept 1 Conditions					2020 Concept 2 Conditions				
Movement	Storage	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q
2: Route 9 at Walnut Street/ Pearl Street																
Weekday Morning																
EB L	150	0.75	72	E	128	m121	0.53	70	E	137	m118	0.75	72	E	128	m104
EB T*/R	**250**	**>1.20**	**>120**	**F**	**~971**	**m#398**	**>1.20**	**>120**	**F**	**~2475**	**m#2077**	**>1.20**	**>120**	**F**	**~2161**	**m#1648**
EB R*	250	-	-	-	-	-	-	-	-	-	-	0.16	19	B	20	m10
WB L	150	0.81	67	E	63	m70	0.43	73	E	66	m72	0.81	67	E	63	m55
WB T/R	**325**	**0.82**	**57**	**E**	**406**	**m366**	**0.80**	**20**	**C**	**716**	**m685**	**1.18**	**>120**	**F**	**~733**	**m404**
NB L/T		0.10	39	D	15	m28	0.12	51	D	25	56	0.10	39	D	15	m28
NB R		0.19	>120	F	77	#127	0.19	59	E	0	89	0.19	>120	F	77	#127
SB L/T/R		0.19	45	D	30	87	0.25	53	D	39	100	0.19	45	D	30	87
Total		0.77	96	F			>1.20	>120	F			>1.20	>120	F		
Weekday Evening																
EB L	150	0.62	78	E	50	m63	0.43	60	E	57	m66	0.62	65	E	50	m53
EB T*/R	**250**	**1.19**	**119**	**F**	**~358**	**#523**	**>1.20**	**>120**	**F**	**~2103**	**m#2333**	**>1.20**	**>120**	**F**	**~1669**	**m#1543**
EB R*	250	-	-	-	-	-	-	-	-	-	-	0.09	28	C	11	m13
WB L	150	>1.20	>120	F	~169	m#159	0.50	59	E	157	m146	>1.20	>120	F	~169	m104
WB T/R	**325**	**1.02**	**27**	**C**	**~605**	**m146**	**0.90**	**8**	**A**	**317**	**m229**	**>1.20**	**>120**	**F**	**~1126**	**m155**
NB L/T		0.07	32	C	11	m29	0.13	55	E	18	46	0.07	32	C	11	m29
NB R		0.07	76	E	5	50	0.07	48	D	0	55	0.07	76	E	5	50
SB L/T/R		0.27	42	D	25	105	0.53	62	E	85	187	0.27	42	D	25	105
Total		0.74	71	E			>1.20	>120	F			1.12	>120	F		

BOLD – Movement altered by bus lane.
* Concept 1 – EB T/R; Concept 2/3 – EB T and EB R

Table 2 Signalized Intersection Capacity Analysis (continued)

Location / Movement	Storage	2020 Design Conditions					2020 Concept 1 Conditions					2020 Concept 2 Conditions				
		v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q
3: Route 9 at Brookline Avenue																
Weekday Morning																
EB L	200	>1.20	>120	F	~526	m#406	1.17	>120	F	~598	m318	>1.20	>120	F	~526	m179
EB T/R	**275**	**0.58**	**3**	**A**	**46**	**m36**	**0.89**	**26**	**C**	**499**	**m330**	**1.10**	**55**	**D**	**~934**	**m46**
WB L/T/R	**600**	**>1.20**	**>120**	**F**	**~411**	**#508**	**1.16**	**>120**	**F**	**~605**	**#744**	**>1.20**	**>120**	**F**	**~781**	**#920**
NB L/T/R		0.74	94	F	70	#116	0.47	62	E	73	105	0.74	94	F	70	#116
SB L	300	0.58	66	E	96	153	0.43	54	D	96	155	0.58	66	E	96	153
SB T	300	0.61	68	E	102	158	0.45	54	D	101	161	0.61	68	E	102	158
SB R	300	0.45	30	C	59	127	0.57	28	C	225	318	0.45	30	C	59	127
Total		0.87	103	F			1.02	88	F			1.15	>120	F		
Weekday Evening																
EB L	200	0.92	75	E	173	m156	1.15	>120	F	~248	m151	0.92	75	E	174	m102
EB T/R	**275**	**0.78**	**35**	**C**	**277**	**m235**	**1.14**	**80**	**E**	**~1256**	**m206**	**>1.20**	**>120**	**F**	**~1159**	**m298**
WB L/T/R	**600**	**>1.20**	**>120**	**F**	**~520**	**#586**	**>1.20**	**>120**	**F**	**~947**	**#1054**	**>1.20**	**>120**	**F**	**~963**	**#1054**
NB L/T/R		0.50	68	E	46	80	0.44	68	E	58	93	0.50	68	E	46	80
SB L	300	>1.20	>120	F	~365	#561	0.85	71	E	332	#554	>1.20	>120	F	~365	#561
SB T	300	>1.20	>120	F	~388	#585	0.89	76	E	350	#585	>1.20	>120	F	~388	#585
SB R	300	0.58	37	D	106	261	0.78	46	D	406	#659	0.58	37	D	106	261
Total		0.92	>120	F			1.19	>120	F			>1.20	>120	F		

BOLD – Movement altered by bus lane.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

As shown in Table 2, all intersections experience a LOS F during the morning peak hour in the Build condition, while in the evening peak hour the Route 9 at Washington Street/ High Street intersection and the Route 9 at Walnut Street/ Pearl Street intersection experience a LOS E. The Gateway East project was developed to manage congestion and queuing through the traffic signal system. The operations along the corridor at all study area intersections degrade from the Build conditions with the dedicated bus lane in place. Specifically, the movements where bus lanes are incorporated in lieu of a vehicle travel lane experience the most impacts where many of the movements double their queues. This is reflective of the elimination of a through lane in each direction. Additionally, the level of service results reflects the need to reduce eastbound Route 9 (Boylston Street) outside of the project limits from two to one through lane. This is necessary to maintain traffic safety and allow traffic to merge to one lane prior to reaching the firehouse.

Person-Delay

As mentioned previously, the concepts along this corridor were also analyzed using person-delay in lieu of vehicle-delay to properly assess the incentives of the implementation of bus-only lanes in the study area. Person delay was calculated for the total amount of time in seconds it takes an individual person to travel the corridor as well as for the cumulative delay in hours experienced by all users at each individual movement over the course of the weekday morning and weekday evening peak hours.

Individual Person-Delay to Travel the Corridor

To better understand how delay will affect users by mode, the total cumulative average delay to travel the corridor experienced by each individual person was calculated and compared for people in vehicles versus people on buses. Table 3 summarizes the results of the total corridor-wide person-delay by mode expected to be experienced by the average person.

Table 3 Individual Person-Delay to Travel the Corridor

		Weekday Morning Peak Hour			Weekday Evening Peak Hour		
Mode	**Direction**	**2020 Build**	**Concept**	***Change***	**2020 Build**	**Concept**	***Change***
Transit Person-Delay (seconds) [a]	Inbound (EB)	205	55	*-150*	211	53	*-158*
	Outbound (WB)	368	77	*-291*	316	67	*-249*
Vehicle Person-Delay (seconds) [b]	Inbound (EB)	248	540	*+292*	198	423	*+225*
	Outbound (WB)	285	281	*-4*	312	360	*+48*

a Transit Person-Delay for movements along the proposed bus lanes (Washington Street and Route 9).
b Vehicle Person-Delay for through movements along Route 9.

As shown in Table 3, the average amount of delay expected to be experienced by a person on a bus traveling through the corridor will decrease by up to 291 seconds per directional trip with the installation of the bus lanes, while the average amount of delay expected to be experienced by a person in a vehicle traveling through the corridor will increase by up to 292 seconds. The greatest time saving for passengers on buses will be in the outbound (westbound) direction while the greatest increase in delay for people in vehicles will be in the inbound (eastbound) direction. It's important to note that the time savings for bus passengers are also likely to translate to time savings along other sections of the route. So, while these calculations are specific to riders on the Route 66 or Route 65 bus along this segment of the route, there are also passengers along other segments of the routes that would benefit with travel time savings.

Cumulative Person-Delay for Each Individual Movement

In addition to calculating the total person-delay for each individual person to travel the corridor, the cumulative person-delay at each movement was summed over the entire course of the weekday morning and weekday evening peak hours. Tables 4 and 5 show the total peak hour movement delay for people on transit (Table 4) versus in vehicles (Table 5) at each movement in the corridor with and without dedicated bus lanes. To calculate the comparative delays, the average delay experienced by all people (by mode) was summed.

Table 4 Cumulative Transit Person-Delay (Hours)

		Weekday Morning Peak Hour		Weekday Evening Peak Hour	
Intersection	**Movement**	**2020 Build**	**Concept**	**2020 Build**	**Concept**
1	Washington St SB L	11	6	4	2
	Washington St WB R	7	2	6	4
2	Washington St EB T	22	2	8	1
	Washington St WB T	6	1	8	2
3	Washington St EB L[a]	15	12	1	0
	Washington St EB T	0	1	2	1
	Washington St WB T	10	2	14	2
	Brookline Ave SB R[a]	0	0	1	1

a Movement does not include bus lane.

Table 5 Cumulative Vehicle Person-Delay (Hours)

		Weekday Morning Peak Hour		Weekday Evening Peak Hour	
Intersection	Movement	2020 Build	Concept	2020 Build	Concept
1	Washington St SB L	9	18	8	16
	Washington St WB R	14	29	6	18
2	Washington St EB T	61	176	46	127
	Washington St WB T	37	14	29	39
3	Washington St EB L[a]	47	39	9	6
	Washington St EB T	2	20	13	27
	Washington St WB T	48	29	74	109
	Brookline Ave SB R[a]	10	2	3	4

a Movement does not include bus lane.

Table 4 shows that bus ridership delay decreased, in some cases substantially, for most movements. In comparison, Table 5 shows that most of the delays for people in vehicles are increased for a majority of movements. This is reflective of the number of vehicle lanes being cut in half while serving similar demands.

The analyses presented in Tables 4 and 5 both assume that the volumes on the corridor will be the same under the 2020 Design Condition as under the three alternatives. In reality, a portion of the volumes are likely to divert or change modes due to the increased delays caused by the reduced vehicle capacity on the corridor. A discussion of the potential reduced and diverted demand is provided later in this memorandum.

Intersection Processing Analyses

Additional analyses have been conducted to understand the processing capacity of the corridor under the 2020 Design plan and under the three bus-lane alternatives. Specifically, analyses have been conducted to understand the number of cycles that will be needed to clear the 95th percentile queue and the overall recovery time needed after the peak periods to recover back to non-peak levels of operations and delay.

Time Needed to Clear Queue

An analysis has been conducted to determine how long it will take a vehicle on Route 9 to clear the first traffic signal on the corridor when approaching the corridor when the queue is almost at its peak. This analysis is based on the 95th percentile queues presented in Table 2. The analyses have been completed for the Route 9 eastbound approach at the intersection of Washington Street / High Street and the Route 9 westbound approach at the intersection of Brookline Avenue, as these are the first traffic signals a driver will encounter in each direction. A summary of the number of cycles and maximum time needed to process the 95th percentile queues is presented in Table 6.

Table 6 Number of Cycles and Time Needed to Clear Max Queue

		Route 9 EB Approach (at Washington Street/High Street)			Route 9 WB Approach (at Brookline Avenue)		
Condition	**Time Period**	**95th Percentile Queue**	**# of Cycles Needed to Clear Queue**	**Time Needed to Clear Queue**	**95th Percentile Queue**	**# of Cycles Needed to Clear Queue**	**Time Needed to Clear Queue**
2020 Design	AM Peak Hour	914 ft	2 cycles	260 seconds	508 ft	1 cycle	130 seconds
	PM Peak Hour	504 ft	1 cycle	120 seconds	586 ft	2 cycles	240 seconds
Alt. 1	AM Peak Hour	1,875 ft	4 cycles	560 seconds	744 ft	2 cycles	280 seconds
	PM Peak Hour	1,149 ft	2 cycles	300 seconds	1,054 ft	2 cycles	300 seconds
Alt. 2/3	AM Peak Hour	1,698 ft	3 cycles	390 seconds	920 ft	3 cycles	390 seconds
	PM Peak Hour	951 ft	2 cycles	240 seconds	1,054 ft	3 cycles	360 seconds

Note: Alternative 1 includes modified signal timings and phasing over 2020 Design Conditions and Alternative 2/3.

As shown in Table 6, under the 2020 Design Condition the 95th percentile queue is expected to be processed in one or two traffic cycles for the first intersections approached on Route 9. Under the three Alternatives, the number of cycles needed at each intersection to process the queue increases to three or four cycles at some locations resulting in a total time needed to clear the queue of up to 560 seconds. It should be noted that these analyses are based on the green and yellow time for each approach and assumes that when the light turns green on the Route 9 approaches the queue will begin to be processed. The analyses do not take into account downstream queues and delays (for example in Boston at Huntington/South Huntington Avenue) which may restrict the processing capacity of each intersection.

Recovery Time

The recovery time is the amount of time needed after the end of the peak period to process the additional vehicles that were not able to be processed during the peak period. Since the volumes during the peak hour may exceed to available capacity, additional time may be needed at the end of the peak period to process the additional vehicles that could not be processed during the peak period. The analyses have been completed for the Route 9 eastbound approach at the intersection of Washington Street / High Street and the Route 9 westbound approach at the intersection of Brookline Avenue, as these are the first traffic signals a driver will encounter in each direction. A summary of the recovery time is presented in Table 7.

Table 7 Recovery Time

Condition	Time Period	Route 9 EB Approach (at Wash. Street/High Street)	Route 9 WB Approach (at Brookline Avenue)
2020 Design	AM Peak Hour	n/a	n/a
	PM Peak Hour	n/a	n/a
Alt. 1	AM Peak Hour	90 minutes	n/a
	PM Peak Hour	50 minutes	n/a
Alt. 2/3	AM Peak Hour	90 minutes	n/a
	PM Peak Hour	50 minutes	n/a

Note: Recovery Time of n/a means that the volume to capacity ratio for the approach is under 1.00 and the volume approaching the intersection during the peak period should be processed during the peak period.

As shown in Table 7, under the 2020 Design Condition both approaches on Route 9 should be able to process the approaching volumes during the peak period and therefore additional recovery time is not expected to be required. Under the three alternatives, recovery time of 50-90 minutes will be needed on the Route 9 eastbound approach to account for the reduction in capacity from two general-purpose lanes to one general-purpose lanes. It should be noted that these analyses assume the non-peak volumes will be less than the available capacity and that the recovery time is able to start as soon as the peak period ends.

Similar to the person-delay analyses, the analyses presented in Tables 6 and 7 both assume that the volumes on the corridor will be the same under the 2020 Design Condition as under the three alternatives. In reality, a portion of the volumes may divert or change modes due to the increased delays caused by the reduced vehicle capacity on the corridor. A discussion of the possible reduced and diverted demand is provided in the following section.

Reduced and Diverted Demand

The analysis above focuses on the implications of providing dedicated bus lanes within the study area while maintaining 2019 peak traffic volumes. With the incorporation of dedicated bus lanes and the elimination of travel lanes through the corridor, non-bus traffic is expected to incur increased delays. However, the MBTA has seen an increase in transit ridership and a decrease in traffic volume along corridors where dedicated bus facilities have been previously installed. Therefore, it is reasonable to assume some traffic diversion would be likely in Brookline as well. The above analyses reflect the worst-case delay/congestion conditions if no diversion or mode shift occurs. This section reflects on the worst case for diversion potential by assuming that the traffic operations expected once the Gateway East project is complete can be maintained with the addition of dedicated bus lanes. In order to maintain current traffic delays with reduced capacity, a mode shift from vehicle to bus and/or a diversion of traffic away from the Gateway East area are needed.

Provision of a dedicated bus lane, regardless of the concept chosen, has a large impact on Route 9 traffic flow. The amount of traffic flow through the area during the peak hours appears to be driven by operations at the intersection of Route 9 at Pearl Street/Jupiter Street, specifically the eastbound movement. In order to maintain traffic operations as they are under current conditions, it was determined that 575 morning peak hour and 405 evening peak hour vehicles, representing about 30 percent of total traffic volume, would need to be removed or diverted from the network. This could occur in a number of ways, primarily: by switching travel mode, altering travel time, or by altering travel route. The MBTA has anecdotal data that suggests traffic volumes may reduce by up to 20 percent when dedicated bus lanes are established. The data suggest bus ridership in the same area increases by about five percent, with the rest of the displaced traffic finding an alternate route, which may be regional or local. In cases where these diversions are evident, there has not been registered complaints of increased traffic on adjacent streets. This suggests that while route choice is affected, a large portion of the diverted traffic may be classified as “cut-through” and be returning to the primary routes they originally diverted from.

In the case of the Gateway East study area, a 20 percent reduction in traffic volumes would not be sufficient to offset travel impacts associated with the implementation of dedicated bus lanes. An additional 190 morning peak hour trips and 135 evening peak hour trips would have to be diverted from the corridor to maintain existing operational levels of service. Local trips may have the option to divert an increased percentage to the adjacent bus routes or Green Line D-branch. Trips of a more sub-regional nature may divert to one of two adjacent neighborhood routes, depending on their ultimate origin or destination:

- Northbound –Cypress Street to Aspinwall Avenue
- Southbound – Cyprus Street to Walnut Street to Pond Avenue or to Jamaicaway

A review of broad-level Street Light data suggest that up to 30 percent of traffic on Route 9 in Gateway East is destined to the Longwood Medical Area (LMA). Based on this information, it is reasonable to assume that up to 30 percent of the traffic that may divert would choose a northbound bypass route. The street light data suggest that up to 60 percent of the traffic on Route 9 in Gateway East is destined to Jamaica Plain, the Tremont Street Corridor, and points east (including I-93). Trips that may divert from Route 9 to these destinations are likely to choose the southbound bypass route via Pond Avenue and the Jamaicaway. The remaining 10 percent are estimated to be destined to the Huntington Avenue Corridor, Copley Square, and downtown Boston. Portions of traffic with these destinations may divert to Walnut Street via Cyprus Street and rejoin the Route 9 corridor at Pond Street or Walnut Street.

It is noted that as of summer 2020, traffic volumes along Route 9 were reduced by about 40 percent compared to 2019 conditions. Under current conditions, the Gateway East area could maintain planned traffic operations without any diversions. It is difficult to pinpoint exactly how many vehicles may divert from the corridor as traffic volumes return to 2019 levels (or how quickly a return to these levels may occur) and which route they might choose. If dedicated bus lanes are implemented, the town should monitor traffic volumes on adjacent local roads and may have to consider additional mitigation along these routes to discourage travel as a way to bypass Route 9.

Proposed Concepts – Traffic Design Issues/Implications

Beyond the calculation of potential benefits and impacts associated with the addition of dedicated bus lanes, the ongoing MassDOT construction project presents a number of challenges from a traffic design perspective. These challenges do not invalidate the benefits of a dedicated bus facility for transit users. However, they will have to be addressed in some way as part of the bus lane implementation to maintain traffic safety in the study area.

- **Brookline Avenue dual left-turns southbound to eastbound Route 9 (easterly project limits)**. With the dedicated bus lane, only one receiving lane remains on Route 9 eastbound. This would require a change in the Brookline Avenue geometry to allow only one left-turn lane from Brookline Avenue to Route 9 EB. The queuing impacts of reducing the number of left-turn lanes are substantive and cannot be modeled accurately in synchro due to their anticipated length. We are highlighting the potential to drop exclusive use of a dedicated bus lane on Route 9 eastbound between Brookline Avenue to Pond Avenue (~200 feet). In this section, the bus lane could be striped with red dashed paint to denote shared use.
- **Route 9 eastbound, west of High Street (westerly project limits)**. This approach has two departure lanes through the intersection and is reduced to one receiving lane in front of the Fire Station due to adding bus lane (~175 feet). Geometrically, our recommendation is to reduce the approach to one through lane and one right-turn lane (to High Street). There is plenty of available distance on Route 9 to accommodate the increased queuing, although there is the potential for bottleneck issue where the lane drop occurs (where the impatient driver tries to go around the queue and cut in). This approach of Route 9 is under MassDOT jurisdiction and the town/MBTA would need to get state approval to drop the lane. An alternate solution to this would be to have a shared bus/vehicle lane along Route 9 in front of the firehouse.
- **Route 9 eastbound at Pearl Street.** In conjunction with above, we reviewed maintain 2 lanes eastbound along Route 9 through Pearl Street, restricting eastbound left-turns from Route 9 to Pearl Street and converting the left-turn lane to a through lane. There are lane alignment concerns associated with this change, as traffic traveling in the left-most through lane would be forced to turn left onto Brookline Avenue. However, given the high left-turn volume at Brookline Avenue, this may be an acceptable compromise. Eastbound traffic destined to Pearl Street would also turn left onto Brookline Avenue and access Pearl Street at its intersection with Brookline Avenue. It is not possible to provide a U-turn for Route 9 eastbound traffic.
- **High Street Northbound at Route 9.** The short block of High Street between Walnut Street and Route 9 (approximately 120 feet) currently provides two northbound through lanes to Washington Street and into Brookline Village. The westbound dedicated bus lane will eliminate a receiving lane for this traffic on Washington Street. In this case, it is suggested to allow for a shared use of the dedicated bus facility between Route 9 westbound and its terminus at Station Avenue. High Street south of Walnut Street experiences substantial queuing under current conditions and exacerbating conditions here would not likely be supportive by residents.
- **Bus Blocking by excessive queuing at signals.** The inbound 95th percentile queue at Washington Street southbound at High Street increases from 294 feet to 817 in the morning and 261 feet to 788 feet in the evening. The outbound 95th percentile queue at Washington Street westbound at Brookline Avenue increases from 508 feet to 920 feet in the morning and 586 to 1054 feet in the evening. Without making the determination about whether the queue increase would be acceptable, queues would block access to the beginning of the eastbound bus lanes, which reduce their benefit. In the westbound direction, it is assumed the bus is already in a dedicated bus lane in Boston, the impact of the queue increase on the bus is eliminated.

Given the overall benefits, impacts, and challenges with installation of the dedicated bus lanes, and in lieu of the recent MassDOT construction project, which is now substantially complete, it appears that dedicated bus lanes can be installed in the westbound direction without extensive disruption or requirements for reconstruction. Provision of dedicated bus lanes in the eastbound direction, regardless of the concept, will likely require more substantive design changes, potential reconstruction of the separated bike lane, and further coordination with MassDOT to modify sections of state highway. A dedicated bus lane in the eastbound direction will take longer to implement due to these challenges. It is likely most beneficial to focus efforts on a westbound dedicated bus lane at this time and follow with eastbound changes in the future.