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TO: City of Cambridge, MassDOT

FROM: McMahon Associates

SUBJECT: Kendall Square Mobility Task Force:
Bus Priority Corridor Traffic Review

DATE: September 30, 2016

This memorandum has been prepared to outline potential impacts and next steps associated with the implementation of bus priority lanes between Lechmere and Kendall Square.

Bus Priority Corridor Overview

The City of Cambridge outlined two potential options for each roadway segment within the proposed bus priority corridor. The two options were developed and analyzed as follows:

- *Option 1: Continuous Bus Lane on One or Both sides of the Street*
 - First Street – Northbound bus lane from Binney Street to Cambridge Street.
 - Binney Street /Galileo Galilei Way – Eastbound and Westbound bus lanes between First Street and Main Street
 - Third Street – Northbound and Southbound bus lanes between Binney Street and Broadway
 - Vassar Street – Southbound bus lane from Main Street to Massachusetts Avenue
- *Option 2: Bus Lane on Alternating Sides of the Street*
 - First Street – Northbound bus lane from Charles Street to Cambridge Street and Southbound bus lane from Charles Street to Binney Street
 - Binney Street – Eastbound and Westbound bus lanes between First Street and Third Street
 - Third Street – Northbound bus lane bus lane between Kendall Street and Binney Street and Southbound bus lane between Potter Street and Broadway
 - Vassar Street – Northbound bus lane approaching Main Street and Southbound bus lane approaching Massachusetts Avenue

The options provided by the City in the September 9, 2016 e-mail from Susanne Rasmussen were used to create roadway cross sections that accommodate the transit, bicycle, and vehicle users along the

potential corridors (See attached). Along corridor segments with existing bicycle treatments, it was considered a priority to maintain the bicycle access in some form. The separated bike lanes on Binney Street and Vassar Street were not considered for removal to incorporate proposed transit lanes. Traffic volumes utilized for the analysis are based on the 2024 future traffic volumes documented in the *Kendall Square Urban Renewal Project (KSURP) Amendment No. 10 Single Environmental Impact Report* prepared by VHB in October 2015.

It should be noted that while the analysis was completed as two options, many of the intersection improvements could be implemented individually. If certain elements of the bus priority move forward, further consideration should be given to how implementation of bus priority fits with various intersections and corridor segments within the street network.

Cross Sections for Consideration

Cross sections for the two bus lane options outlined above were developed based on the City's recommendations. For each roadway segment, multiple options with varying levels of exclusivity for transit and bicycles within the existing curb-to-curb widths were developed. At the intersections, shared turn and bus lanes could be considered to balance vehicle and bus operations. The cross sections considered along the corridors, along with a list of pros and cons for each cross-section variation, are presented in an attachment for consideration by the Kendall Square Mobility Task Force (KSMTF). The cross-sections identified as "Option 1A and 2A" are also depicted in plan view along First Street and Third Street.

Key Findings by Roadway Segment

First Street

- Transit lanes eliminate all existing parking and loading areas. The City of Cambridge and the KSMTF may want to explore allowing off-peak parking in the bus lane.
- Roadway lanes for buses or parking could be created by eliminating the bike lanes on First Street and instead diverting bicycle traffic to Second Street. This would allow creation of a creating a low stress bike route as proposed in the Bicycle Master Plan.
- At the Cambridge Street and Binney Street intersections, special attention should be given to right turn bus and vehicles lanes to further evaluate conflicts and turning radius.
- Further consideration of transition lengths for the termination and beginning of the Option 2 alternating bus lanes at Charles Street will be required.
- Coordinate with the North Point project regarding access into Lechmere Station and the presence of dedicated bicycle facilities.

Binney Street/Galileo Galilei Way

- By using the median and outside travel lane, the desired bus lanes and separated bicycle lanes can fit in the curb-to-curb cross section.
- Intersection layout at the First Street, Third Street, and Broadway intersections will require careful attention to turning buses along the desired transit route.

- At the Broadway intersection under Option 1, the median, bicycle, and travel lanes can be reduced to fit a northbound and southbound left turn lane.
- The Grand Junction path could be used for southbound bicycle travel, freeing up space for transit and additional vehicle lanes within the existing roadway.

Third Street

- Too narrow to implement transit lanes and separated bike lanes on both sides without significantly narrowing sidewalk/landscaping space.
- There may be opportunity for widening on the southern segment of Third Street in coordination with the redevelopment of the Volpe Center.
- Bus lanes eliminate all existing parking and loading areas. May want to explore allowing off-peak parking in bus lane.
- Removing turning lanes on the Third Street approach to Broadway impacts the current signal phasing that separates pedestrian and vehicle conflicts.

Vassar Street

- The roadway is too narrow within existing curb-to-curb widths to create a bus lane from the parking lane, as the parking lane is only 7- feet wide. Implementation of a bus lane would require additional width be taken from existing landscaping buffer against the separated bike lane.

Recommended Next Steps

1. Refine the intersection geometries and connections between the bus lane segments on the preferred bus priority corridor alignment. Develop the roadway treatment required for the beginning and ends of bus lanes.
2. Design the roadway connections at the limits of the potential corridor.
3. Develop a design of bus stop locations considering bus and bike conflicts.
4. Review a one-way pair with Vassar Street and Albany Street to accommodate bus lanes.
5. Review Second Street as a potential alternative bike route to First Street to allow more transit and vehicle improvements.
6. Compile as-built plans and available right-of-way plans to more accurately depict the implementation impacts.
7. Evaluate if First Street and Athenaeum Street could be used for the Lechmere- Kendall Square bus corridor instead of the narrow northern section of Third Street.
8. Complete a survey of the proposed bus priority corridor to develop more detailed roadway information.

Key Findings from Capacity Analysis

A Synchro capacity analysis was performed in order to evaluate the conceptual implementation of bus priority lanes. Traffic volumes developed in the KSURP Amendment 10 report were utilized in addition to the intersection geometries proposed as part of the project. The transit lane configurations

were carried through to the intersections, showing the most impact possible from the implementation of transit lanes. Reduced impacts from shared turning/transit lanes were not evaluated. Cycle lengths were increased to 120 seconds where an appreciable LOS change was possible. Improvements to signal operations by improving coordination along the transit corridor were not accounted for. A table with the results and assumptions of the traffic analysis is provided in the attachments.

First Street at Cambridge Street

- The southbound approach was changed to a right and a through lane
- Both Option 1 and Option 2 have the same capacity impacts to the intersection.
- The weekday afternoon is the critical peak hour and shows that volumes are more than double capacity on the critical northbound right turn movement.
- Northbound queuing extends an additional 200 to 500 feet from the 850-foot base configuration queues.

First Street at Binney Street

- The westbound approach was modified to an exclusive left turn lane and a shared through-right lane to accommodate the bus lane farside of the intersection. This significantly reduces the available queue storage along Binney Street.
- Under Option 1, the eastbound bus lane left turn goes with the eastbound left lane because it has the receiving northbound bus lane. Under Option 2, the eastbound left goes during an exclusive phase to act as a queue jump.
- Cycle lengths were increased to 120 seconds in order to increase capacity for both options during the weekday afternoon
- The overall intersection delay increases significantly (4-5 times) from the base configuration and is greater for Option 2 than Option 1 during both peak periods

Third Street at Binney Street

- Option 1 and Option 2 both require adding an exclusive bus-left turn phase to provide safe access from Binney Street to Third Street.
- Option 1 and Option 2 maintain the exclusive eastbound and westbound left turn lanes and phases.
- Option 1 and Option 2 convert the northbound approach to a bus lane and a shared left-through-right lane by eliminating the exclusive right turn lane.
- Option 1 converts the outside lanes on Binney Street to bus lanes.
- Option 2 converts the westbound outside lane on Binney Street to a transit lane and the eastbound outside lane to a right turn lane to make room for the transit lane farside of the intersection.
- Option 2 performs better than Option 1 (Continuous Bus Lane) and the weekday afternoon volume to capacity ratio doubles from the base year and is well over capacity.
- Providing exclusive transit lanes on both Binney Street and Third Street may be too constrictive to the intersection with the current available right-of-way and desired cross section.

Third Street at Broadway

- The intersection is shown to operate with a v/c ratio well over 1.00 during both peak hours under the base condition.
- Both options require removing the southbound right turn lane and changing the through-left lane into a shared right-through-left lane. Modifying the lanes removed the phasing sequenced being used to provide time separation between turning vehicles and pedestrians.
- Cycle lengths were increased to 120 seconds in order to increase capacity for both options during the weekday morning.
- Vehicles on the southbound approach are shown to experience more delay under both options.
- Vehicular operations are worse with the transit lane in place, not as bad as other intersections in the corridor. However, implementation of transit lanes results in significant decrease in pedestrian safety.

Galileo Galilei Way at Broadway

- Modifications to this intersection are only made under Option 1(Continuous Bus Lane), which include changing the northbound and southbound approaches to have a left turn lane and a shared thru right lane and transit lane. The signal provides an exclusive bus southbound left turn phase onto Broadway.
- The intersection is shown to operate during the base condition at overall LOS D with a v/c ratio just under 1.00 during the weekday morning and weekday afternoon peak hours.
- Under Option 1 during the weekday morning, the southbound movement is shown to experience a significant increase (4-5times) in delay from the base condition. The v/c ratio is shown to be 1.41.
- Under Option 1 during the weekday afternoon, the eastbound left and southbound through/right movements are also shown to increase significantly in delay.
- Evaluating this intersection based on “person-delay” may show that the decreases to vehicles are outweighed by improvements to transit.

Galileo Galilei Way at Main Street/Vassar Street

- This intersection has the most available capacity of all the study area intersection and is shown in the base condition to operate at overall LOS C or better, with volume to capacity ratios under 1 during both peak periods.
- Both options require reducing the northbound Vassar Street approach to one left-through-right lane.
- Option 1 modifies the southbound approach to a right lane and a share through-left lane, while Option 2 makes no modifications.
- Implementing a transit lane does not significantly degrade traffic operations at the signal.

Recommended Next Steps

1. Review adjacent intersections and smaller intersections like First Street at Charles Street, First Street at Second Street, and Binney Street at Fulkerson Street for potential impacts.

2. Analyze other scenarios for shared bus/vehicle lanes at intersections that may reduce impacts to vehicles along the corridor.
3. Determine the appropriate bicycle accommodations for the bus priority corridor.
4. Analyze the bus delay at intersections as part of the total corridor travel times.
5. Refine the priority corridor and intersection concepts and optimize the coordination of the signals within the system.
6. Modifying the turn lanes along Galileo Galilei will impact the phasing for the train pre-emption that exists along the Grand Junction railway. Subsequent analysis should account for this.
7. Review a “person-delay” metric at each intersection for the operations analysis to help evaluate bus improvements.
8. Consider Broadway as part of a transit priority because intersection and roadway capacity seems to exist along Galileo Galilei Way and Binney Street as opposed to Third Street.
9. Investigate First Street between Binney Street and Athenaeum Street.

Bus Operation Considerations

Bus Frequency

Bus and bike conflict management is primarily based on the frequency of bus service within the corridor. For shared bus and bike lanes the *NACTO Transit Street Design Guide* recommends that headways be longer than 4 minutes. At bus stops, the *FHWA Separated Bike Lane Planning and Design Guide* says a bus headway of 15 minutes or longer is appropriate for mixing bicycles with bus stops. The proposed bus frequency along the corridor was estimated as follows based on the bus route alternatives under consideration:

Bus Route	Headway	Frequency
EZ Ride	7 min	8
92A	15 min	4
CT 4	10 min	6
Transit Corridor	3.3 min	18

At the levels of transit use along the corridor noted above, it would be preferable to separate bicycles and buses with their own lanes and at bus stops based upon the available guidance. This should be reviewed as transit volumes along the corridor become more clear.

Bus Stop Locations

As part of the bus priority corridor, bus stops are proposed as follows:

- First Street at Charles Street, farside in both directions for both options.
- Third Street at Binney Street
 - Nearside Binney for direction to Kendall
 - Farside Binney for direction to Lechmere

Bus Stop Treatments

At the bus stops along the corridor, varying types of stops can be considered based on the amount of space available and separation desired. The ideal bus stop adjacent to a bicycle lane is shown in Figure 1 below. Cyclists are separated fully from the bus and boarding and alighting passengers. In constrained locations, it may be appropriate to allow bus passengers to board and alight from within the separated bike lane while still separating cyclists from the buses, which is shown in Figure 2. Enhanced markings and signage within the separated bike lane make cyclists and passengers aware of the potential conflicts. To prioritize transit users, separated bike lanes could remain at street level as a regular bike lane and buses could pull into the lane to board and alight passengers waiting on the sidewalk. This option is shown in Figure 3. Within a shared bus/bike lane it would be ideal to allow passing space for cyclists to overtake buses at stops. This option is shown in Figure 4. As the design of the corridor progresses, bus stops will need to be evaluated within the available cross sections widths. To make space for bus stops, transit lanes, medians, and bike lanes can be reduced in width for short sections within the corridor.

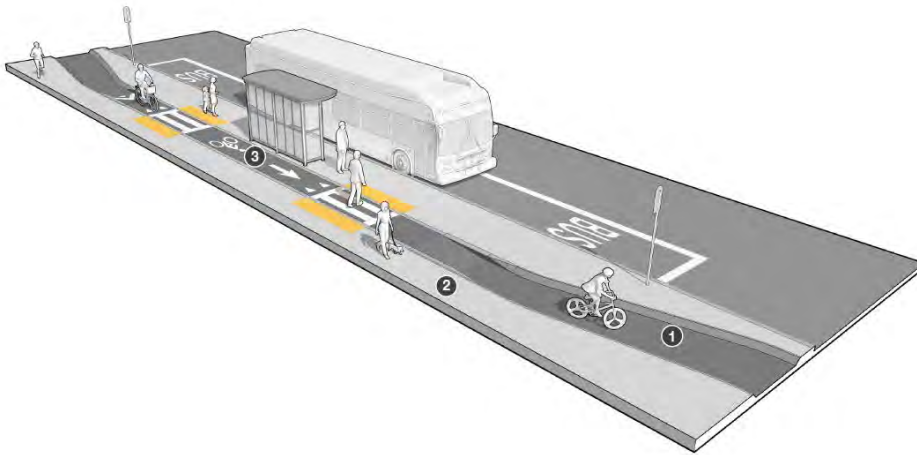


Figure 1: Unconstrained Bus Stop with adjacent Separated Bike Lane (MassDOT)

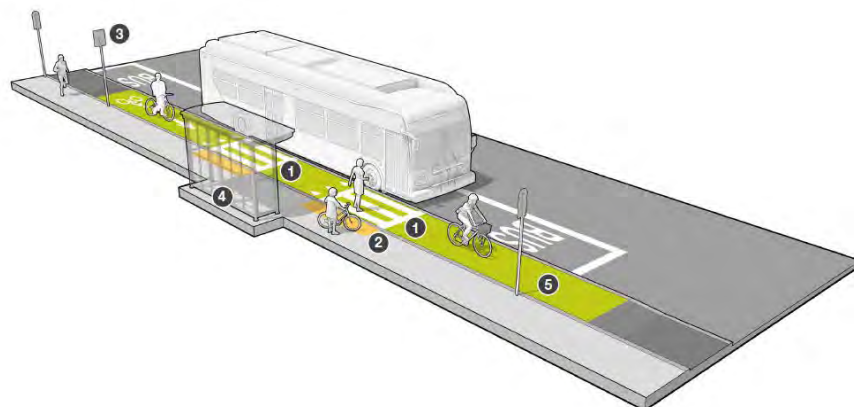


Figure 2: Constrained Bus Stop with adjacent Separated Bike Lane (MassDOT)

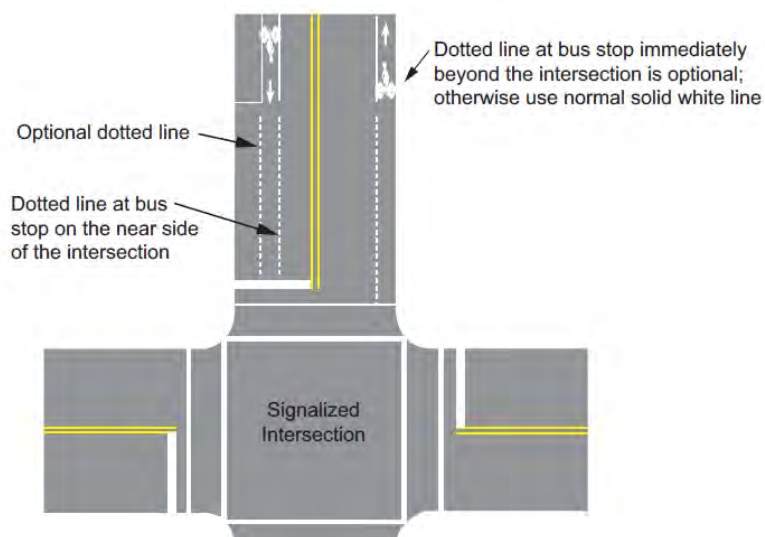


Figure 3: Bus Stop with adjacent Bike Lane (AASHTO)

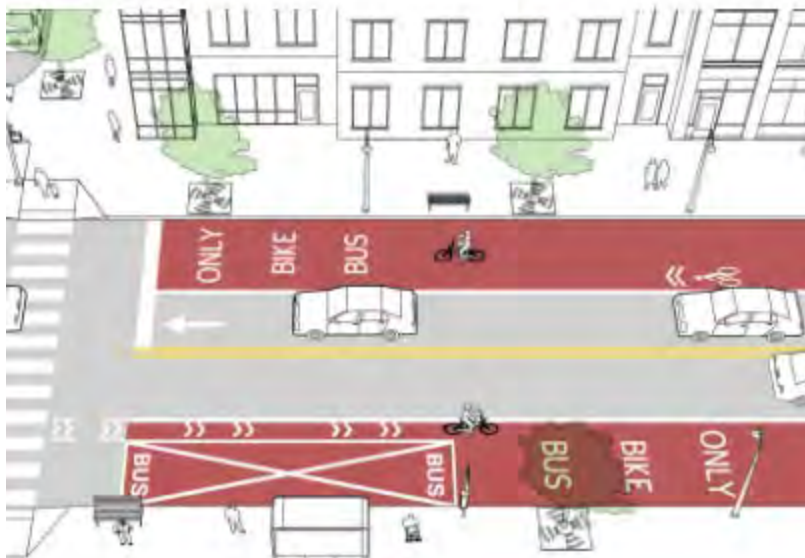


Figure 4: Bus Stop within Shared Bus-Bike Lane (NACTO)

Attachments:

1. Cross Section Summary
2. First Street Concept Option 1
3. First Street Concept Option 2
4. Third Street Concept Option 1
5. Third Street Concept Option 2
6. Capacity Analysis Summary