NORTHEASTERN UNIVERSITY

Department of Civil Engineering - Master's Report

Report Title: **Transit Lane Design on Huntington Avenue, Mission Hill Section**

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Approved for Report Requirement of the Master of Science Degree - Civil Engineering

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Abstract: This project was to make a traffic simulation model of how the road would operate if the middle lanes of Huntington Ave, from Brigham Circle to South Huntington Avenue, are reserved for bus and streetcar only, with median platforms so that passengers getting off a transit vehicle don't have to step directly into the street. This project includes both physical design and traffic control design, including retiming signals, turn restrictions, and adding left-turn bays. Parking lanes for residents were maintained, although 20 parking spaces had to be removed in order to provide median platforms. Simulation analysis using VISSIM software shows that limiting the general traffic to one lane per direction would reduce capacity to only slightly less than current p.m. peak traffic volumes. Reserved transit lanes will reduce peak hour transit delay from 6.5 minutes to 1.5 minutes, offering a large benefit to both the transit agency and to transit users. The addition of median platforms would greater safety to transit users. We also show that it by moving the curbs, it is possible to add cycle tracks, greatly improving bicycling safety as well.

Key words: transit priority; transit lane; bus delay; simulation; VISSIM

§1. Introduction

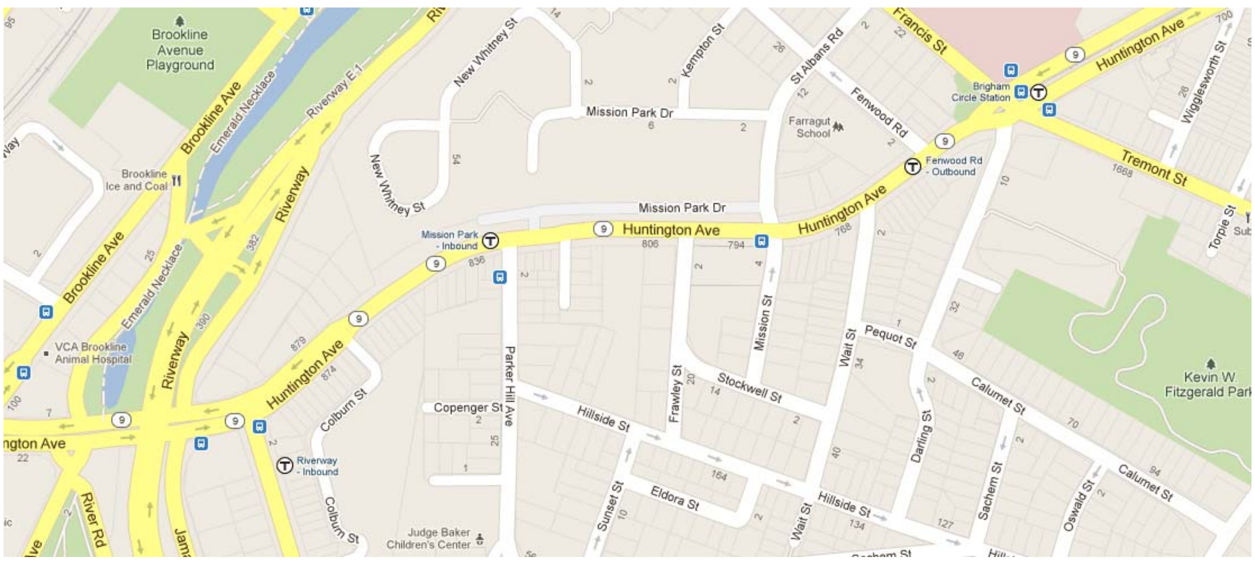

Figure 1: Huntington Ave in Mission Hill section

§1.1 Background

Huntington Avenue, a part of state route 9, is an important access between downtown Boston and western suburbs. In the section of, this corridor is a gateway to Boston. This project focuses on the Mission Hill section of Huntington Avenue, from Brigham Circle to South Huntington Avenue. Two heavily used bus route – the route 39 and route 66 – use this corridor, along with the heavily used Green Line E branch, operating in mixed traffic.

Table 1 shows the frequency of transit on this section of Huntington Ave. A calculation done in Table 2 shows that while transit represents only 3% of the vehicles, it carries 70% of the people. Therefore it makes sense that traffic on this corridor should be managed in a way that gives priority to transit. Allowing transit vehicles to be severely delayed by private traffic represents a failure in traffic management.

Table 1: Frequency of Transit (Peak Hour/Peak Direction)

Route	Frequency	Vehicle Type
Bus 66	9 min	Standard bus
Bus 39	6 min	Articulated bus
Green Line E	6 min	2-car trains, each car articulated

Table 2: Number of People Carried by Transit vs Cars (Peak Hour/Peak Direction)

		Assumed Load per veh (passenger/veh)	Vehicular volume (veh/hr)	Passenger volume (people/hr)
Auto		1.15	864	994
Transit	Bus 66	30	6.7	200
	Bus 39	50	10	500
	Green Line	160	10	1,600
	Total Transit		26.7	2,300
Corridor Total			891	3,294
Transit Share			*3%*	*70%*

§1.2 Safety Problem for Train Riders

On this 4-lane undivided road, streetcars operate on the middle lanes in mixed traffic. There's no platform for streetcar passengers. When the train comes to a station, same-direction traffic in both lanes is obligated, by state law, to stop. Passengers leaving the train step directly into the street, and have to walk across one travel lane (plus a parking lane) to reach the sidewalk. Passengers waiting for a train wait on the sidewalk, then cross to the middle of the street to enter the train when it arrives. This is a potential safety problem for all train users.

Lack of platforms also makes it very difficult for people with disabilities to use those stations. Evenutally, the MBTA will be required to make these stations accessible, which will require some combination of platforms and low-floor vehicles.

§1.3 Congestion

This corridor is heavily congested on the outbound direction during the PM peak (Figure 2). Buses and trains are often stuck in traffic. Traffic can be congested all the way to Brigham Circle.

In addition to cars interfering with transit, buses and streetcars also interfere with general traffic. When buses are stopped at a station for boarding or alighting, they block the right lane (while buses pull over to the curb, the parking lane is not wide enough to hold a bus, and so the bus still blocks a travel lane). When streetcars stop, both lanes of traffic are stopped. This interference reduces traffic capacity, and causes queues that often spill back to delay not only general traffic but also other buses and streetcars. Click to see a TRAFFIC SIMULATION OF EXISTING CONDITIONS, P.M. PEAK.

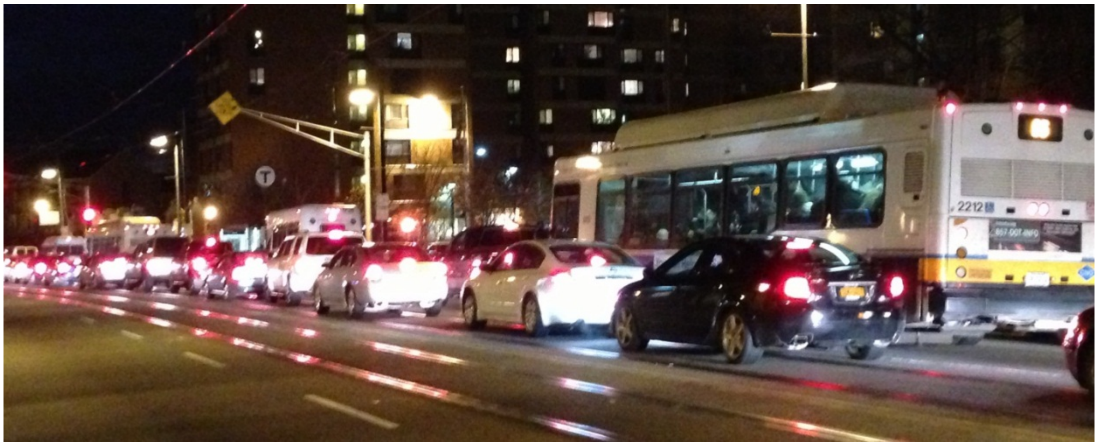

Figure 2: Long queues causing delay to buses

§2. Design Goal and Study Objectives

§2.1 Design Goal

This street has been redesigned to better balance the use of space against user needs. There are three levels of the design goals, with lower level goals treated as subservient to the higher level goals.

- Highest level goal: Priority for transit. This design is aimed at eliminating nearly all delay for transit. It is impossible to give transit priority using only signal priority due to congestion. Separate transit lanes are needed. Delay caused by buses and streetcars having to wait for one another is acceptable.
- Highest level goal: Safety for transit users. Platforms are needed to improve the safety for train users.
- Second level goal: Maximize the capacity for private traffic, while maintaining parking lanes for residents.
- Third level goal: Improve bicycle safety by providing cycle tracks.

§2.2 Study Objectives

1. Detailed design (including physical design and signal design).
2. Estimating the maximum traffic capacity that will result from limiting cars to only one through lane.
3. Estimating impacts to transit, general traffic, parking, pedestrians, and bicyclists

§3. Corridor and Data Description

§3.1 Corridor and Intersections

The street is 60 feet wide, with two travel lanes and a parking lane on each side, as shown in Figure 3. Cars and buses use all travel lanes. Streetcars use only the inside lanes, which is where there tracks lie.

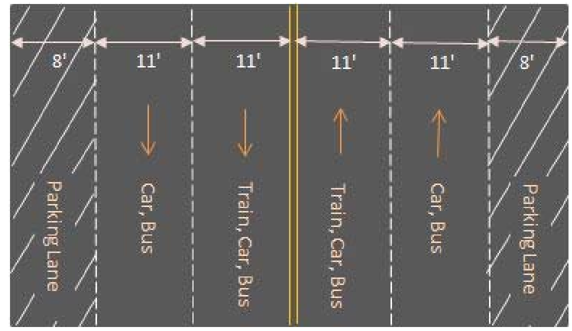

Figure 3: Existing Layout

There are seven intersections in this corridor. Only two, one at Frawley Street and the other one at Wait Street, are unsignalized. The others are all signalized. (see Figure 4).

Each direction has 2 stops for buses and Green Line streetcars: Fenwood Road and Mission Park.

In the outbound direction, Bus 39 and the Green Line turn left onto South Huntington Avenue at the western end of the study section, while Bus 66 continues through on Huntington Avenue to the west.

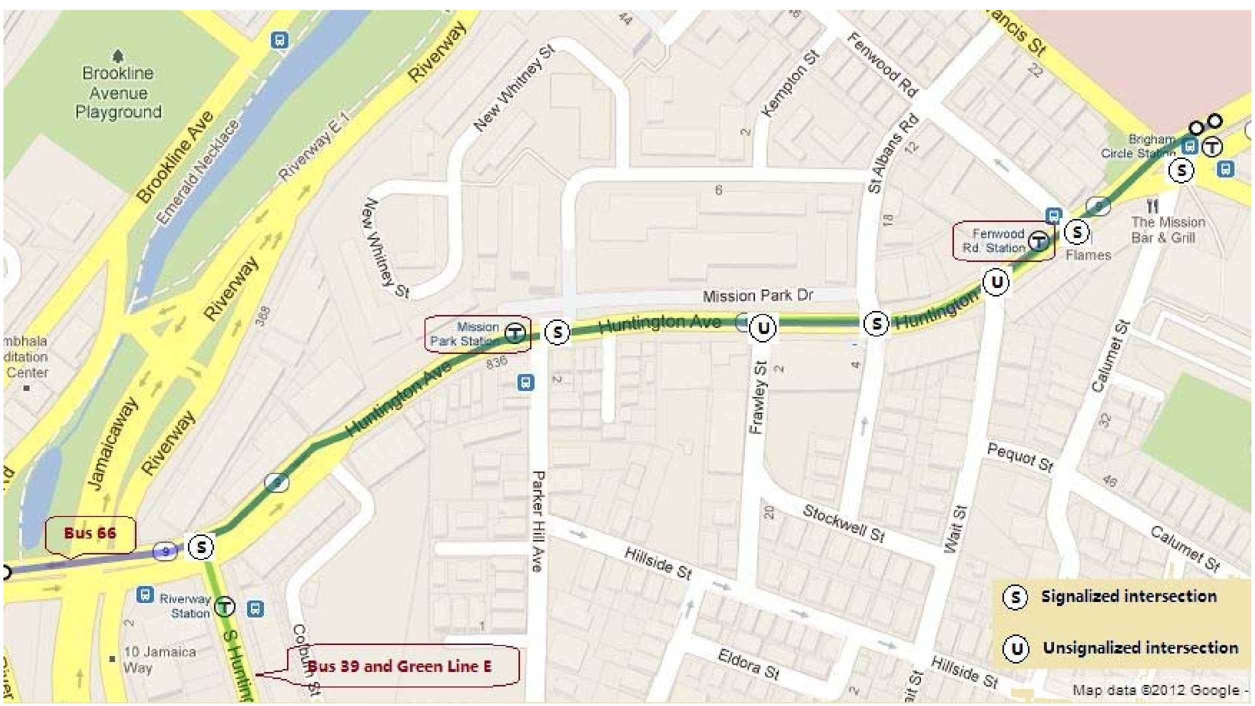

Figure 4: Transit Lines, Transit Stops, and Signals

§3.2 Data Description

Traffic Counts:

- A 2009 study by VHB was provided by MASCO covering the 3 eastern intersections;
- We did additional counts on August 15, 2012. It's a consistent count made by 7 people simultaneously. The volumes that day were 17% lower at the eastern intersections than that in the VHB counts. Therefore all of the 2012 counts were expanded by 17% to match the VHB count for westbound approach to Fenwood. It is not unusual for summer counts to be lower than average, and it is standard industry practice to scale them to a benchmark volume.

Pedestrian volumes were not counted, but they are not needed because pedestrian phases run every cycle.

Transit dwell time was assumed to be a random variable taken from a normal distribution. For bus, mean = 20 s and std dev = 5; for train, mean = 25 s and std dev = 5.

Default VISSIM model parameters for traffic flow were used. They correspond approximately to a saturation flow rate of 1800 veh/h/lane.

Existing signal timing was measured in the field.

§4. Physical Design

In Christopher Boll's thesis *Congestion Protection for Public Transportation: Strategies and Application to MBTA Bus Route 66* [3], he proposed physical changes and signalling changes at five "black spots" (places where buses suffer from traffic congestion) along Route 66. One of those black spots is the Mission Hill section of Huntington Avenue. Some of his ideas are adopted by this report, while the detailed physical designs are improved to meet higher level of safety and efficiency demand.

§4.1 General Lane Configuration

The basic design, with curb lines unchanged, is (Figure 5):

- Inside lane for transit only (bus and streetcar),
- Outside lane for general traffic.

To show the distinction from the regular travel lane, the transit lane can be paved a few inches higher than the travel lane (see Figure 6), with a beveled curb so that cars can enter the transit lane if the regular travel lane is blocked (say, by a delivery vehicle). This design is used in Brussels, and is effective outside of commercial areas.

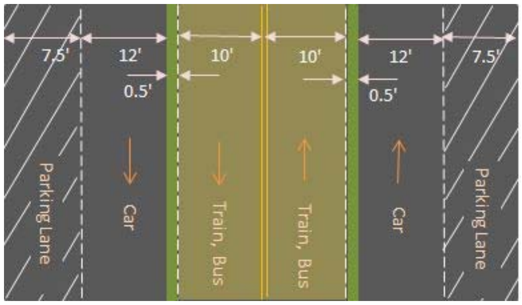

Figure 5: Proposed Lane Configurations on Huntington Ave

This design has a great benefit for fire response and ambulance.
They can use the transit lanes to bypass the queue, and also switch back to general traffic lanes if the transit lane is blocked by a bus or streetcar.

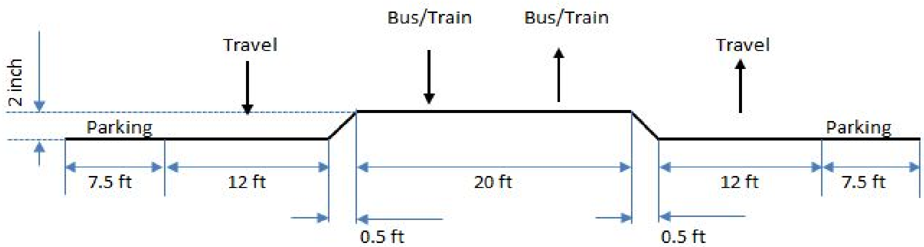

Figure 6: Profile Showing Raised Transit Lanes

§4.2 Design at Stations

§4.2.1 Platforms

At each stop, raised mid-street platforms are proposed. In order to serve the Green Line, which uses two-car trains 135 feet long, the platform is 150 feet long and 7 feet wide. Parking will be prohibited along the platform, and the space that is elsewhere given to the parking lane will provide this 7 feet width for platforms. Each

Figure 8: Mid-street Platform for Transit on Queensway, Toronto

platform is connected to both sides of street with a signal protected crosswalk. Figure 8 is an example of Mid-street streetcar stop on Queensway in Toronto, Canada.

§4.2.2 Parker Hill Ave @ Huntington Ave

At the intersection of Huntington @ Parker Hill Ave, we propose far-side platforms (i.e., platforms downstream of the intersection), as shown in Figure 9. Both platforms are connected to the sidewalks by signal-protected crosswalks. A left turn bay is provided for left-turn traffic to prevent left-turners from blocking through traffic. Eastbound, the left turn to Mission Park Drive has been prohibited. Instead, cars can turn left at St Albans Road.

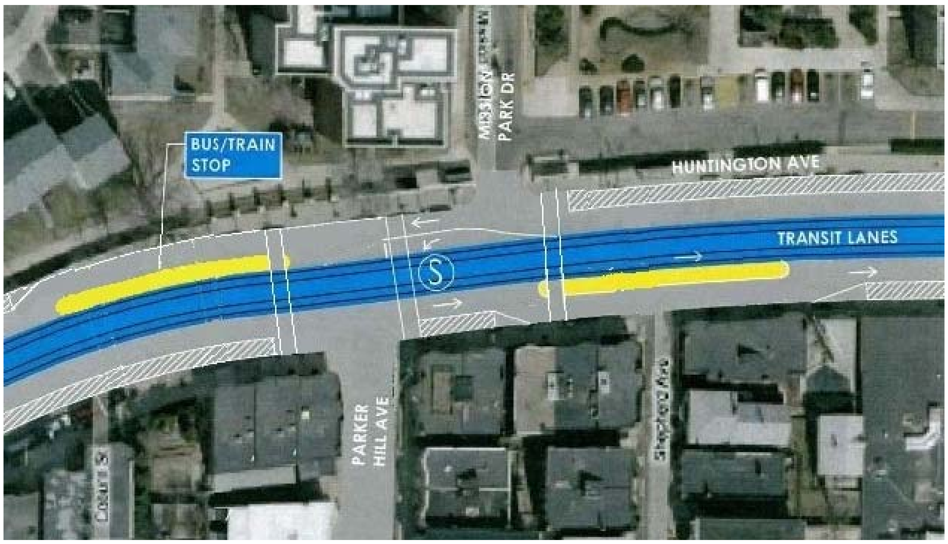

Figure 9: Proposed physical design at Parker Hill Ave @ Huntington Ave [3]

§4.2.2 Fenwood Rd @ Huntington Ave

Mid-street platforms are designed at Fenwood Rd intersection as well, as shown in Figure 10. We propose making left turns prohibited for eastbound traffic; cars can turn at St Albans St and Francis Street instead.

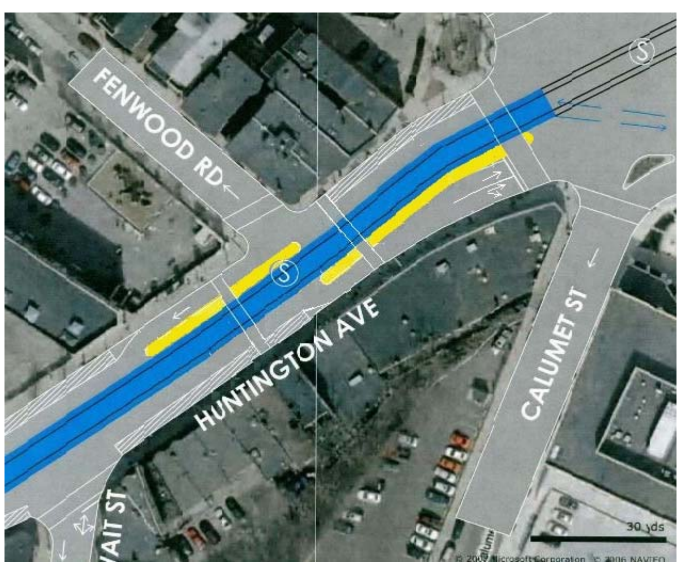

Figure 10: Proposed physical design at Fenwood Rd @ Huntington Ave [3]

§4.2.3 St. Albans @ Huntington Ave

At the intersection of St. Albans and Huntington, there is no transit stop. A left-turn pocket is proposed for eastbound motor traffic. Mission Street will continue to be one-way northbound.

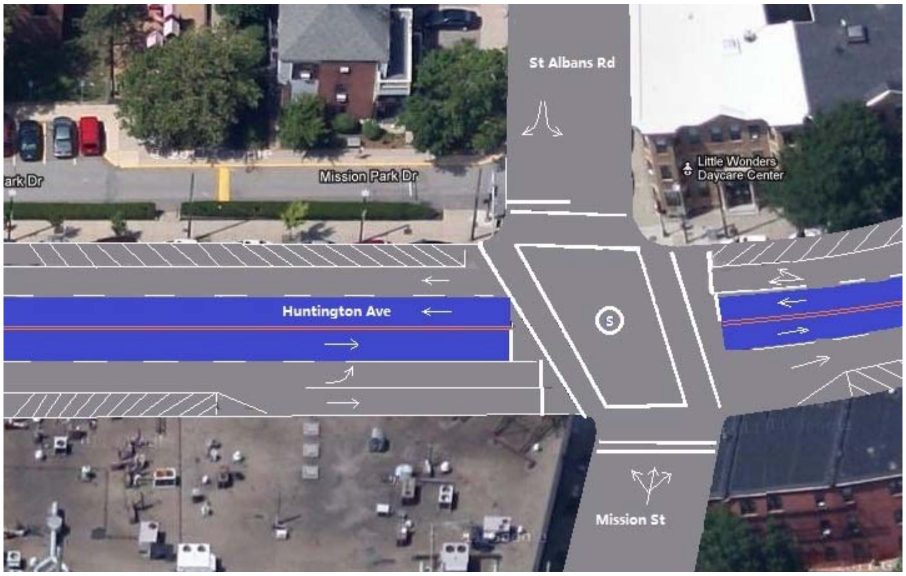

Figure 11: Proposed physical design at St. Albans @ Huntington Ave

§4.3 Design for Safe Bicycling

Cyclists are poorly served in the existing corridor due to the heavy traffic. Bikes have to share the street with heavy traffic, including many buses and streetcars, which is not safe. With the heavy queuing, cyclists often ride between lanes as well as in the left lane, where streetcar tracks pose a danger. A cyclist whose wheel got caught in the tracks was killed by a bus in 2010. What if we build a cycle track in this corridor for them? Definitely that would benefit the cyclists a lot.

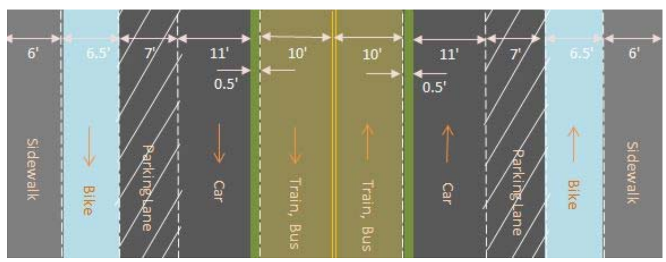

Figure 12: Proposed Layout with Curbs Shifted

In fact, a sidewalk-level cycle track is feasible on this corridor, by shifting the curbs. Figure 12 shows a possible layout, based on a measured 82' wide right-of-way. With the curbs shifted 1.5 ft inward, the sidewalk area would be wide enough to support a footpath (6 ft wide) and a cycle track. The proposed width of the cycle track and a buffer, 6.5', allows space for street signs, utility poles, and snow banks. However, this design leaves no space for street trees unlike parking spaces. A total of 33 small trees would be lost.

While street trees are desirable, they are a lower priority than bicyclist safety. Whether street trees are a lower priority than parking, however, is something that the community can consider. Street trees could be reintroduced by constructing bulbouts with tree wells into the parking lane, as is done in many older European cities and in at least one Florida city (West Palm Beach).

§4.4 Left-Turn Pockets and Prohibitions

Since the proposed design only has one travel lane in each direction, left-turning cars could block the whole traffic stream while waiting for a gap. Therefore our design adds left-turn pockets at the intersection where left-turns are allowed.

Moreover, it is dangerous to allow left-turning cars to cross the two-directional transit lanes, especially considering that during congested times transit vehicles may be going fast compared to general traffic. Therefore, our design follows the policy that left turns are allowed only with a protected left-turn signal phase. In the most recent redesign of the section of Huntington Avenue east of Brigham Circle, most permitted left turns were either banned or converted to protected lefts for the same reason.

Left-turn pockets are part of the design at Parker Hill Avenue (for westbound traffic) and St Albans Road (for eastbound traffic), as shown in Figure 13. At South Huntington Avenue, left-turning cars will be allowed to use the transit lane. They don't really block transit, because transit is also turning left.

At the same time, we propose that left turns be prohibited at Mission Park Drive, Frawley Street, Wait Street, and Fenwood Road (see Figure 13). Eastbound traffic can turn left at St Albans Street or Francis Street to get to points north of Huntington Ave., and westbound traffic can turn left at Parker Hill Ave or Calumet Street to get to points on Mission Hill (south of Huntington Ave.).

Figure 13: Proposed Left-Turn Pockets and Turn Prohibitions

§4.5 Parking Impact

There is already no parking allowed at the existing bus stops. The new platforms will be longer than the existing stops, and also require some space for the travel lane to shift between its normal position and its position along the curb at transit stops. Some curb space is also needed to fit left turn bays at St. Albans Street and at Parker Hill Ave. In total, 20 parking sites (none of them metered) need to be removed.

§5. Signal Design

Signal design concerns the p.m. peak hour. Other periods were not studied because developing a successful design during the most congested period (the p.m. peak) will prove feasibility.

Signals along the corridor will operate in coordinated-actuated mode with a 120 s cycle length during the p.m. peak, as they do in the existing condition. In addition, no change in signal phasing or timing is proposed at Brigham Circle or Fenwood Road.

§5.1 Proposed Signal Improvements

Parker Hill Ave @ Huntington Ave:

At Parker Hill Ave., a protected lagging left phase is added. The splits are adjusted to favor WBT on Huntington Ave. Ring diagrams show the phase splits in seconds.

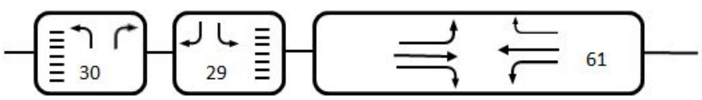

Figure 14 a: Existing Ring Diagram at Parker Hill Ave

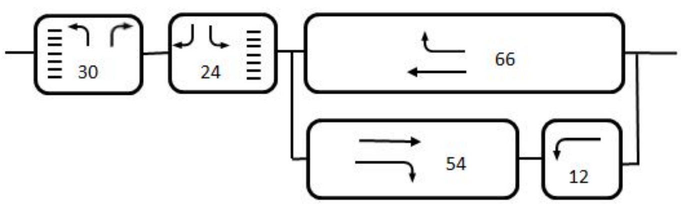

Figure 14 b: Improved Ring Diagram at Parker Hill Ave

S Huntington Ave @ Huntington Ave

At S Huntington, we keep the same phasing, but with some split adjustments (reducing the time given to NBL to favor Huntington Avenue traffic). Recall that WBL general traffic is allowed to use transit lane.

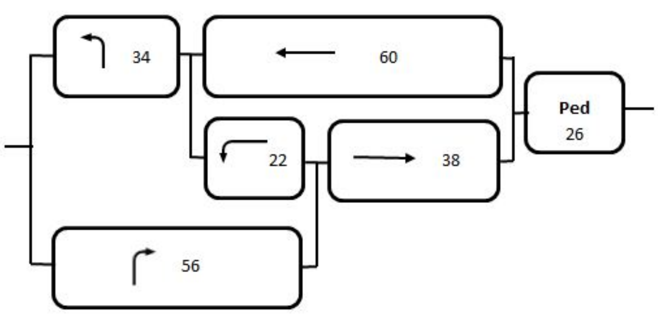

Figure 15 a: Existing Ring Diagram at S Huntington Ave

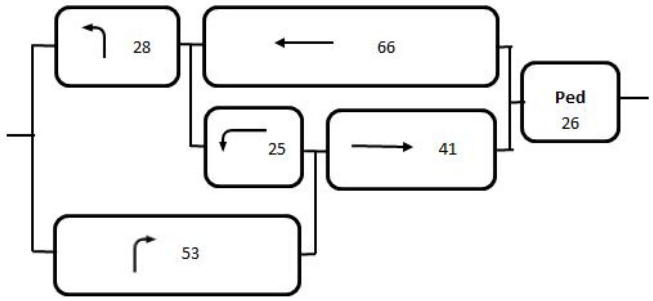

Figure 15 b: Improved Ring Diagram at S Huntington Ave

St. Albans Rd @ Huntington Ave

At St. Albans Rd and Huntington Ave, a protected left-turn signal phase will be added for the eastbound cars turning onto St. Albans Rd. This phase will only be activated by a call from the detector. The pedestrian phase here is pushbutton activated, and can remain that way since pedestrian volumes are not large (there is no transit stop here).

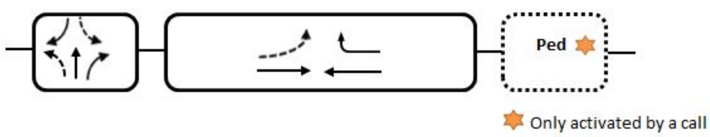

Figure 16a: Improved Ring Diagram at S Huntington Ave

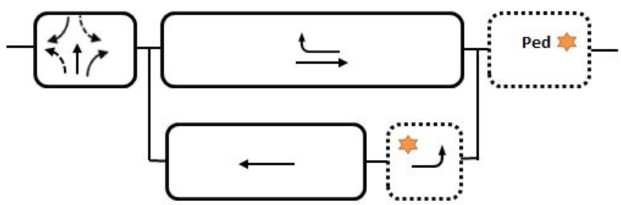

Figure 16b: Improved Ring Diagram at S Huntington Ave

§5.2 Transit Signal Priority

Transit signal priority was not modeled. However, it could be added to further reduce transit delay.

§6. Capacity Analysis

§6.1 Bottleneck Capacity Calculation

The intersection of Huntington with S Huntington is the bottleneck of the whole corridor. So the capacity calculation begins at this intersection.

Through motor traffic has been limited to one lane. For the critical movement (westbound through),

Capacity= (green time/Cycle)*saturation flow rate=(55/120)*1800=825 veh/hr.

However, the existing through volume counted at that intersection is 945veh/hr.

This suggests that the proposed layout will require a throughput reduction of (945-825) = 120 vehicles/h, or 13% of the current westbound through volume. This is a relatively small figure, considering that the number of lanes available to traffic is reduced by 50%!

§6.2 Calculation of the Needed Input Reduction

It was assumed that volume reduction would come about mainly by diverting westbound traffic entering the corridor at Brigham Circle (in the PM peak). Existing entering volume at Brigham Circle is 864 veh/h. Let X be the fraction by which entering traffic is reduced, such that the reduction in entering volume will be 864 X.

Traffic counts show that for every 100 cars entering the corridor at Brigham Circle, 72 pass through the bottleneck point (westbound through at South Huntington Ave), while others turn off. Therefore, the reduction in volume at the bottleneck point will be 864 * 0.72 * X. Equating this to the needed volume reduction at the bottleneck point (945 – 825, or 120) yields

X=20%.

Therefore, the bottleneck calculation suggests that an input reduction of roughly 20% is needed.

§6.3 Capacity Analysis Using Simulation

In order to determine the needed reduction in input volume more exactly, simulations were done with varying input volumes. These simulations also helped confirm that the intersections with left turn bays were operating properly without causing backups that block traffic.

When the input was reduced to 690veh/hr, traffic still flowed well. But at 700veh/hr, the congestion became heavy that the whole road network was in a mess. So it’s justified to say that the input capacity for the corridor under the proposed design is 690veh/hr, which is 20% less than existing. This result confirms the rough capacity calculation described earlier.

§6.3 Options for Diverted Traffic

In keeping with general transportation planning principles, traffic forced to divert can respond in 3 main ways:

1. Change in time – make the trip outside of peak hours.
2. Change in route (use alternative roads such as Riverway, Massachusetts Turnpike, Columbus Ave.).
3. Change in mode (switch to transit, walking, or bicycling). Because this design provides substantial improvements to transit and bicycling, it presents good alternatives to driving.

§7. Simulation Analysis Results

Traffic simulations for both existing traffic and the proposed design were done using VISSIM. Each case was run 5 times for 1 hour after a 15 minutes warm-up period; average results are presented. Click here for a VISSIM SIMULATION OF PROPOSED CONDITIONS P.M. PEAK

When simulating proposed conditions, all traffic volumes entering the corridor are the same as existing, with one exception: westbound traffic entering Huntington Ave. at Brigham Circle has been reduced from 864 to 690veh/hr.

Tables 3 compare delay between the existing and proposed conditions; Table 4 makes the same comparison for travel time. One can see that in the peak direction, westbound, bus delay is reduced from 6.3 to 1.5 min, and train delay from 7.7 to 1.8 min. This represents a dramatic improvement.

Table 3: Delay for existing and proposed design, PM peak

Delay	Westbound (peak direction)			Eastbound		
Veh Type	Bus (min)	Train (min)	Car (min)	Bus (min)	Train (min)	Car (min)
Existing	6.3	7.7	7.0	1.2	2.2	1.4
New	1.5	1.8	2.1	0.5	1.0	1.2

Table 4: Travel Time for existing and proposed design, PM peak

Travel Time	Westbound (peak direction)			Eastbound		
Veh Type	Bus (min)	Train (min)	Car (min)	Bus (min)	Train (min)	Car (min)
Existing	8.3	9.9	7.7	3.2	4.3	2.3
New	3.6	4.0	3.2	3.0	2.5	2.0

Delay for peak-direction cars is reduced dramatically, from 7.0 to 2.1min, because once cars enter the corridor, traffic will move smoothly if the entry volume is limited as we have described. If more cars try to enter, delay to private traffic will increase substantially. In addition, this calculation does not include delays that will occur at the entry to the corridor, where the road will be reduced from two lanes per direction to one. There will probably be long queues there; in effect, one can think of the priority treatment as a way of shifting the queues (congestion) from *within* the Mission Hill section of Huntington Avenue to *just outside* the Mission Hill section. That's good traffic management, since queues outside the Mission Hill section of Huntington Ave don't delay streetcars. (They will delay the Route 39 bus; that could be mitigated by allowing buses to use the Green Line reservation on the approach to Brigham Circle.)

In the opposite direction, there are smaller but still significant changes in delay for transit.

§8. Impacts

§8.1 Transit

The operation and passengers cost saving could be calculated by following assumption.

- Daily impact can be assumed to be peak hour impact multiplied by 5, for 253 weekdays per year. This accounts for a similar impact in the a.m. peak hour and smaller impacts during other hours of the day.
- Cost per hour: $120 for bus, $360 for train, $12/h for passengers.
- Equivalent capital cost is the present value of an ongoing stream of benefits due to delay reduction, using a discount rate of 4%. A cost any less than this amount would represent a net benefit to society. No amortization period is used because the conversion would not involve any recurring construction cost beyond the normal repaving that would be required if the corridor were left unchanged.

Table 5: Operating Cost and Travel Time Savings Impacts

		Annual Saving	Total	Equivalent Capital Cost
Operating Cost	Bus	$237,000	$776,000	$20,000,000
	Train	$539,000		
Value of Passenger's Time			$3,422,000	$85,000,000
Total			$4,200,000	$105,000,000

§8.2 Private Traffic

The impacts to cars are mixed.

- Peak direction capacity: Confining general traffic to one travel lane per direction lowers the capacity of the street to accept entering traffic by 20% compared to 2009 volumes.
- Peak direction travel time. This design has a large reduction in travel time to most cars, but some have to change their travel time, path or mode. The large reductions in travel time will be offset, at least in part, by increased queuing delays at the entries to the corridor where general traffic is forced from two lanes to one.
- Reverse direction: There is no significant impact in either capacity or delay. The same can be projected for off-peak hours, for traffic in either direction.

§8.3 Pedestrians

The proposed changes have no impact in terms of delay. However, they have great gain in safety from introduction of platforms, for pedestrians getting on and off of trains. In addition, introducing platforms allows the stations along this part of the corridor to become accessible to people with disabilities.

§8.4 Bicycles

Bicycle safety would not be improved if the curbs are left as they are.

However, if curbs are shifted and a cycle track built, bicycle safety will dramatically improve.

§8.5 Resident Parking

Because it was a goal of the design to preserve resident parking, the existing parking lanes will remain. However, about 20 spaces will have to be removed, mainly to accommodate the median transit platforms.

§8.6 Street Trees

This corridor currently has a total of 33 street trees, all of them rather small. If the curbs are not moved, there will be no change to street trees. However, if curbs are moved in order to provide cycle tracks for bicycling safety, the existing street trees would have to be removed. If residents put more priority on street trees than on parking, street trees could be added back by adding bulbouts into the parking lane.

§9. Conclusions

This study aimed to test the feasibility of changing the Mission Hill section of Huntington Avenue, giving first priority to transit, which carries 70% of the people in the peak direction.

It shows that while such a change would reduce the number of lanes available to general traffic by 50%, it would reduce traffic capacity by much less than this. Corridor entry capacity would be reduced by only 20% of 2009 volumes. This is a level of change that the transportation system can absorb by people shifting time, route, or mode of travel.

It might be noted that during extended periods of construction around the year 2000, this corridor was reduced to one lane per direction. The proposed design will offer a substantially better level of service than what was available during that construction period because transit vehicles will be operating in their own lane where they won't block traffic, and because left turn bays will allow cars to turn left with blocking traffic.

The study shows that, as expected, reserved transit lanes will dramatically reduce delay to streetcars and buses. The savings in operating and travel time cost, with a net present value of about $100 million, is far greater than the expected cost of implementing this design.

The physical design exercise shows that reserved transit lanes and median platforms for transit user safety can be provided within the existing roadway footprint and with only a small loss in parking capacity. It also shows that the very serious problem of bicycling safety on this street could be solved by constructing sidewalk-level cycle tracks within the constraints of the available right-of-way.

§10. Opinion

Personally, I like this design. I hope one day, this project can be implemented by the transportation department.

§11. Further work

1. Transit signal priority can be considered. If that was done, the delay of transit could almost be eliminated.
2. Models could be made in other hours. Different designs, especially signal designs, could be made, due to the change of traffic volume in other hours.
3. Detailed bike lane design. This report mentioned that cycle tracks could be built in this corridor by shifting the curb. More details about the cycle track design need to be done in future.

§12. References

[1] Vanasse Hangen Brustlin, Inc, *2009 Existing traffic Volumes (Medical Area)*

[2] MBTA, *http://www.mbta.com/*

[3] Christopher M. Boll, *Congestion Protection for Public Transportation: Strategies and Application to MBTA Bus Route 66.* Master's thesis, Northeastern University (Peter Furth, advisor), 2007.