  

H/I Streets Bus Improvements

Final Technical Report

October 2013

PREFACE

District of Columbia's downtown, home to the White House and the Capitol, is a vibrant community – its diverse cultural, commercial and entertainment attractions allow for the District's businesses compete at a national level. According to the Downtown DC Business Improvement District, in 2012, employment located within the greater downtown area was 383,400 and population located within a one mile radius of city center was 58,000. The downtown also has approximately 9.5 million annual visitors to Downtown's attractions.

The District of Columbia is actively planning for the future development in its downtown that will transform neighborhoods and create new opportunities. Over the next ten years, multiple development projects throughout downtown will add significant retail, residential and office space. DC's downtown is also building upon its development dynamic by adding 4.6 thousand multifamily units under construction within 1.5 miles of Downtown.

The unprecedented level of growth has added capacity constraints to the transportation network. The District Department of Transportation (DDOT) and the Washington Metropolitan Area Transit Authority (WMATA) are currently actively working to explore various transportation improvements that will facilitate the east-west and north-south movements of vehicles, transit, pedestrians and bicycles throughout the downtown area, from ongoing implementation of Metrobus Priority Corridor Network, bike lanes and transit signal optimization to the potential development of bus lanes and streetcar over short and long terms.

This Technical Report documents the collective effort by DDOT and WMATA to explore bus improvements on H and I Streets in downtown, the region's most heavily traveled and most productive bus corridor. The H and I Streets Bus Improvements Project investigated traffic management improvements and bus-only lane options with the objective of providing reliable and efficient bus service and alleviating Metrorail core congestion through surface transit improvements. Based on the findings of technical and policy analysis, this report calls for further evaluation of the collective benefits and effects of the H and I Streets bus lanes and other planned transportation improvements on the downtown transportation network.

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EXECUTIVE SUMMARY

Overview

The H/I Streets Bus Improvements Technical Report examines the feasibility of traffic management improvements and bus-only lanes within the downtown core of Washington, D.C. Bus-only lanes have the potential to improve operational efficiencies for public transit as well as provide an enhanced bus passenger experience by bypassing traffic congestion and achieving predictable bus arrival and travel times. Additionally, segregating automobile and bus travel modes reduces the "friction factor" between the modes and improves travel speeds for all users of the corridor.

Bus improvement options developed for analysis include (see **Figure ES-1**):

- Optimized No-Build: Traffic Management Improvements through Traffic Signal Optimizations and Right-Turn Restrictions;
- Alternative 1: Weekday, Peak-Period, Pair of East-West Concurrent Flow Bus-Only Lanes on H/I Streets;
- Alternative 2: Westbound Contra-Flow Bus-Only Lane on H Street; and
- Alternative 3: Pair of East-West Contra-Flow Bus-Only Lanes on H/I Streets.

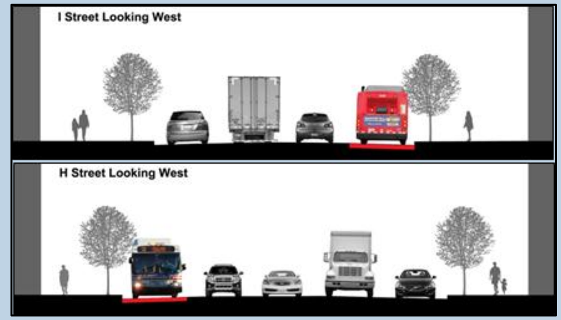
A comprehensive operational evaluation found that all alternatives perform well in achieving the project purpose for both short and long terms. Among them, Alternative 2 – a westbound contra-flow lane on H Street – has the best operational performance based on quantitative simulation and benefit-cost analysis results. The concurrent flow bus-only lane, Alternative 1, also performs well, nonetheless it heavily relies on the enforcement of bus lanes and turning restrictions. Alternative 3, the contra-flow bus-only lanes couplet, provides better bus operations in both directions, however shows greater traffic impacts on I Street.

In the short-term, the Optimized No-Build improves the east-west traffic and transit travel times. In comparison with the three bus lane alternatives, the Optimized No-Build provides fewer benefits for bus operations and passengers. In the long term, traffic growth will diminish the traffic and transit benefits of the Optimized No-Build. By 2030, Alternatives 1 and 2 show auto and transit travel time savings while the Optimized No-Build barely maintains traffic operations conditions at an acceptable level.

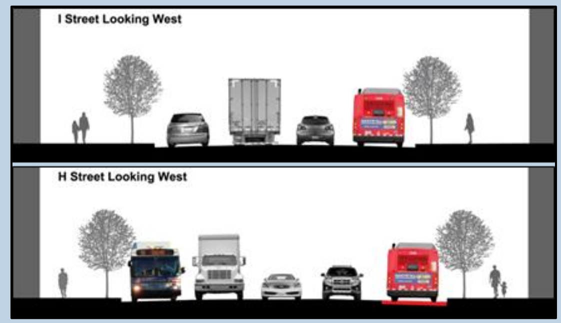
The findings of this Technical Report will support decision makers in determining the next steps of implementing bus improvements on H and I Streets.

ES-1: Bus-Only Lane Alternatives Cross Sections

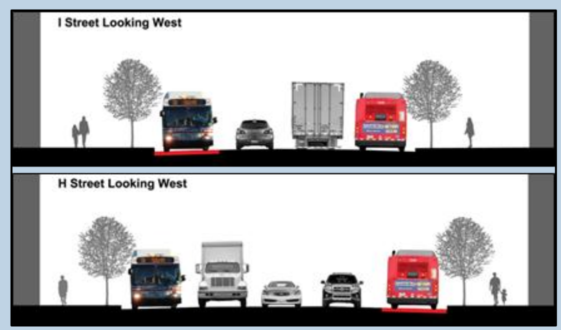
Alternative 1: Concurrent Flow on H/I Streets



Alternative 2: Contra-Flow on H Street



Alternative 3: Contra-Flow on H/I Streets



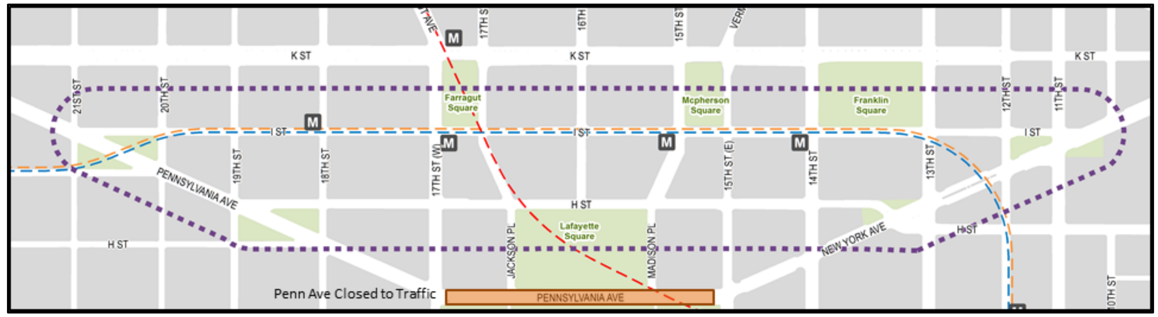
Project Purpose and Need

In 2010, the District of Columbia Department of Transportation (DDOT) and the Washington Metropolitan Area Transit Authority (WMATA) formed an inter-agency working group to identify roadway segments for traffic improvements and bus-only lane implementation. The inter-agency group identified the H/I Street couplet due to the very high number of WMATA buses traveling these segments. The H/I Bus Improvements Technical Report was developed to identify bus improvement alternatives along these corridors and provide comprehensive assessments of potential costs and benefits for all corridor users.

The study corridor (**Figure ES-2**) is served by 33 bus routes that provide service to many communities across the Washington, D.C. region. These routes include six corridors in WMATA's Priority Corridor Network (PCN) plan, which are among the most frequent and have the highest ridership and ridership growth in the entire Metrobus system (10% growth over the past two years). Daily bus trips using the H/I and K Streets corridor account for approximately 25% of all daily WMATA Metrobus trips and 20% of daily ridership.

The H/I Street corridor, along with K Street, make up the east-west spine of DC's Central Business District. According to the Downtown DC Business Improvement District (BID), in 2012, employment located within the greater downtown area was 383,400 and population located within a one mile radius of city center was 58,000.[1] All users of this corridor (pedestrians, bicyclists, automobile drivers, bus transit riders, and freight/package delivery) experience severe crowding and congestion, with average vehicle speeds observed to be as low as 10 mph within the corridor. Street closures implemented in 1995 (made permanent in 2001) associated with increased security precautions adjacent to the White House have increased downtown congestion and made cross-town travel less reliable. For bus operations, traffic congestion severely affects bus travel times and reliability, and discourages corridor travelers from choosing to ride the bus.

Figure ES-2: H/I Streets Bus Improvements Study Area



Implementing bus improvements in highly congested road segments can decrease the delay to Metrobus vehicles; for instance, the

[1] http://www.downtowndc.org/sites/default/files/uploads/files/reports/pdf/dcbid-stateofdowntown-2012.pdf

Each of the bus-only lane alternatives would improve bus customer experience and bus operational efficiencies through the downtown core and support the implementation and operation of the proposed K Street Transitway and future Union Station to Georgetown Premium Transit.

bus-only lane alternatives developed and evaluated in this study result in a reduction of bus travel time through the corridor by 30-70% in the current year. This could allow for resources to be redeployed improving bus service on other corridors.

Further, improving transit speed and reliability increases the attractiveness of surface transit and can increase transit mode share and decrease automobile demand. The bus-only lane alternatives were developed to provide reliable and efficient bus service in the region's most heavily traveled bus corridor and to help alleviate Metrorail core congestion through surface transit improvements. The study provides a comprehensive assessment of potential benefits, effects, and costs associated with each of the bus-only lane alternatives on the corridor users, including traffic, transit, non-motorized transportation and curbside uses.

Additionally, many delivery trucks illegally park on the curbside lanes of H & I Streets severely obstructing the traffic flow, particularly the buses. There is a need to streamline the truck delivery activities along the corridor. Bus-only lanes can help reduce the friction and conflicts between buses and curbside activities.

Finally, DDOT has recently completed the Union Station to Georgetown Alternatives Analysis (USGAA) that will advance premium transit with an alignment through the downtown core primarily on K Street. Bus-only lanes on H/I Streets could facilitate this premium transit project in two ways. First, during construction, local buses on K Street and other streets can be rerouted to H/I Streets that would have extra capacity with the bus lanes. Second, as part of the transit service planning effort of the future K Street transitway operation, local buses can be rerouted to H/I Streets to free up capacity for premium transit. The H/I bus-only lanes would also improve transit travel times and reliability, both of which are important aspects of premium transit. Therefore, combined with the proposed K Street transitway, these treatments would expand the premium transit services to a broader downtown area, providing premium transit options in both corridors, reducing traffic congestion, and providing peak congestion relief to Metro's Orange, Blue and Red lines.

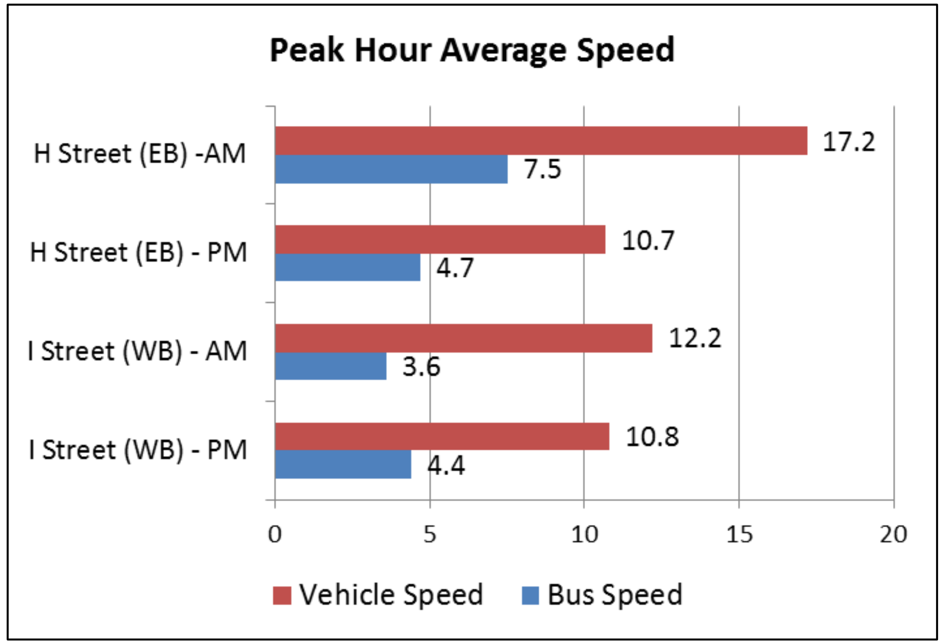
Congestion on I Street caused by bottleneck at 17th Street, creating long queues backing up to 15th Street.

Existing Conditions

The H/I Streets study corridor is located between New York Avenue and Pennsylvania Avenue, and extends approximately one mile. The H/I Streets, along with K, L and M Streets provide east-west connectivity through the downtown core. There are approximately 15,000 vehicles per day on each of the two streets.[2] About 3,000 daily bus trips, which use the H/I corridor as part of their route structure, carry 62,300 riders per day, 80% of which are DC residents. This level of ridership requires frequent service. Routes from around the region converge in this corridor; the combined Metrobus frequency averages about a bus every minute during peak period and every 2 minutes in the midday period on weekdays and Saturdays. Additionally, bicyclists are observed frequently in the study corridor as well as on the adjacent streets. The corridor is heavily used by pedestrians driven by not only the dense urban land uses but also by the frequent bus service and Metrorail stations. Finally, other users, including commuter buses, tour buses, delivery trucks and taxis frequent the curbside lanes.

An assessment of the existing conditions of the study corridor based on a combination of field observations and transportation network simulation (VISSIM) results identified the conditions and issues of all users of corridor. The assessment concluded that congestion severely impacts bus travel times and reliability on the H/I Streets corridor. Bus operations are typically slower than general traffic due to passenger boardings and alightings, as well as the acceleration and deceleration of the bus. In the case of H/I Streets, this slower speed is compounded by constant friction with vehicular traffic, including general traffic flow, parking, and loading activities from block to block. **Figure ES-3** shows the peak hour average bus speeds compared to average general traffic speed.

Figure ES-3: Existing Bus vs. Vehicle Travel Speeds



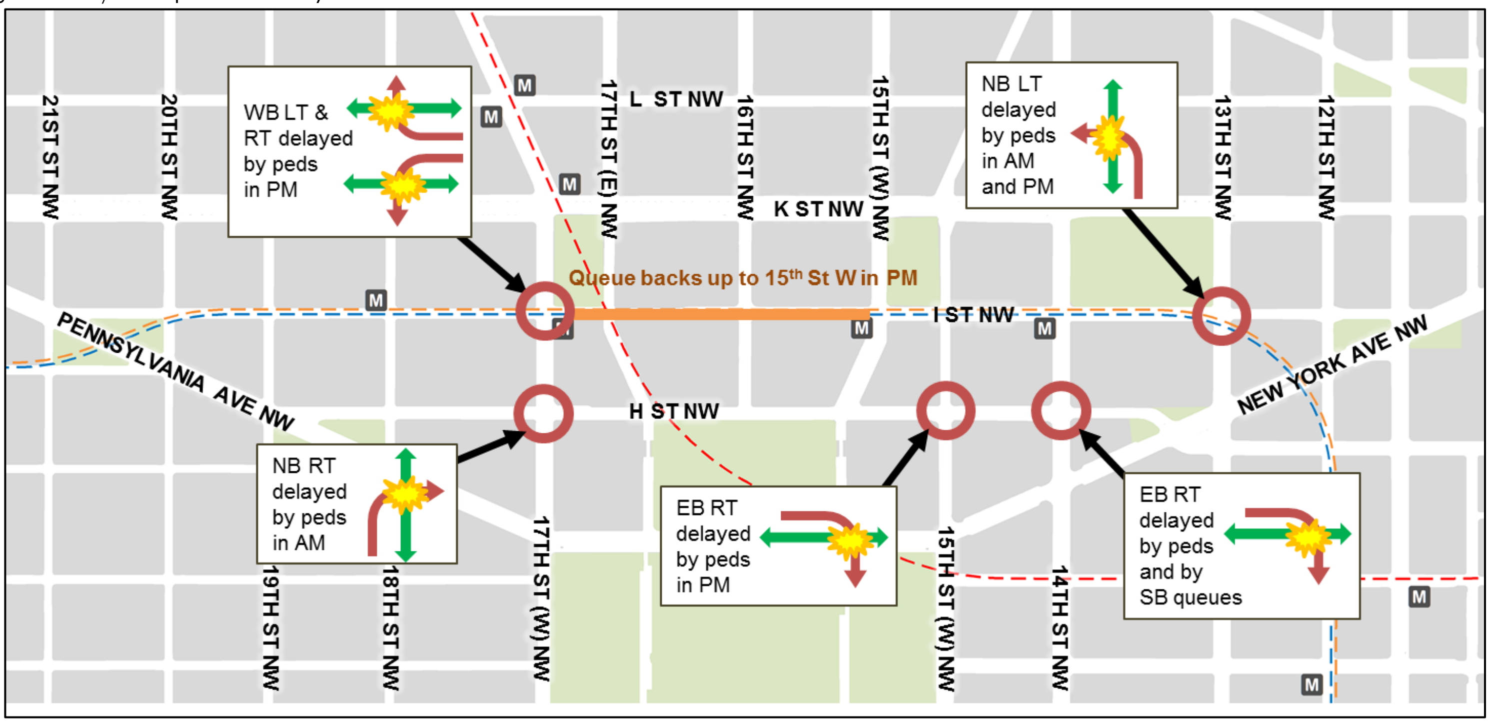
[2] 2010 DDOT Traffic Volume Map

Bus priority treatments will be able to improve bus travel speeds, improving their operating efficiency and reliability making them more attractive to riders.

There are also other major on-going multi-modal projects in the greater study area, including the Union Station to Georgetown Alternatives Analysis focusing on K Street and the L and M Street bicycle lanes. An understanding of these ongoing projects in the study area is necessary to evaluate the combined effects of transportation improvements in the downtown core and the study corridor.

Overall, corridor congestion is the result of a few bottlenecks and friction points between modes, specifically between buses and autos, and between turning vehicles and pedestrians. As shown in **Figure ES-4**, these bottlenecks are located at I Street and 13th Street, I Street and 17th Street (W), H Street and 17th Street, H Street and 15th Street, and H Street and 14th Street. Improving the travel conditions at these bottlenecks by segregating buses and autos can yield travel time savings for both modes and an improved bus customer experience.

Figure ES-4: H/I Bus Improvements Study Area Intersection Bottlenecks



Improvement Options Considered

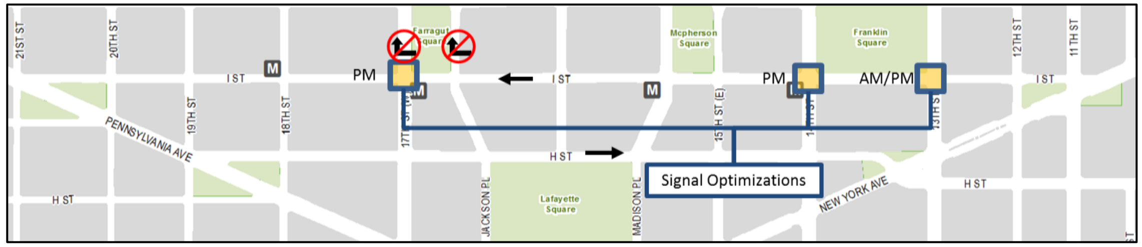
Four types of improvements options were considered in the technical report: Optimized No-Build traffic management improvements and three dedicated bus-only lane alternatives.. The bus-only lane alternatives were developed after documenting the existing traffic and transit operations in the corridor, extensive field observations, and VISSIM traffic simulation of today's conditions. The study team researched best practices for bus improvements and applied best engineering judgment in the development of the four alternatives based on field observations and data analysis.

Bus improvement options were developed for analysis (see **Figure ES-5**):

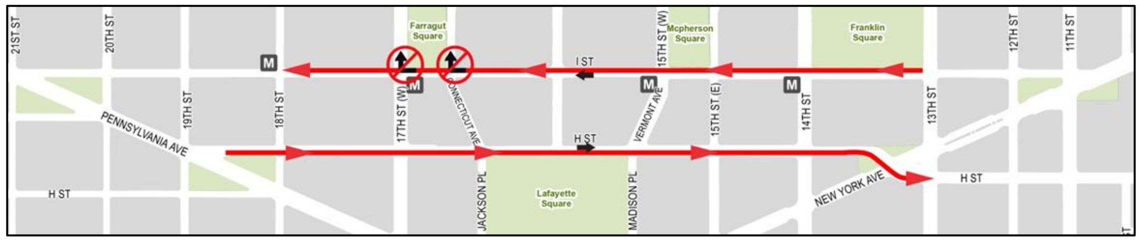
- Optimized No-Build: Traffic Management Improvements through Traffic Signal Optimizations and Right-Turn Restrictions;
- Alternative 1: Weekday, Peak-Period, Pair of East-West Concurrent Flow Bus-Only Lanes on H/I Streets;
- Alternative 2: Westbound Contra-Flow Bus-Only Lane on H Street; and
- Alternative 3: Pair of East-West Contra-Flow Bus-Only Lanes on H/I Streets.

ES-5: Bus Improvement Options Considered

Optimized No-Build: Traffic Signal Optimizations and Right-Turn Restrictions (2012)

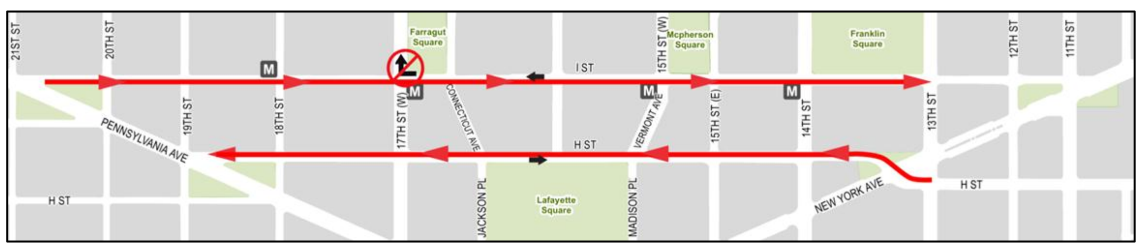


Alternative 1: Concurrent Flow on H/I Streets



Alternative 2: Contra-Flow on H Street

Alternative 3: Contra-Flow on H/I Streets



Technical Analysis Findings and Policy Implications

Based on existing traffic condition analysis, several models were developed using VISSIM simulation software to understand traffic impacts under the current and future build conditions. The 2030 models assumed future conditions including traffic growth, bus ridership growth and increased bus dwell times, bus operation frequencies, and modification of bus routes for each of the three build alternatives.

The alternatives were evaluated based on the following quantitative performance metrics:

- Bus Travel Time Changes;
- Auto Travel Time Changes;
- Person Delay Changes;
- Bus Reliability; and
- Intersection Level of Service (LOS).

Bus Travel Time Changes:

Bus travel-time changes were documented for eastbound- and westbound-traveling buses for each improvement option. Changes were determined by comparing existing bus travel times in mixed traffic to bus travel times in bus-only lanes. For the Optimized No-Build, bus travel times were compared to those buses traveling along the right-side curb lane.

Westbound concurrent and contra-flow bus-only lanes provide significant travel time savings for buses and passengers in the peak-periods, resulting in a reduction of bus travel time by 30-70% or a maximum of 5 to 7.5 minutes. Contra-flow bus-only lanes on H Street provide the most westbound bus travel time savings.

Alternatives 1 and 2 do not provide benefits from the existing condition in the eastbound direction. Alternative 3, with a contra-flow bus lane on I Street, is the only alternative that provides eastbound bus travel time benefits.

Westbound bus lanes in all three alternatives perform exceptionally well during rush hours, resulting in a reduction of bus travel time by 30-70%.

The Optimized No-Build provides transit and traffic travel time savings comparable to Alternative 1 in the short-term, however these benefits lessen as traffic conditions worsen into the future years.

Bus travel time savings in segregated bus-only lanes will increase in future years as traffic continues to grow on H and I Streets.

All alternatives assumed full compliance of turning and operating restrictions in the bus-only lanes.

Auto Travel Time Changes:

Auto travel-time changes were documented for eastbound and westbound travel for each improvement option. Changes were determined by comparing existing mixed-

Table ES-1: 2012 Bus Improvements Technical Report Findings Summary

Alternatives	Max Bus Travel Time Savings (minutes)*	Max Auto Travel Time Savings (minutes)	Net Corridor Person Delay Savings (minutes)	Potential Reduction in Travel Time Standard Deviation (minutes)
Opt. No-Build	4.5	3.0	106	1.2
Alternative 1	5.0	2.5	143	1.4
Alternative 2	7.5	2.5	158	1.8
Alternative 3	7.0	1.0	119	2.2

*Maximum travel time savings in westbound direction traffic travel times to the mixed-traffic travel times in the Optimized No-Build and the three bus-only lane alternatives.

To be conservative and consistent with the baseline conditions, the technical report did not assume any decrease in auto demand and increase in bus passenger demand. Additionally, the existing traffic levels as well as the future year projections were operationally accommodated within the study corridor with the bus lane alternatives. This was achieved by optimizing traffic signal operation as well as restricting right-turn movements at several intersections. As such, potential through traffic diversion to neighboring streets is expected to be minimal. The effect of rerouted right-turns (about 280 peak hour trips) beyond the study corridor was not operationally analyzed. Subsequent studies, such as the planned environmental impact assessment for the Union Station to Georgetown premium transit project, are recommended to analyze the benefits and impacts for a larger area.

The Optimized No-Build shows auto travel time savings comparable to Alternatives 1 and 2 in 2012. In 2030, the traffic improvements seen in the Optimized No-build are required to maintain an acceptable traffic level of service and the Optimized No-Build scenario is used as the base of comparison for the bus-only lane alternatives. With the addition of bus-only lanes seen in Alternatives 1 and 2, auto travel times are improved over the Optimized No-Build even with increased traffic growth. In 2030, the auto travel time savings can be attributed to the separation of bus and auto traffic.

The bus-only lanes in all three alternatives have marginal effects on the eastbound traffic. Eastbound auto travel time experiences +/- 30 seconds change in the rush hours. Westbound bus-only lanes provide auto travel time savings of up to 2.5 minutes in 2012 due to separation of bus traffic from general traffic (less friction) along with signal timing optimizations at several key intersections. An eastbound contra-flow bus lane on I Street shows auto travel time increase due to reduced auto capacity and projected traffic demand growth on I Street traffic in 2030.

Person Delay Changes:

Person delay (person hours/hour) is the measure of time required to move individuals, rather than measuring time required to move vehicles. Measuring person delay rather than vehicle delay is an analysis approach that captures the overall impact of transportation improvements. Person delay changes are a function of person throughput and bus and auto travel time changes. All of the bus improvement options, including the three alternatives provide net person delay improvements. Alternative 2 provides the most person delay improvements in both 2012 and 2030.

Bus Reliability:

The bus travel time reliability is reflected by travel time standard deviation. A low standard deviation indicates the travel times tend to be close to the average; a high standard deviation indicates the travel times are more spread out over a large range of values. As the bus travel time standard deviation becomes smaller, the more reliable and constant the bus operations are. The results show that all three alternatives provide smaller bus travel time standard deviation than in the mixed traffic, which means implementing the bus-only lanes will help improve the bus travel-time reliability and runtime consistency. In the westbound direction, the maximum time to travel the corridor decreases and the variability becomes more constant in both the AM and PM peak-periods. In the eastbound direction, the variability of bus travel time shows marginal improvement or similar runtime reliability to the existing condition in all alternatives.

All three bus-lane alternatives provide bus reliability improvements over the existing conditions.

Alternative 3 provides the best bus reliability results in terms of potential reduction of travel time standard deviation in the westbound direction.

Intersection Level of Service (LOS):

Under the existing conditions, three intersections in the study area were determined to be failing in either the AM or PM peak-periods: I St and 17th St E; I St and 13th St; and H St and 17th St.

In 2012 and 2030, all three bus lane alternatives maintain the same LOS or provide LOS improvements at existing failing intersections on H/I Streets, under the assumption that there would be no traffic diversion or reduction resulting from the implementation of bus-only lanes.

Effects of Turning Restrictions and Signal Optimizations:

Proposed right-turn restrictions were tested at intersections of I and 17th Streets W and E to further understand the operational benefits of these turn restrictions on the corridor operations and how much potential violators would negate these benefits. The results showed that signal timing optimization contributes to auto and bus travel time savings of approximately 1.5 and 3.5 minutes respectively in the westbound direction for all build alternatives.

While Alternative 1 and 3 could accommodate occasional violations of restricted right-turns in the rush hours (1 to 2 vehicles per signal cycle) without negating the bus-only lane performance, any increase in violations will quickly lead to the breakdown of the bus-only lane operations. The ultimate success of these treatments depends on the effectiveness of enforcement, whose costs are included the *Benefit Cost Analysis* section of the Final Report and page ES-11 of the Executive Summary. Alternative 2 did not include any right-turn restrictions.

As discussed earlier, while traffic rerouting due to these restrictions were operationally accommodated in the study corridor acceptably, their effects on the neighboring streets need to be assessed further.

Curb Lane Uses Effects

An inventory of curbside uses was performed to document the varying uses and users of the curb lanes within the H/I Streets corridor. Additionally an analysis of potential parking revenue loss was completed for each of the three alternatives. Effects to these curbside uses differ by alternative. The Optimized No-Build preserves the current operating environment for curb lane uses.

Alternative 1, as a peak-period only facility, shows the least impact to existing on-street parking, and experiences marginal potential parking revenue loss (approximately $100/day) due to off-peak on-street parking being maintained; the only revenue loss is due to the conversion of 8 all-day parking spaces to off-peak parking.

Alternative 2 shows the least impact to loading areas, has a moderately high amount of on-street parking loss (120 spaces removed), and potential parking revenue loss at about $2,200 per weekday.

Alternative 3 impacts the largest amount of curb lane uses on both H/I Streets, has the largest amount of on-street parking impacts (266 spaces removed,) and a potential parking revenue loss at about $5,000 per weekday.

Relocation and potential consolidation of loading areas to adjacent streets as well as their potential traffic impacts remain to be discussed with public stakeholders. Additionally, the policy level implications of parking revenue loss needs to be discussed further.

The side bar on the right summarizes mitigation strategies for curb lane uses and potential safety improvements.

Mitigation strategies for curb lane uses and potential safety improvements:

- Promote off-street parking downtown with signage;
- Implement performance parking for on-street parking and loading activities to mitigate the potential parking revenue loss and reduced parking supply;
- Relocate or consolidate loading zones on adjacent side streets in coordination with the Downtown and Golden Triangle BIDs;
- Install visual warnings for pedestrians, bicyclists, drivers, and driveway access to reduce conflicts with bus-only lanes; and
- Conduct a public education campaign to introduce the concept of the bus-only lane as well as raise awareness of the potential safety issues.

New York City has stenciled pedestrian warnings at 110 of the most dangerous intersections in the city.

Table ES-2: Curb Uses Inventory and Effects Summary

Alternatives	Parking Spaces Removed* (Off-Peak / All-Day)	Potential Daily Weekday Maximum Revenue Loss	Loading Areas	Driveway Access
Alternative 1	0/8	$99	6 (350 ft)	14
Alternative 2	115/5	$2,220	3 (130 ft)	12
Alternative 3	248/18	$5,015	9 (740 ft)	25

*Assumes 20 Feet per Parking Space

Benefit Cost Analysis

A Benefit Cost Analysis (BCA) was conducted to compare the three bus-only lane alternatives quantitatively in terms of the individual project costs and the associated benefits. Each alternative's benefits are summed and then divided by its associated costs to yield the BC ratio. **Table ES-3** provides a brief summary of the costs and benefits associated with each alternative. Note that the Optimized No-Build was not analyzed as part of the BCA.

All three alternatives provide good to excellent returns on investment. Alternative 1 and 2 provide excellent returns on investment, whereas Alternative 3 provides a good return.

Alternative 1 has the lowest capital cost as it requires the smallest amount of physical construction and modification. However, Alternative 1 also has the highest enforcement costs and the benefits documented are highly contingent on enforcement. Alternatives 2 and 3 require new bus stop locations and modification of existing signals that make up the majority of the capital costs.

Additionally, alternatives 2 and 3 provide off-peak and weekend benefits not provided by Alternative 1, a peak-period only facility.

All three alternatives provide good to excellent returns on investment.

Table ES-3: Benefit-Cost Analysis

Alternatives	Costs		Parking Revenue Loss**	Peak-Period Benefits			Off-Peak and Weekend Benefits***	Net Benefits	BC Ratio
	Capital	Enforcement		Bus Passenger	Auto Driver	Transit Operator	Bus Passenger		
Alternative 1	$0.9	$1.3 - $2.3*	-$0.3	$61.0	$8.8	$4.7	--	$74.6	23-33*
Alternative 2	$3.3	$0.1	-$7.3	$68.6	$8.3	$7.9	$12.5	$96.5	29
Alternative 3	$7.5	$0.8	-$16.6	$54.1	-$5.6	$8.7	$16.5	$73.7	9

Shown as $1,000,000

* Depending on periodic or dedicated enforcement scenario
** Parking revenue loss not included in net benefits or BC ratio
*** Off-peak and weekend benefits presented for Alt 2 and Alt 3 are derived from peak period benefits. Per guidance from WMATA, these are based on On-time performance/Speed data for certain bus routes and thus reflect order of magnitude estimates. Realizing these benefits assumes that the bus-only lane is made available all the time during off-peak and weekends.

Operational Management Considerations and Enforcement Strategies:

There are several operational management and policy considerations that are vital to the successful implementation of bus-only lanes on H/I Streets. These operational management and policy considerations include the hours of operation, vehicle access policy, and bus lane enforcement strategies, and may vary between the three alternatives.

Table ES-4: Bus-Only Lane Hours of Operation

Alternative	Hours of Operation
Alternative 1	Weekdays, Peak Periods
Alternative 2	24/7
Alternative 3	24/7

Enforcement Strategies

Signage and Pavement Markings: Signage would clearly communicate the restrictions of the bus-only lanes, including the hours of operation, vehicles permitted, and fines for violations in all alternatives.

Enforcement Personnel: Concurrent flow bus-only lanes require on-going enforcement personnel in order to ensure the peak operational efficiency of the facility. Contra-flow is typically self-enforcing by design. Enforcement personnel would be required during the early implementation period for all alternatives to help change driver behavior. The Optimized No-Build and Alternatives 1 and 3 require continuous enforcement of right-turn restrictions by DDOT traffic control officers. DPW and MPD personnel would continue to enforce parking and traffic violations in the corridor in all alternatives.

Table ES-5: Bus-Only Lane Access Policy

Alternative	WMATA Buses	DC Circulator	Publicly Operated Commuter Buses	Private Shuttles/ Charters/ Long Distance Providers	Taxis	Bicycles
Alternative 1	X	X	1	3	3	X
Alternative 2	X	X	2			
Alternative 3	X	X	2			

1 – Permitted, as WMATA/DC Circulator buses are able to overtake dwelling commuter buses
2 – Through buses permitted only (no stopping)
3 –Allowed only outside of restricted hours

Table ES-6: Bus-Only Lane Enforcement Strategies

Alternative	Signage and Pavement Markings	Enforcement Personnel for Right-Turn Restrictions	Enforcement for Mid-Block Operating Restrictions
Alternative 1	X	X	X
Alternative 2	X		
Alternative 3	X	X	

Technical Report Conclusions

Optimized No-Build:

- Lowest cost solution with good benefits
- Lowest level of impacts to traffic and curb uses
- Turning restrictions enforcement needed to ensure benefits

Optimized No-Build: Traffic Signal Optimizations and Right-Turn Restrictions (2012)

H Street Contra-Flow Bus-Only Lane:

- Medium cost solution with nearly all the possible benefits
- Benefits not contingent on enforcement

Alternative 2: Westbound Contra-Flow on H Street

Concurrent Flow Bus-Only Lanes:

- Low cost solution with good benefits
- Turn and operating restrictions enforcement needed to ensure benefits

Alternative 1: Concurrent Flow on H and I Streets

Contra-Flow Bus-Only Lane Couplet:

- Highest cost solution
- Marginal increase in benefits
- Turn restriction enforcement required for congestion management

Alternative 3: Contra-Flow on H and I Streets

Performance:	Best	Moderate	Least

Technical Report Conclusions (cont.)

Table ES-7 and the text below illustrate the overall performance of each bus-only lane alternative and the general conclusions of this Technical Report.

Transit Performance: Alternative 3, the contra-flow bus-only lanes couplet, provides better travel times with exclusive bus lanes in both travel directions, however when bus person throughput is measured Alternative 2 performs the best.

Traffic Impacts: Alternative 2 provides the best results in terms of traffic impacts including improved automobile travel times and no significant impacts to intersection LOS.

Curb Lane Impacts: With the preservation of off-peak on-street parking, Alternative 1 performs the best in terms of curb lane impacts.

Capital and Enforcement Costs: Alternative 1 has low upfront capital costs compared to the other two alternatives. However, Alternative 1 has the highest enforcement costs.

BCA Standard Benefits: Alternative 2 provides the most monetary benefits as determined by the BCA in terms of travel time savings (bus and automobile), bus reliability savings, and bus emission savings.

All three alternatives provide good to excellent returns on investment. Alternative 1 and 2 provide excellent returns on investment, whereas Alternative 3 provides a good return.

BCA Operating Cost Reduction Benefits: Alternative 3 provides the most monetary benefits as determined by the BCA in terms of operating cost reduction benefits.

Other Major Findings:

- Generally, both vehicular traffic and buses gain benefits in the westbound direction. Eastbound mixed traffic and buses are marginally affected (both positively and negatively varying on alternative).
- As a result of bus travel time savings and bus reliability improvements, WMATA would experience operational benefits in terms of fleet savings under all three alternatives by 2030.
- Because bus service is cyclic, bus-only lane improvements would benefit the entire route under all alternatives. Passengers would experience more predicable travel times and uniform headways, resulting in reduced waiting time at bus stops.
- Intersection LOS is not negatively affected due to the addition of bus-only lanes in any alternative. All alternatives improve or maintain LOS at existing failing intersections on H/I Streets.
- Enforcement of right-turn restrictions are needed to ensure the desired bus-only lane performance as simulated (100% compliance), with the recognition that occasional violators could be tolerated by the bus-only lane. Occasional violations are highly likely to happen even under diligent enforcement.
- One potential benefit of Alternative 2 is the removal of buses from busy I Street without dedication of a general purpose lane to bus operations. Bus route modifications move 23 peak-hour bus trips off of I Street onto the westbound contra-flow bus-only lane on H Street during the PM peak hour.
- Signal timing optimizations and right-turn restrictions improve westbound traffic flow on I Street from the existing condition.

Optimized No-Build:

- Applying traffic management improvements without bus lanes, such as signal timing optimizations and right-turn restrictions, can improve westbound traffic flow on I Street from the existing condition in the near-term.

Table ES-7: Bus-Only Lanes Alternatives Performance Summary Matrix

Alternative	Transit Performance	Traffic Impacts	Curb Lane Impacts	Capital and Enforcement Costs	BCA Standard Benefits	BCA Operating Cost Reduction Benefits
Alternative 1: Concurrent Flow Bus-Only Lanes on H/I Streets	○	◐	●	●	◐	○
Alternative 2: Contra-Flow Bus-Only Lane on H Street	●	●	◐	◐	●	◐
Alternative 3: Contra-Flow Bus-Only Lanes on H/I Streets	◐	○	○	○	○	●

Performance: Least to Best ○ → ●

Technical Report Findings and Next Steps

The Technical Report analyzed and evaluated bus operational improvements and bus lane alternatives through a combination of quantitative operational measures and policy considerations, including travel time savings, curb lane impacts, enforcement strategies, and costs. This study found that all bus improvement alternatives provide good to excellent returns on transit investment, and identified a technical preference for the H Street contra-flow bus-only lane (Alternative 2).

In consideration of the ongoing land use development and transportation improvement initiatives in Downtown, a short-term traffic management option, as seen in the Optimized No-Build scenario, could provide immediate benefits to the existing traffic and transit operations in the east-west corridor of H/I and K Streets and allow flexibility for a later determination of transit investment.

This Technical Report recommends further analysis of the bus-lane alternatives in order to understand the overall benefits and effects to the downtown transportation network, including traffic diversion and reroutings due to turn restrictions. While the technical report assumed auto traffic would remain on the H and I Streets, the proposed operational changes including turning restrictions could potentially induce traffic diversion to other streets.

If a bus-lane alternative were selected for implementation, DDOT would require NEPA & Section 106 approval. Therefore, subsequent studies could include the recommendations and findings of this study, which would also allow for the determination of the benefits and impacts at the network level.

Relocation and potential consolidation of loading areas to adjacent streets as well as their potential traffic impacts remain to be discussed with public stakeholders. Additionally, the policy level implications of parking revenue loss needs to be discussed further.

BACKGROUND/PURPOSE

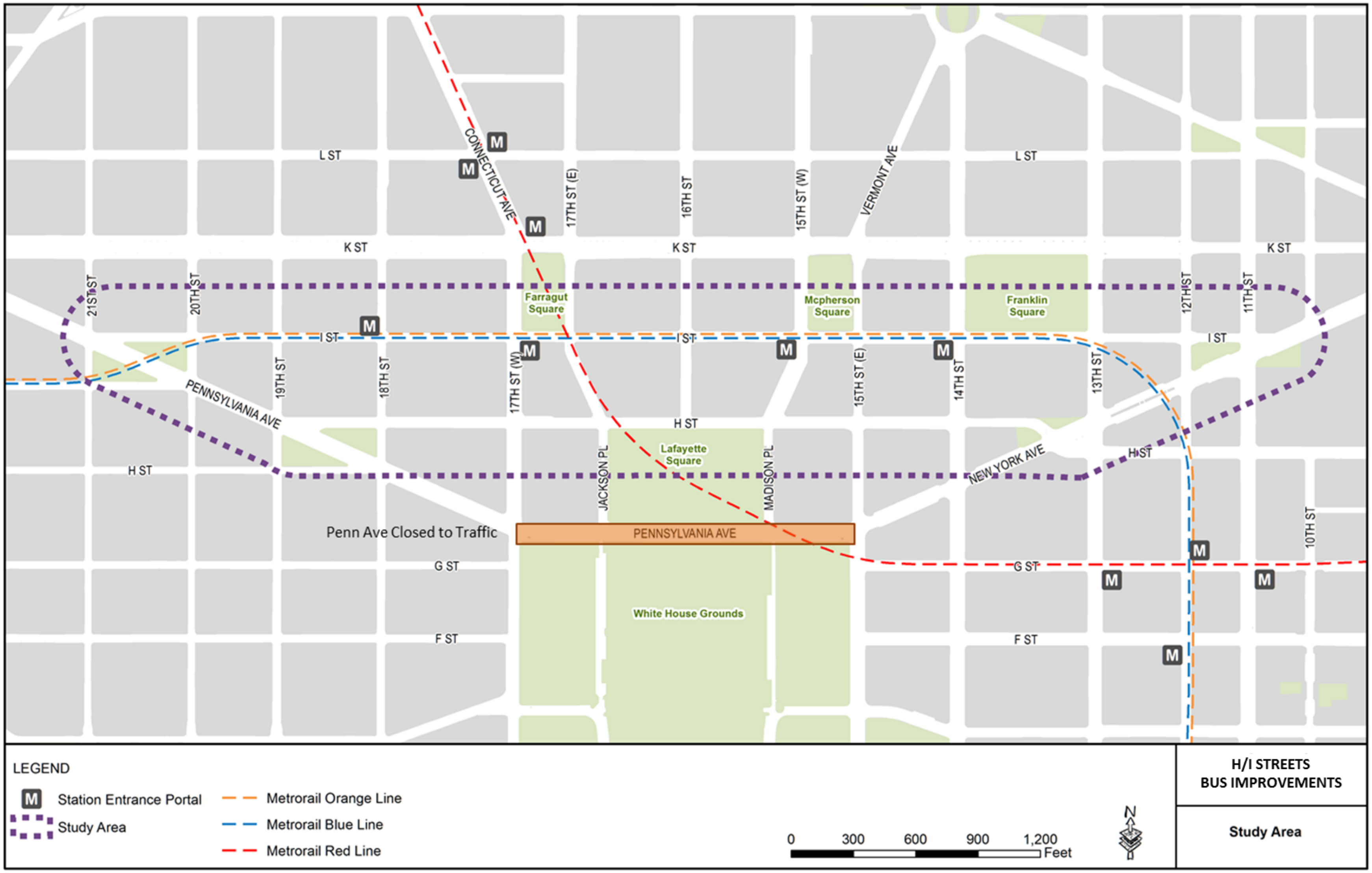
The purpose of the H and I Streets Bus Improvements Technical Report is to develop bus improvement options on the H/I Streets couplet in downtown Washington, D.C. The report focuses in examining traffic improvement and the feasibility of future bus-only lane alternatives to provide reliable and efficient bus service in the region's most heavily traveled bus corridor and to alleviate Metrorail core congestion through surface transit improvements. The study provides an assessment of potential benefits, effects, and costs associated with each of the bus-only lane alternatives on the corridor users, including traffic, transit, non-motorized transportation and curbside uses. The elements of the technical report will need to be further evaluated to better understand the overall impact to the downtown transportation network. This Technical Report presents the bus improvement options, summarizes the existing conditions of the corridor, documents the findings, discusses operational policy issues, and provides alternatives to move forward for further analysis.

The Washington, D.C. region continuously ranks as one of the most congested traffic metropolitan areas in the United States. Metrobus plays an important role in alleviating regional traffic congestion, but since Metrobus vehicles operate within mixed traffic in most areas, they often experience travel delays and struggle to maintain schedule adherence. In Fall 2010, the District of Columbia Department of Transportation (DDOT) and the Washington Metropolitan Area Transit Authority (WMATA) formed an inter-agency working group to identify roadway segments that could be considered in the future for bus-only lane implementation. Primary goals of the group were to increase choice ridership, improve pedestrian and vehicle safety and support the management of traffic congestion and private automobile vehicle demand in the downtown. The inter-agency group identified the H/I Street couplet (see **Figure 1**) on eastbound H Street NW from 19th Street NW to New York Avenue NW/13th Street NW and on westbound I Street NW from New York Avenue/13th Street NW to Pennsylvania Ave/21st Street NW. These two locations were selected due to the very high number of WMATA buses traveling these segments. Bus-only lanes along this corridor have the potential to improve bus travel speeds and reliability. The H/I Streets bus-only lanes are in the DDOT Constrained Long Range Plan (CLRP) for near term implementation and support WMATA's strategy for bus-only lane infrastructure as a key element of the Priority Corridor Network.

Metrobus Traveling on H Street

Besides the H/I technical report, DDOT has also recently completed the Union Station to Georgetown Alternatives Analysis (USGAA) that will advance premium transit with an alignment through the downtown core. Each of the bus-only lane alternatives, due to the availability of additional bus carrying capacity, could potentially help mitigate construction impacts on K Street as part of the planned premium transit by DDOT. Local bus routes can be shifted to H/I Streets during construction. The findings of both efforts will be coordinated as the Union Station to Georgetown premium transit environmental documentation process begins.

Figure 1: Study Area Map



Project Needs

The H/I Streets corridor, along with K Street, make up the east-west spine of the District's Central Business District. All users of these corridors experience severe traffic congestion, including pedestrians, bicyclists, automobile drivers, and bus transit riders. Street closures associated with the increased security precautions adjacent to the White House in 1995 (made permanent in 2001) have increased downtown congestion and made cross-town travel less reliable. As noted in the 2011 White House Area Transportation Study, the loss in street grid continuity and capacity caused by the street closures has led to increases in congestion on parallel streets, vehicular travel times, turning movements, and conflicts between motorized and non-motorized traffic.

For bus operations, congestion severely affects bus travel times and reliability, and discourages corridor travelers from choosing to ride the bus. As the District and region are forecasted to experience increased residential and commercial growth, travel associated with the growth will exacerbate the existing congestion.

As seen in **Figure 2**, the study corridor provides the most frequent bus service in both the peak and off-peak-periods, rival to only bus connections at three Metrorail stations: Pentagon, Anacostia, and Silver Spring. Metrobus services using H/I and K Streets are among the region's most frequent and productive ridership lines, making up approximately 25% of the entire WMATA daily bus trips and 20% of the entire WMATA bus ridership (see **Table 1**). During the peak hours, the combined Metrobus frequency reaches 1 bus every minute, carrying as many as 850 passengers per hour in the most heavily traveled segment. While travel time savings due to the bus-only lanes would only benefit the passengers traveling on the corridor, the reliability improvements would affect the experience of all riders, as shown in Table 1, along the routes that serve the H/I corridor. Additionally, bus fleet savings would be possible if the bus lanes save a full headway under current conditions or deter additional fleet requirements in the near future for those routes currently approaching operating capacity.

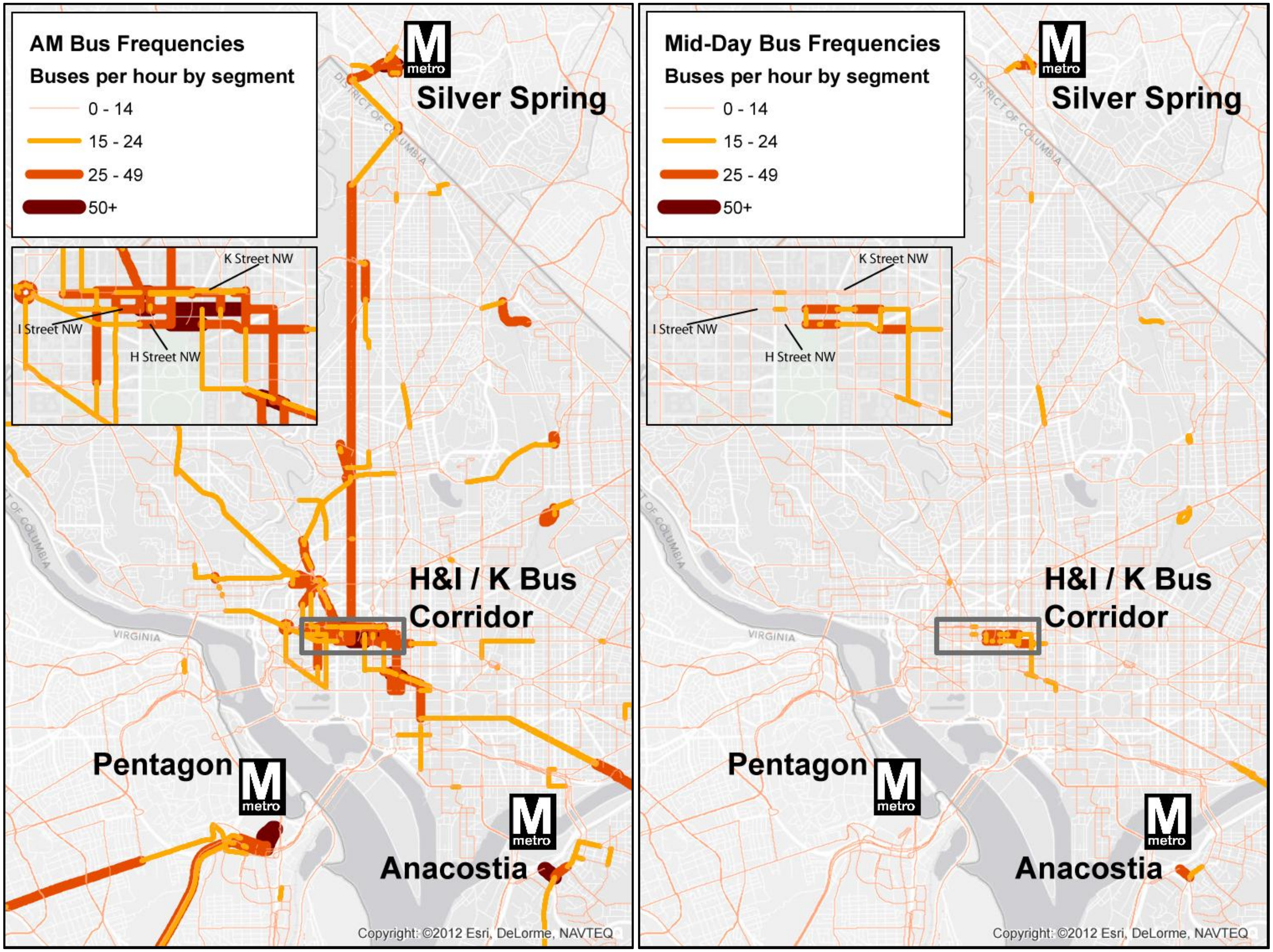
The H/I and K corridors include six of Metrobus' Priority Corridors which, as seen in **Figure 3**, serve the greater Washington, D.C. metropolitan area. These Priority Corridor Network (PCN) routes include the 30s, 80s, S, X, 16s, and the G8 lines. Under today's operating conditions, bus transit capacity is maxed out on both H/I Streets and K Street. Comprehensive improvements are needed to enhance pedestrian, automobile, and bus experience along H, I, and K Streets traveling east-west across the city.

Table 1: H/I and K Street Bus Ridership

	Daily Ridership		Daily Bus Trips	
H and I	62,300	14%	3,000	21%
K	26,700	6%	900	6%
Metrobus System	438,000	100%	14,400	100%

Note: This table only includes Metrobus and DC circulator service and does not account for commuter bus.

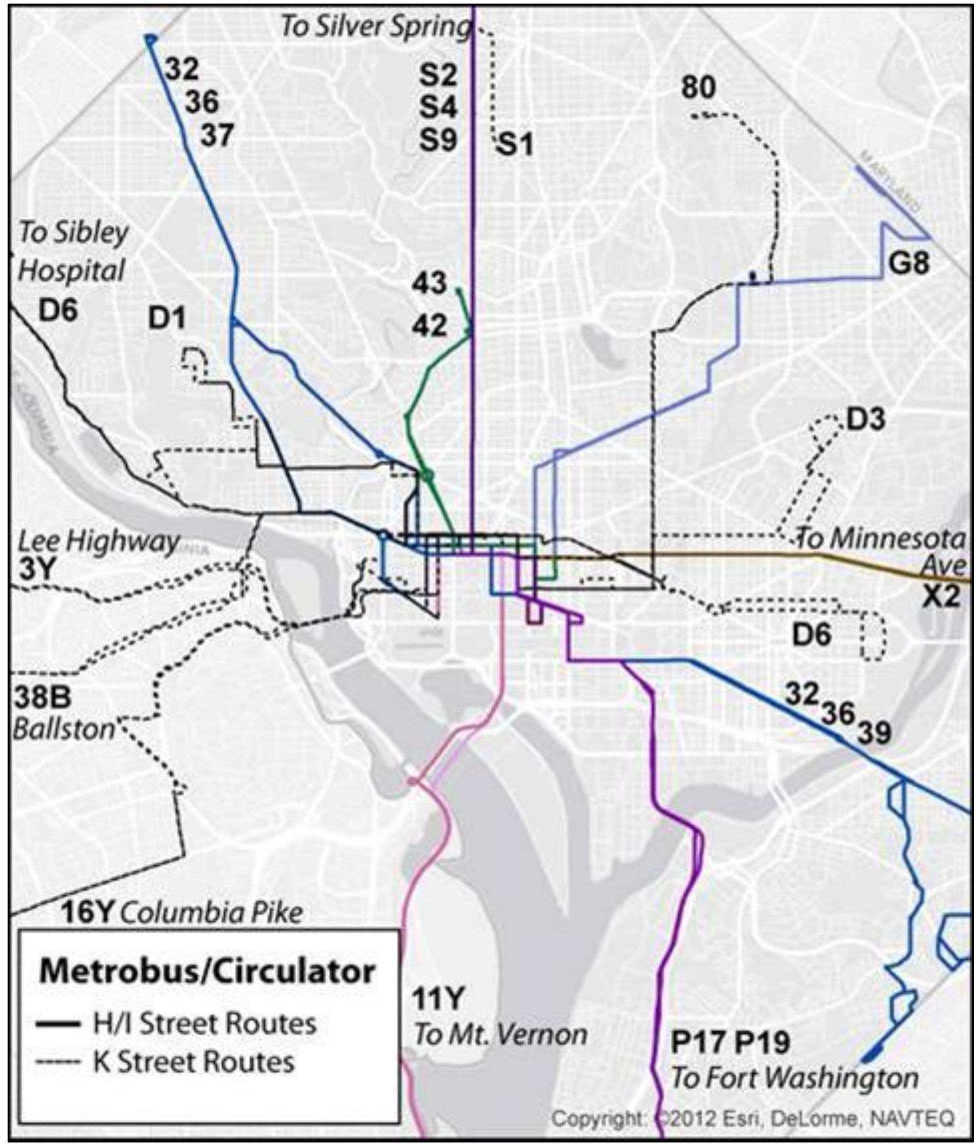
Figure 2: Regional Bus Frequencies (Peak, Off-Peak)



Study Process

In February 2012, WMATA and DDOT initiated the H/I Bus Improvements Technical Report. This report developed traffic improvements and bus-only lane alternatives for the H/I Street couplet in downtown Washington, D.C. Coordination between WMATA and DDOT was established early in the project development. After completing an assessment of the existing conditions, the project team developed a set of bus-improvement alternatives to further analyze. In the development of the alternatives, the project team reviewed best practices for enhancing bus conditions and bus-only lanes as well as incorporated experience from other local bus-only lane projects in the Washington, D.C. metropolitan area. A traffic simulation was developed for the bus-only lane alternatives using the VISSIM software model. Traffic and bus operations results were developed for the existing (2012) and future build (2030) conditions. After the study and stakeholder outreach process is complete, WMATA and DDOT will select a preferred alternative to develop further.

Figure 3: Regional bus routes converging on H/I and K Streets



Document Organization

This report summarizes the findings of the H/I Streets Bus Improvements Technical Report and is organized as follows:

- Existing Conditions Summary
- Alternatives Simulation and Results
- Cost Benefit Analysis
- Operational Management and Policy
- Enforcement Issues and Strategies
- Conclusion and Recommendations

EXISTING CONDITIONS SUMMARY

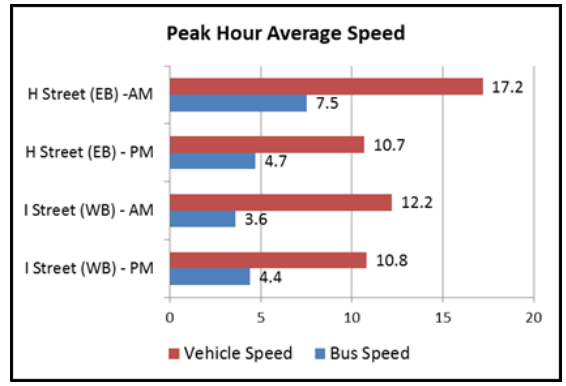
The assessment of the existing conditions included field observation visits, data provided by WMATA and DDOT, and a VISSIM existing conditions traffic simulation. VISSIM was used to measure queues and travel times of personal autos and buses. Intersection Level of Service (LOS) determination was obtained by post-processing VISSIM delay data, which were measured for each approach from the stop bar to the adjacent upstream intersection. For short segments, queues often extend beyond the upstream intersection. In those instances, this methodology only captures delays up to the upstream intersection, where LOS will then include all the remaining vehicle delay. Therefore, there might be differences in the LOS results that are obtained from other software packages such as SYNCHRO.

The following summarizes the conditions and issues of all users of the corridor based on a combination of field observations and model simulation results. The full existing conditions technical memorandum can be seen in **Appendix A.**

Transit Conditions

- **Downtown transit core.** The H/I Streets are located in the downtown transit core. The mile-long study corridor between New York Avenue and Pennsylvania Avenue is served by 33 bus routes, sixteen stops and connected with 3 Metrorail stations— Farragut North, Farragut West and McPherson Square, providing access to Red, Orange, and Blue Lines. Twenty-four local bus routes include those operated by Metrobus and DC Circulator. Additionally, nine commuter bus routes are operated by Loudoun County Transit and Potomac and Rappahannock Transportation Commission (OmniRide). Combined with bus service on K Street just one block north, the H/I Streets and K Street corridors formed the core of downtown surface transit for east-west movements.
- **High level of Metrobus service.** Twenty-three Metrobus routes serve H/I Streets from the District, Virginia and Maryland, including six (6) PCN lines: 30s, 80s, S, X, 16s, and G8. The combined Metrobus frequency averages 1 bus every minute in the peak on weekdays and 1 bus every 2 minutes in the midday on weekdays and Saturdays. The Metrobus lines using H/I carry 63,000 ridership on a daily basis and the most heavily traveled segment on I Street carries more than 850 passengers in the PM peak hour. Based on the 2008 Metrobus Survey, 80% of the trips on routes that use H/I Streets are made by District residents.
- **Severe congestion impacts on bus travel times and reliability.** Bus operations are typically slower than general traffic due to passenger boardings and alightings, as well as the acceleration and deceleration of the bus. In the case of H/I Streets, this slower speed is compounded by constant friction with vehicular traffic, including general traffic flow, parking and delivery trucks from block to block. Additionally, the high volume of turning movements at intersections, slowed by crossing pedestrians, results in the spillover of vehicle queue for several blocks, further delaying bus travel. **Figure 4** below shows the peak hour average bus speeds compared to average general traffic speed. Bus priority treatments will be able to improve bus travel speeds, improving their operating efficiency and reliability, making them more attractive to riders.

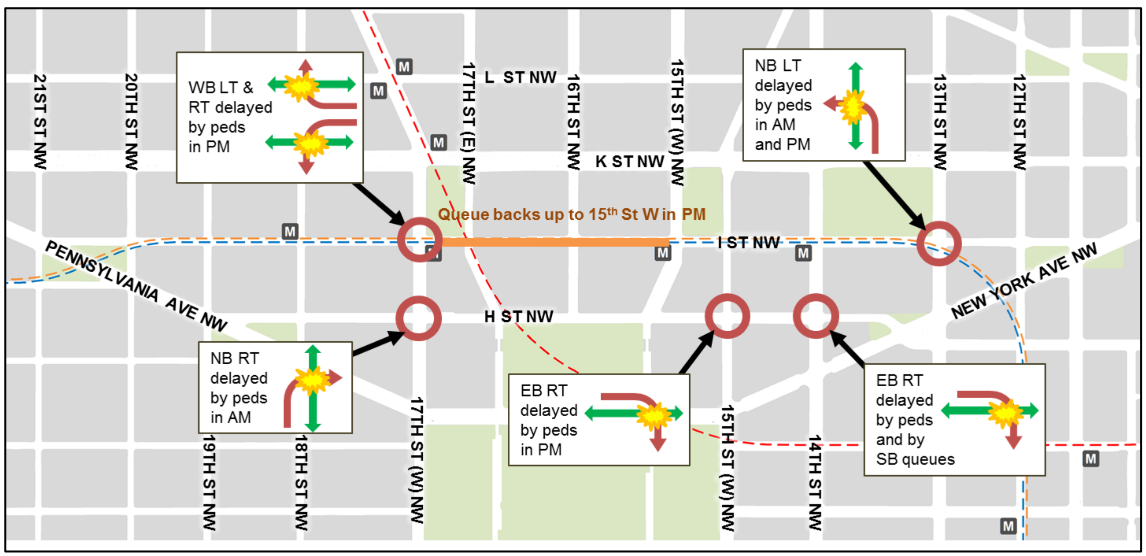
Figure 4: Bus vs. Vehicle Travel Speeds



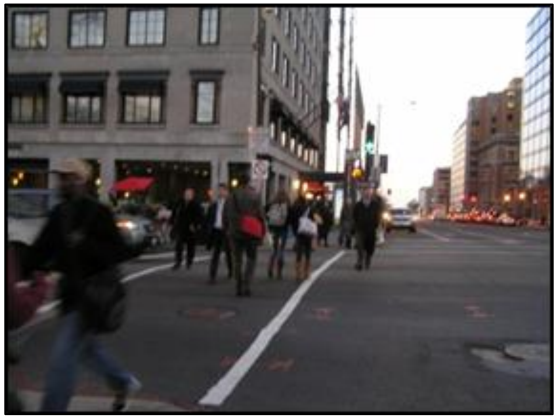
Traffic Conditions

- **Intersection Level of Service (LOS).** During the AM and PM peaks, most of the intersections operate at LOS D or better. Intersections operating at LOS E and F are: AM Peak - H and 17th, I and 13th; PM Peak – I and 17th E, I and 13th.
- **Westbound travel is more congested than eastbound travel.** I Street experiences more congestion than H Street in both the AM and PM peak-periods. H Street generally has one more travel lane than I Street and experiences less friction between pedestrians and loading activities. The only two intersections along H Street which experience queues and delays are 14th Street and 15th Street where eastbound right-turning vehicles are delayed by heavy pedestrian activities. Queues and delays at H and 14th Streets are also caused by southbound queues on 14th Street blocking the box and queues spilling over into the southbound movements from H Street.
- **Long traffic queues.** Insufficient green time at some intersections leads to long queues and poor levels of service. Long queues were observed to extend for multiple blocks. In the PM peak, westbound I Street between 17th Street and 16th Street is highly congested and long queues are observed that extend beyond 16th Street.
- **Auto travel speeds.** Auto travel speeds are observed to be as low as 15 mph in the AM peak and 10 mph in the PM peak. Vehicle speeds in the PM peak indicate a highly congested segment on I Street between 15th Street (W) and 17th Street (W).
- Overall, corridor congestion is the result of a few bottlenecks at intersections and friction between buses, automobiles, and crossing pedestrians (see **Figure 5**). Improving the travel conditions at these bottlenecks and segregating the modes (i.e. bus and auto) can yield travel time and LOS improvement for all users of the corridor.

Figure 5: Study Area Bottlenecks



Congestion on I Street caused by bottleneck at 17th Street, creating long queues backing up to 15th Street.



Heavy volumes of pedestrian crossings at I Street and 17th Street creates conflicts between turning vehicles, creating delays.

Pedestrian Conditions

- An enforcement challenge is jay-walking – where 25% to 50% pedestrians cross the roadway while the signal is red.

- High volume of pedestrian activity at several intersections causes automobile and bus traffic to experience long delays, resulting in long queues. Some of these delays can be attributed to high volumes of pedestrians accessing Metrorail stations on I Street which conflict with right-turning vehicles.

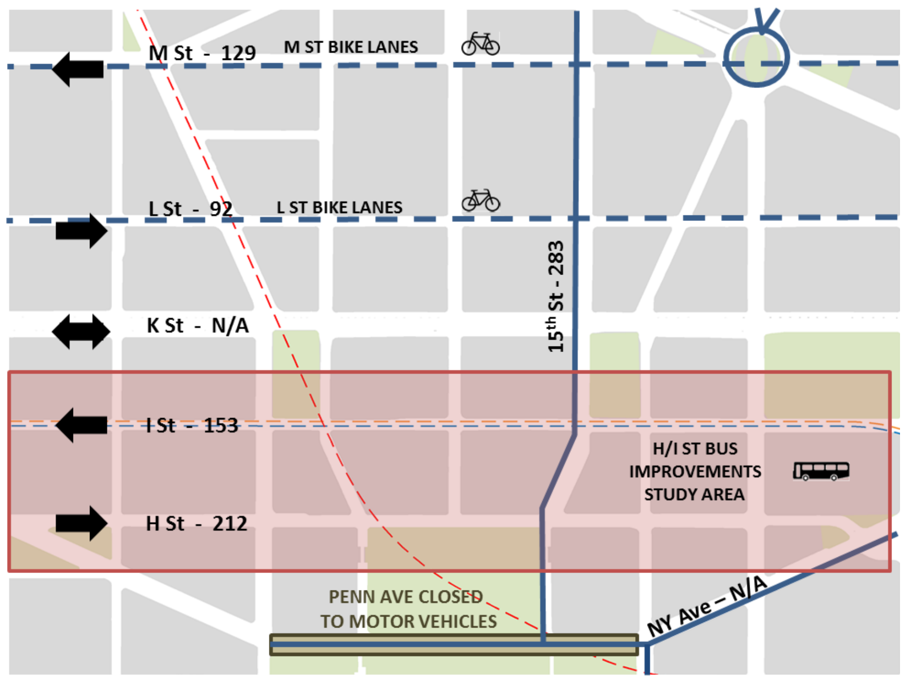
Bicycle Conditions

- The H/I Street corridor as well as corridors directly adjacent have high volumes of bicycle riders. **Figure 6** shows the peak hour peak volumes of bicyclists within the study corridor and adjacent streets.
- DDOT currently maintains cycle tracks on 15th Street through the corridor and has bicycle lanes on New York Avenue and Pennsylvania Avenue. DDOT has implemented bicycle lanes on L Street in 2012 and is currently implementing the M Street bicycle lanes.
- District of Columbia law does not allow bicycle riding on the sidewalks in the downtown area of the city, which is another enforcement challenge.

Curb Use Conditions

- Although, there are a few locations that allow all-day parking, on-street parking is generally restricted in the corridor during peak hours. Curb lanes are also open for delivery and loading activity during off-peak hours.
- Several vehicles including taxis, trucks and private automobiles were observed violating the peak-period parking regulations. Illegally parked vehicles in curb lanes during peak hours interrupt traffic flow, reduce travel speeds and force vehicles to change lanes, which may

Figure 6: Peak hour peak bicycle volumes (2012 – pre L/M Bicycle lanes implementation)



Sources: H/I Study Traffic Volume Counts (AECOM - 2012); DDOT/MWCOG Bicycle Counts (June 2012) be a safety concern and could lead to crashes. Stricter enforcement and higher fines may be required to deter violations.

- There are several driveways providing access to alleys and garages in the corridor. Vehicles trying to access these driveways and alleys come in conflict with through traffic, including transit vehicles, and negatively impact transit travel speeds.
- Stricter enforcement of existing laws would free up the curb lanes to improve traffic flow through the study area.

Ongoing Projects in the Study Area

An understanding of the ongoing projects in the study area is necessary to evaluate the combined effects of transportation improvements in the downtown core and the study corridor.

- DDOT implemented cycle tracks on L Street and is currently developing cycle tracks on M Street, which provides an east-west connection adjacent to the H/I Street Bus-only Lanes study corridors. The L and M bicycle tracks will form the northern portion of a downtown network of cycle tracks.
- DDOT is performing an Alternatives Analysis Study for premium transit service in the Union Station to Georgetown corridor. The study will evaluate premium transit on various alignments in the corridor and result in an Alternatives Analysis Report in Fall of 2013. Premium transit is high-quality transit that offers improved reliability and speed from normal bus operations. It is typically achieved through limited stops, faster fare collection, signal priority and some level of dedicated right-of-way. At the time of this report, DDOT has not selected a preferred alignment or mode for the premium transit service currently under evaluation in the alternatives analysis.
- The District Transportation Improvement Program (TIP) has allocated funds for the design and construction for an East-West Transitway. The transitway will run in the median of K Street between Mt. Vernon Triangle and Washington Circle, serving the downtown area. The new roadway will provide improved transit and vehicular mobility, reduce congestion and air pollution, and improve transportation safety.

ALTERNATIVES SIMULATION

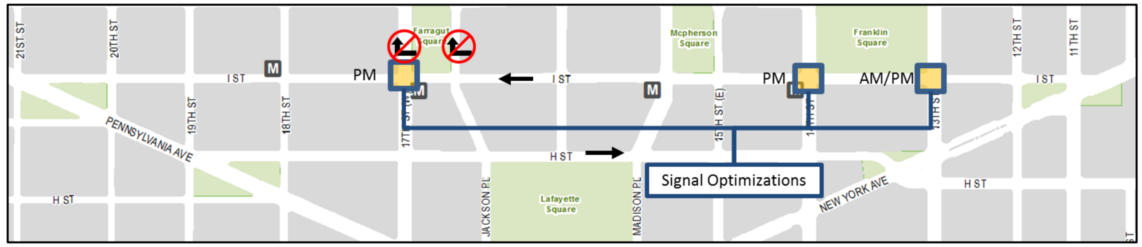
Improvement Options Considered

Four types of improvements options were considered in the technical report: Optimized No-Build traffic management improvements and three dedicated bus-only lane alternatives. The bus-only lane alternatives were developed after documenting the existing traffic and transit operations in the corridor, extensive field observations, and VISSIM traffic simulation of today's conditions. The study team researched best practices for bus improvements and applied best engineering judgment in the development of the four alternatives based on field observations and data analysis. The four alternatives are as follows:

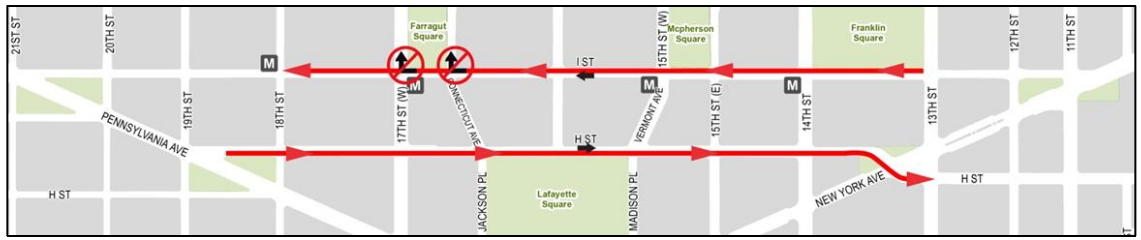
- Optimized No-Build: Traffic Management Improvements through Traffic Signal Optimizations and Right-Turn Restrictions;
- Alternative 1: Concurrent Flow Bus-Only Lanes on H/I Streets;
- Alternative 2: Contra-Flow Bus-Only Lane on H Street; and
- Alternative 3: Contra-Flow Bus-Only Lanes on H/I Streets.

The following discussion details the four alternatives, including the physical design and the operational assumptions for each alternative.

Optimized No-Build: Traffic Signal Optimizations and Right-Turn Restrictions (2012)

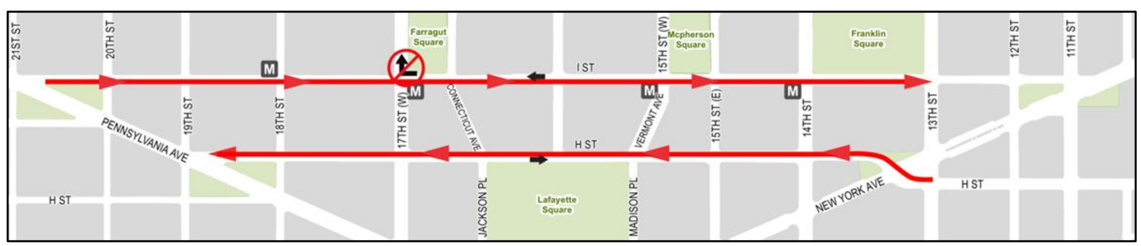


Alternative 1: Concurrent Flow on H/I Streets

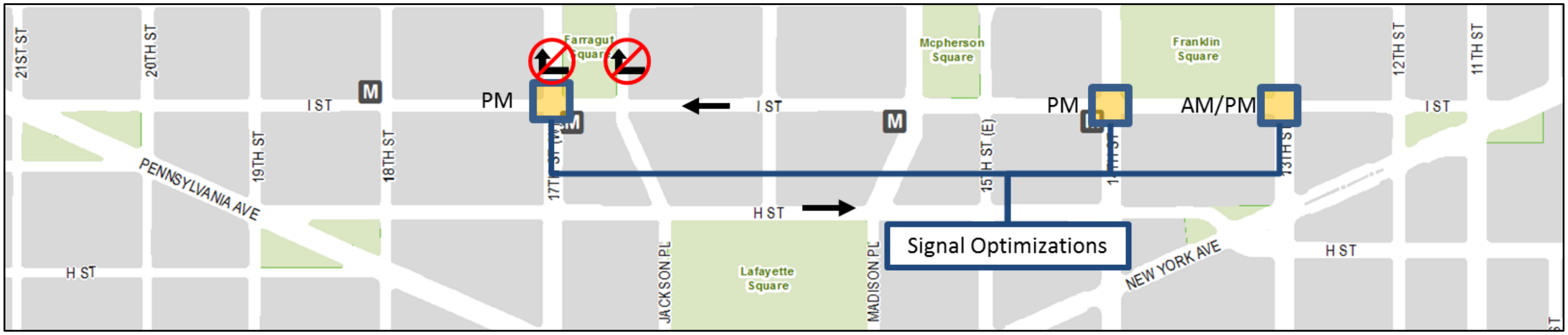


Alternative 2: Contra-Flow on H Street

Alternative 3: Contra-Flow on H/I Streets



Optimized No-Build (2012)



The 2012 Optimized No-Build is an improvement on the Existing Conditions which creates the optimal existing traffic condition by implementing signal timing optimization and turning movement restrictions. Due to the congestion along I Street in the existing condition, the signal timings at the following intersections are optimized to provide better traffic operation:

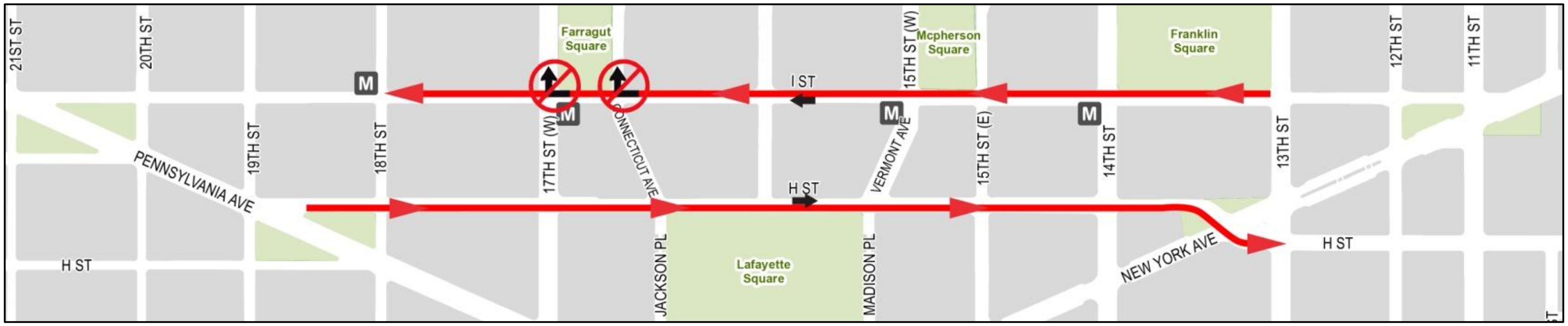
- 13th Street/I Street (AM and PM)
- 14th Street/I Street (PM)
- 17th Street/I Street (PM)

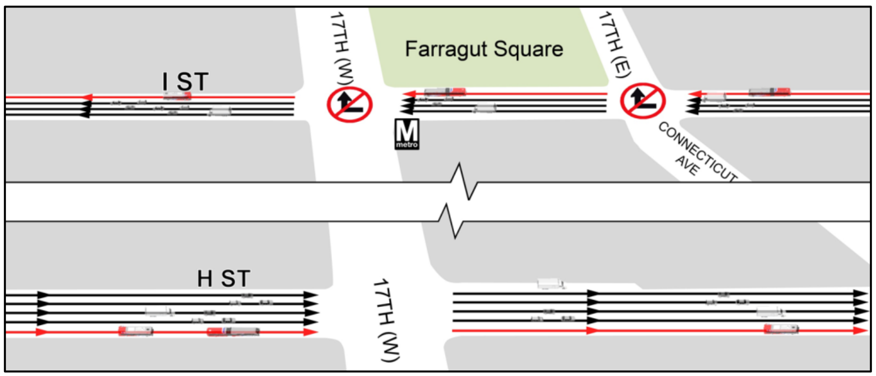
As the intersection of 17th Street (W) and I Street is the major bottleneck along the I Street corridor due to the heavy pedestrian activities, the right-turning movements at 17th Street (W) and 17th Street (E) were restricted during the AM and PM peak hours. The existing right-turning vehicles at these intersections will use 15th Street (W), 16th Street, 18th Street, 19th Street or 20th Street instead to reach their destinations.

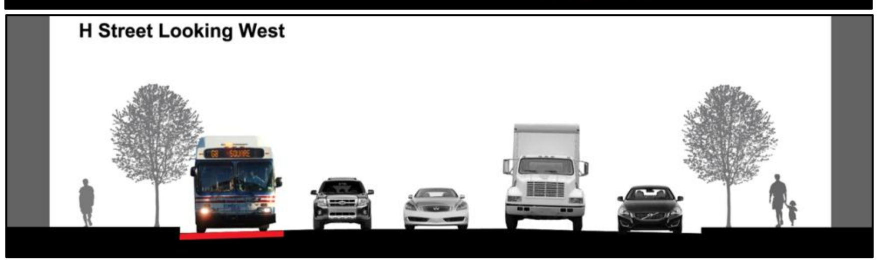
For 2030, traffic volumes, bus ridership, frequency and routes were adjusted to reflect the future conditions. The 2030 Optimized No-Build shows the optimal traffic condition without implementing the bus-only lanes. No right-turn restrictions are required in the 2030 Optimized No-Build. However, additional signal timing optimizations are required at several intersections where the existing signal operation was not able to provide adequate capability to process future traffic growth as well as ridership growth along H Street and I Street. The optimized intersections are listed as follows:

- 13th Street/I Street (AM and PM)
- 14th Street/I Street (AM and PM)
- 15th Street (E)/I Street (AM)
- 17th Street (W)/I Street (AM and PM)
- 17th Street (E)/I Street (AM)
- 15th Street/H Street (PM)
- 19th Street/H Street/Pennsylvania Avenue (AM and PM)

Alternative 1 – Concurrent Flow on H/I Streets





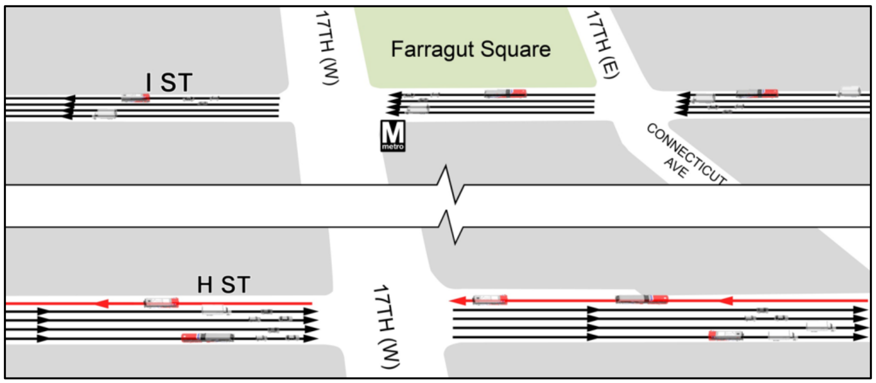


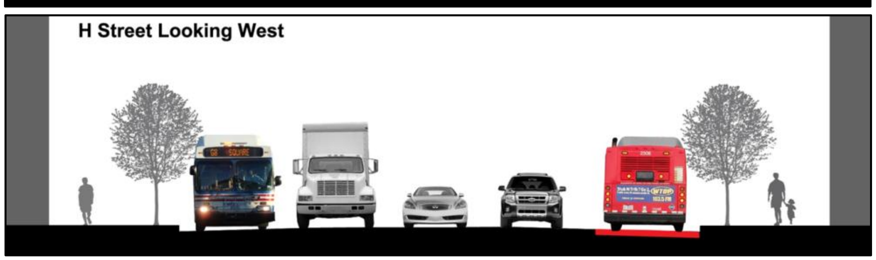
Build Alternative 1 includes a pair of concurrent flow (with general flow of traffic) bus-only lanes on both H/I Streets. The H Street bus-only lane will be located on the south curb in the eastbound direction with from Pennsylvania Avenue/19th Street to New York Avenue/13th Street. The I Street bus-only lane will be located along the north curb in the westbound direction from 13th Street to 18th Street. Alternative 1 is proposed for bus operations in the peak periods and to be open to general traffic, on-street parking, and loading activities during off-peak hours.

This alternative converts two peak-period travel lanes used for bus stops, right turns and through travel and dedicates the lanes to bus travel. This alternative will require right-turn restrictions for general traffic on I Street at the 17th Street (E) and 17th Street (W) intersections adjacent to Farragut Square to prevent excessive traffic queues from forming due to the reduction of capacity at I Street and 17th Street (W). Implementation of the peak-only concurrent flow bus-only lanes could allow for the preservation off-peak on-street parking.

Since the bus-only lanes will not be physically separated from the general flow of traffic, enforcement of bus-only lane restrictions and right-turn restrictions is imperative for effective operations and must continue through the life of the facility.

Alternative 2 – Contra-Flow on H Street



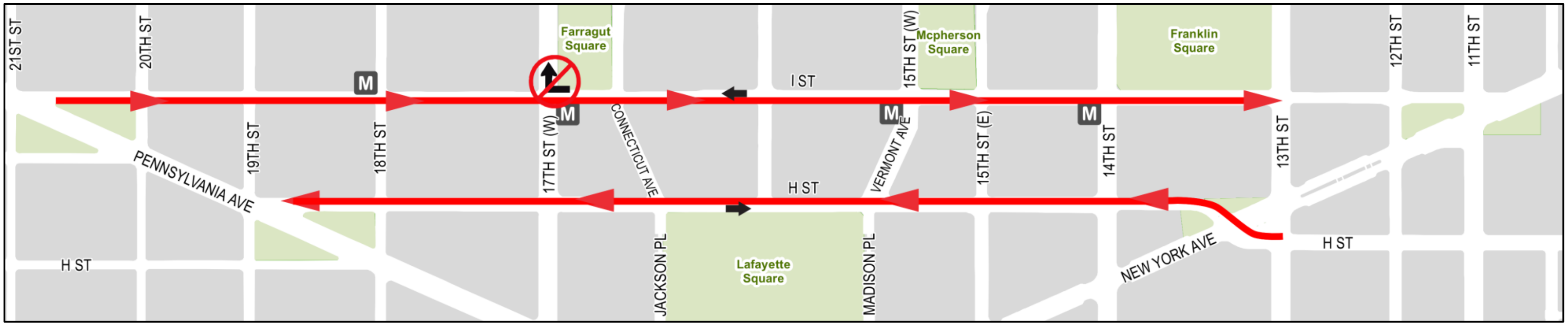


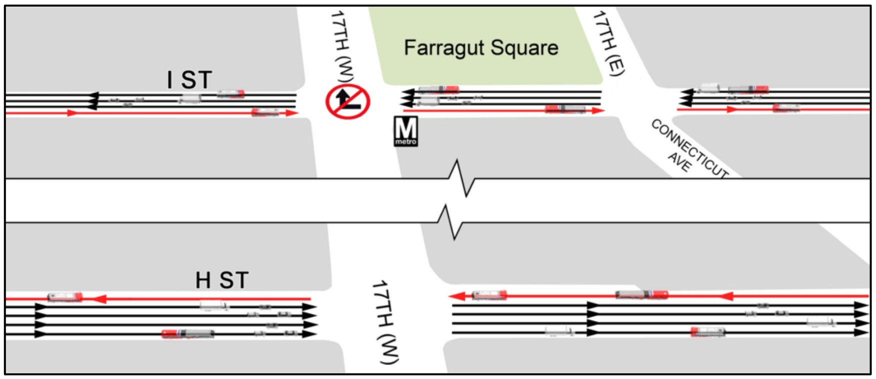
Build Alternative 2 includes a single contra-flow (opposite direction of general flow of traffic) bus-only lane on H Street. The contra-flow lane on H Street will be located on the north curb in the westbound direction from New York Avenue/13th Street to Pennsylvania Avenue/19th Street. Buses in the eastbound direction will continue to operate in mixed traffic on H Street. This alternative requires exclusive bus operations in the westbound bus-only lane 24 hours a day and 7 days a week.

This alternative converts a travel lane used for bus stops, right turns and through travel and dedicates the lane to bus travel. This lane is currently used for on-street parking in the off-peak. Implementation of the contra-flow bus-only lane does not allow for the preservation off-peak on-street parking on the north curb of H Street.

This alternative requires the bus-only lane to be separated from the general flow of traffic as well as special bus signalization at intersections. Physical separation could include double yellow lines and other low impact devices, such as raised concrete or plastic/rubber barriers, or flexible pylon stanchions. Physical barriers would be designed to allow lane access for emergency situations. Raised barriers can also complicate snow removal. Signal timing optimizations at some signalized intersections is also assumed as part of this alternative.

Alternative 3 – Contra-Flow on H/I Streets





Build Alternative 3 includes a pair of contra-flow bus-only lanes on H/I Streets. The contra-flow lane on H Street would be located on the north curb in the westbound direction from New York Avenue/13th Street to Pennsylvania Avenue/19th Street. The contra-flow lane on I Street would be located on the south curb in the eastbound direction from Pennsylvania Avenue/21st Street to 13th Street. This alternative would require exclusive bus operations in the eastbound and westbound bus-only lane 24 hours a day and 7 days a week.

This alternative converts two travel lanes used for bus stops, right turns and through travel and dedicates the lanes to bus travel. These lanes are also used for on-street parking in the off-peak. Implementation of the contra-flow bus-only lanes does not allow for the preservation off-peak on-street parking on the north curb of H Street and the south curb of I Street.

This alternative would also require the bus-only lanes to be separated from the general flow of traffic as well as special bus signalization at intersections as described in Alternative 2. Additionally, right-turn restrictions for general traffic on I Street at 17th Street (W) in the PM peak and signal timing optimizations at some signalized intersections are also assumed as part of this alternative. Enforcement of right-turn restrictions is imperative for effective traffic operations.

Contra-Flow Operations (Alternatives 2 and 3)

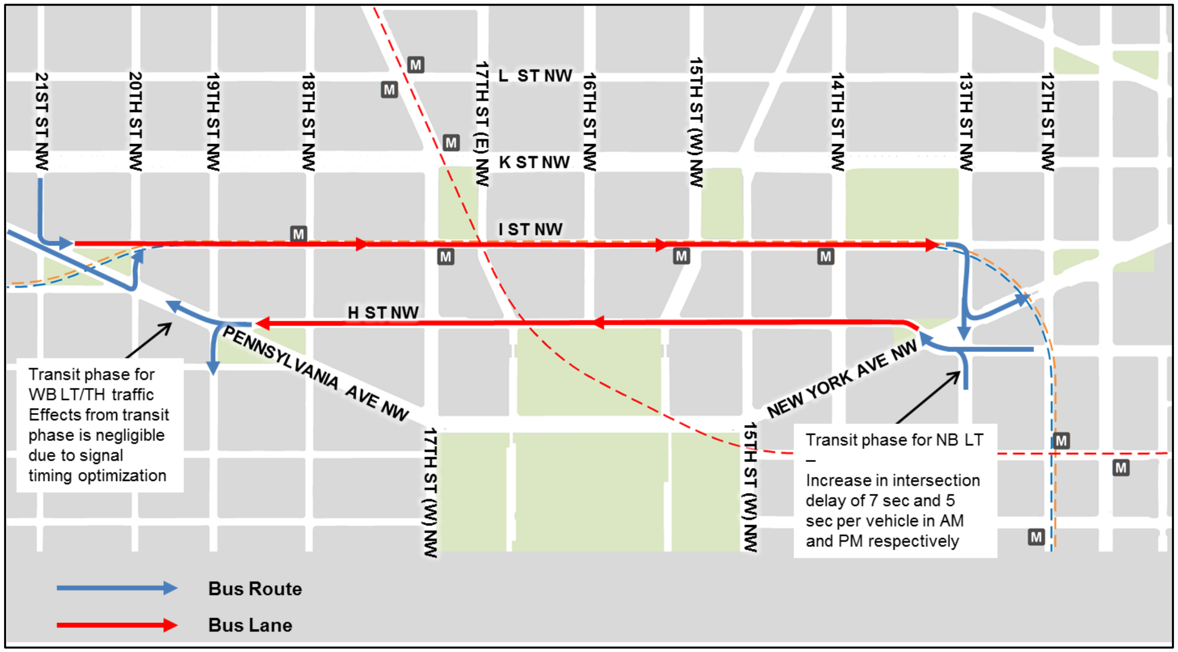
Contra-flow curb lanes are designated transit lanes that operate in the opposite direction of general traffic. Contra flow curb lanes are applied almost exclusively on one-way streets. Contra flow curb lanes are typically self-enforcing, but limit passing opportunities around stopped buses, require changes to current traffic signals to allow for two-way traffic operations. In the initial operations phase, it would require safety awareness campaign and outreach for pedestrians and drivers to become familiar with the contra-flow bus-only lane.

General traffic making left turns across the contra-flow lanes will yield to oncoming bus traffic, just as vehicles yield to oncoming traffic on two way streets. Bus volumes (approximately 1 to 2 buses per signal phase during the peak hour) will allow sufficient gaps to allow for left turn volumes. Intersections with heavy left turn volumes, such as I Street and 17th Street (W) for example, will receive a protected left turn phase before the bus is allowed to proceed through the intersection in Alternative 3. The I Street and 17th Street intersection will continue to have two left-turn lanes and the middle left-turn lane will be shared through.

The beginning and end of each lane will include special transit signal phases. **Figure 7** shows the entry and exit transitions where the bus-only lanes begin and end along H/I Streets.

The proposed signal modification includes new signal head and mast arms. They do not include active transit signal priority technology which enables a bus to adjust the signal phase as it approaches an intersection (green extension/red truncation).

Figure 7: Contra-flow Exit and Entry Transitions



Examples of contra-flow bus-only lanes in downtown Pittsburgh.

Analysis Methodology: Establishing No-Build vs. Build Alternatives

Based on existing traffic condition analysis, traffic simulation models were developed to understand traffic impacts under no-build and build conditions. The 2012 Optimized No-Build model is an improvement to the Existing Conditions model which represents the optimal existing traffic condition by implementing signal timing optimization and turning movement restrictions. This model helps differentiate the traffic impacts from the signal timing optimizations, turning movements, and bus-only lane operation. Three Build models are developed to simulate the traffic conditions with three proposed bus-only lane alternatives. Build Alternative 1 shows the concurrent-flow dedicated bus-only lane operation on I Street from 13th Street to 18th Street, and concurrent-flow dedicated bus-only lane operation on H Street from 19th Street to 13th Street. Build Alternative 2 has the contra-flow dedicated bus-only lane operation on H Street from 13th Street to 19th Street. The eastbound buses remain in the mixed operation on H Street. Build Alternative 3 shows contra-flow dedicated bus-only lanes on I Street from 21st Street to 13th Street, and on H Street from 13th Street to Pennsylvania Avenue.

The 2030 Optimized No-Build and Build models were also developed to forecast future year traffic conditions. 2030 Optimized No-Build model represents the optimal traffic condition without implementing the bus-only lanes in 2030. The base 2030 model required optimizations due to observed gridlock when traffic growth projections were applied to the existing conditions model. It is reasonable to expect that these traffic signal optimizations will be applied in the study corridor. Signal timing was optimized at several intersections where the existing signal operation was not able to provide adequate capability to process future traffic growth as well as ridership growth along H Street and I Street. The 2030 Build models assume the same configurations of bus-only lanes as for the 2012 models.

The following section discusses in detail the model assumptions and inputs for 2012 and 2030 No-Build and Build models (see **Table 2** for all Model Simulations developed).

Table 2: Model Simulations

Current Condition	Future Condition
Model Simulation	**Model Simulation**
2012 Existing Conditions (Base for Comparison) 2012 Optimized No-Build	2030 Optimized No-Build (Base for Comparison)
2012 Alternative 1	2030 Alternative 1
2012 Alternative 2	2030 Alternative 2
2012 Alternative 3	2030 Alternative 3

Model Assumptions and Inputs

Future Traffic Growth

In order to estimate the future traffic growth rate along the H/I Street corridors, available data on annual average daily traffic (AADT) volumes between 2002 and 2009 within the study area were analyzed. The AADT data were obtained from DDOT's online website. **Table 3** provides a comparison of AADT volumes for select road segments in 2002 and 2009. Based on this data, an annual growth rate was determined for each of the segments.

Table 3: Annual Traffic Growth

Road Segment	Annual Average Daily Traffic (AADT), 2002	Annual Average Daily Traffic (AADT), 2009	Annual Growth Rate
I Street: Between 13th and 14th Street	8.9	9.3	0.63%
I Street: Between 17th Street and Connecticut Avenue	16.0	16.4	0.35%
I Street: Between 14th and 15th Street	15.9	15.9	0.0%
H Street: Between Vermont Avenue and 16th Street	20.0	20.5	0.35%
H Street: Between 16th and 17th Street	16.0	15.7	-0.27%
H Street: Between 17th Street and Connecticut Avenue	15.0	15.4	0.38%

Note: The volumes shown are expressed in thousands, rounded to the nearest 100.

AADT comparison indicated that while some road segments experienced a steady increase in traffic volumes, volumes along other segments stayed constant or slightly decreased. An average growth rate of 0.4% was estimated based on data across all the segments within the study area.

To further analyze the traffic volume projections, the project team also looked at projections from Metropolitan Washington Council of Governments (MWCOG) version 2.3 model. Link level traffic volume estimates from the 2012 and 2035 COG models were analyzed. Based on the model outputs, annual growth rates of 0.54% and 0.35% were estimated for the AM and PM peak period, respectively.

Considering the growth rates estimated from the two sources (AADT data and MWCOG model outputs), an annual traffic growth rate of 0.45% is assumed for both AM and PM peak periods along H/I Streets.

Future Bus Ridership Growth and Dwell Time

The 2010 Metrobus Fleet Management Plan estimates that Metrobus ridership between 2009 and 2020 will grow at a steady 1.4 percent annual rate. The study also anticipates that a similar growth trend up to 2030 for the regional transit market consisting of Metrobus and local services. Actual ridership data from Metrobus indicates an average of 4.2% annual growth rate from 2005 to 2012 of major bus routes serving the H Street and I Street corridors. Considering the growth rates from the Plan and historical data, the study team agrees that 2% annual growth rate which leads to a total growth of 36% from 2012 to 2030 is a fair assumption to project the future ridership growth along H Street and I Street. The ridership growth will be reflected by longer dwell time at each bus stop for each bus route.

The ridership growth rate of 2% was also applied to other bus services along the corridors including PRTC Omni Ride, Loudoun County, and DC Circulator. Both PRTC and Loudoun County buses provide one-way commuter services, which is more of a schedule-based operation. The bus dwell time is assumed to be the same as the existing condition considering the same bus operation schedule in 2030.

Future Bus Operation Frequency

The current bus routes which are currently near their maximum load will likely require more service in the future years. In the 2030 model, additional buses were added to accommodate ridership growth on the following routes: 37, 39, 42, 43, 52, 54, 80, G8, N2, N4, S2, S4, X2, and X9.

Modification of Bus Operations

In coordination with WMATA bus planners, existing bus routes were evaluated and modified to take advantage of the proposed bus-only lanes under each alternative. Rerouting some WMATA bus routes to the proposed bus-only lanes along H/I Streets may improve bus operations thereby improving reliability while also fully utilizing the infrastructure investment. All commuter bus routes remained unchanged in all alternatives. **Table 4** shows a summary of the bus route modifications by build alternative. See **Appendix E** for detailed route by route maps for bus route modifications.

Individual Model Assumptions

The 2012 Optimized No-Build model is an improvement on the Existing Conditions model which creates the optimal existing traffic condition by implementing signal timing optimization and turning movement restrictions. Due to the congestion along I Street in the existing condition, the signal timings at the following intersections are optimized to provide better traffic operation:

- 13th Street/I Street (AM and PM)
- 14th Street/I Street (PM)
- 17th Street/I Street (PM)

As the intersection of 17th Street (W) and I Street is the major bottleneck along the I Street corridor due to the heavy pedestrian activities, the right-turning movements at 17th Street (W) and 17th Street (E) were restricted during the AM and PM peak hours. The existing right-turning vehicles at these intersections will use 15th Street (W), 16th Street, 18th Street, 19th Street or 20th Street instead to reach their destinations.

The 2012 Build Alternative 1 model uses the existing curb travel lane as a dedicated bus-only lane shared with right-turning vehicles on both H Street and I Street. This alternative could reduce the friction between buses and autos while on other hand reducing the roadway capacity for automobile traffic. To generate ideal traffic condition in this alternative, same signal timing optimization plans and right-turn restrictions as in the 2012 Optimized No-Build model were tested and modeled in the 2012 Build Alternative 1 model.

The 2012 Build Alternative 2 model assumes the north-side curb lane on H Street to be used as a contra-flow bus-only lane. The majority of WMATA bus routes currently running on I Street will be rerouted to H Street. This alternative will relieve the current traffic congestion along I Street while potentially worsening the traffic along H Street. Signal timing optimization/adjustment was conducted at the following intersections to accommodate bus-only lane operation in this alternative:

- 14th Street/I Street (PM)
- 13th Street/I Street (PM)
- 13th Street/H Street/New York Avenue (AM and PM)
- 19th Street/H Street/Pennsylvania Avenue (AM and PM)

Exclusive transit signal phase was provided at the intersections of 13th Street/H Street/New York Avenue and 19th Street/H Street/Pennsylvania Avenue to allow buses to enter and exit the contra-flow bus-only lane.

H Street becomes a two-way roadway in this alternative. The eastbound left-turning vehicles on H Street will yield to the westbound buses. No additional left-turn traffic phase will be provided.

Table 4: Bus Route Modifications Summary

Route	Current Routing	Alternative 1	Alternative 2	Alternative 3
11Y	H St EB from 18th St to 15th St; I St WB from 14th St to 19th St	Extend EB alignment	Reroute to EB and WB on H St, extend entire length of bus-only lane	Reroute to EB to I St and WB on H St
3Y/16Y	K St EB from 18th St to 14th St; K St WB from 15th St to 19th St	Remain As Is	AM: Remain As Is PM: Reroute WB to H St Bus-only lane	Remain As Is
32, 36, 37, 39	H St EB from Penn Ave to 15th St; I St WB from 15th St to Penn Ave	Extend EB and WB alignment east to 13th St	Reroute to EB and WB on H St, extend entire length of bus-only lane	Reroute to EB to I St and WB on H St, extend entire length of bus-only lane
38B	I St WB from 17th St to Penn Ave	Remain As Is	Remain As Is	Remain As Is
42, 43	H St EB from 17th St to 9th St; I St WB from 11th St to 17th St	Remain As Is	Reroute to EB and WB on H St	Reroute to EB to I St and WB on H St
53	I St WB from 13th St to 14th St	Reroute WB alignment to layover at McPherson Square	Extend route south; discontinue Franklin Park turnaround	Extend route south; discontinue Franklin Park turnaround
80, 80/	80: K St EB and WB from 19th/18th St to 13th St 80/: I St WB from 13th St to 15th St	80: Remain As Is 80/: Remain As IS	80: Remain As Is 80/: Reroute WB alignment to H St	80: Reroute from K St to EB to I St and WB on H St, extend entire length of bus-only lane 80/: Remain As Is
D3	K St EB and WB from 19th/18th St to 13th St	Remain As Is	Remain As Is	Remain As Is
D4	I St WB from 13th St to 14th St	Extend WB alignment to layover at McPherson Square	Remain As Is	Remain As Is
D5	I St WB from 17th St E to 17th St W	Extend WB alignment	Remain As Is	Remain As Is
D6, D6/	D6: K St EB and WB from 19th to 13th St D6/: I St WB from 17th St E to 17th St W	D6: Remain As Is D6/: Remain As Is	D6: Remain As Is D6/W: Remain As Is D6/E: Reroute to EB and WB on H St	D6: Reroute from K St to EB to I St and WB on H St, extend entire length of bus-only lane D6/W: Remain As Is D6/E: Remain As Is
G8	H St EB from Conn Ave to 13th St; I St WB from 13th St to 17th St	Discontinue Farragut Square turnaround	Reroute to EB and WB on H St	Reroute to EB to I St and WB on H St
L2, N2, N4, N6	H St EB from 17th St E to 18th St	Reroute south to Penn Ave, discontinue Farragut Square turnaround	Reroute south to Penn Ave, discontinue Farragut Square turnaround	L2: Reroute south to Penn Ave, discontinue Farragut Square turnaround N2, N4, N6: Remain As Is
P17, P19, W13	H St EB from 17th St to 13th St; I St WB from 11th St to 17th St	Extend WB alignment to 19th St	Reroute to EB and WB on H St, extend entire length of bus-only lane	Reroute to EB to I St and WB on H St, extend route via 11th St
S2, S4	H St EB from 16th St to 11th St; I St WB from 11th St to 16th St	Remain As Is	Reroute to EB and WB on H St	Remain As Is
S4/, S9	H St EB from 13th St to 16th St	Remain As Is	Remain As Is	Remain As Is
X2	H St EB from 16th St to 13th St; I St WB from 13th St to 16th St	Extend EB and WB alignment to 19th St	Reroute to EB and WB on H St, extend entire length of bus-only lane	Reroute to EB to I St and WB on H St, extend entire length of bus-only lane

The 2012 Build Alternative 3 model assumes contra-flow bus-only lanes on both H Street and I Street. This alternative reduces the friction between buses and automobiles while reducing the roadway capacity for auto traffic on both corridors. For I Street which currently operates under congested condition, the capacity reduction creates great traffic impacts on the traffic operation. Signal timing optimization/adjustment was conducted at the following intersections to accommodate bus-only lane operation in this alternative:

- 13th Street/I Street (PM)
- 14th Street/I Street (PM)
- 17th Street (W)/I Street (PM)
- 13th Street/H Street/New York Avenue (AM and PM)
- 19th Street/H Street/Pennsylvania Avenue (AM and PM)
- 21st Street/I Street/Pennsylvania Avenue (AM and PM)

Exclusive transit signal phase was provided at the intersections of 13th Street/ H Street/ New York Avenue, 19th Street/ H Street/ Pennsylvania Avenue and 21st Street/ I Street/ Pennsylvania Avenue to allow buses to enter and exit contra-flow bus-only lanes.

Based on the modeling, the reduction of roadway capacity for auto traffic on I Street will create major traffic impacts and potentially fail the corridor operation. In order to minimize this impact, the study team adjusted signal timing at the intersection of 17th Street and I Street by minimizing the pedestrian walk and flash-don't-walk (FDW) time across the north and south legs of the intersection during the PM peak hours. However, it should be noted that this adjustment will cause severe delays as well as crowding for pedestrians given the high pedestrian activities at this intersection. Westbound right-turning movement was also restricted at this intersection during the PM peak hours to facilitate the traffic operation.

The 2030 Optimized No-Build model shows the optimal traffic condition without implementing the bus-only lanes in 2030. Traffic volumes, bus ridership, frequency and routes were adjusted to reflect 2030 assumptions discussed above. Signal timing was optimized at several intersections where the existing signal operation was not able to provide adequate capability to process future traffic growth as well as ridership growth along H Street and I Street. The optimized intersections are listed as follows:

- 13th Street/I Street (AM and PM)
- 14th Street/I Street (AM and PM)
- 15th Street (E)/I Street (AM)
- 17th Street (W)/I Street (AM and PM)
- 17th Street (E)/I Street (AM)
- 15th Street/H Street (PM)
- 19th Street/H Street/Pennsylvania Avenue (AM and PM)

The 2030 Build Alternative 1 model assumes the same bus-only lane operation as in the 2012 Build Alternative 1 model. Signal timing was optimized for the following intersections:

- 13th Street/I Street (AM/PM)
- 14th Street/I Street (PM)
- 17th Street (W)/I Street (AM/PM)
- 17th Street (E)/I Street (AM)
- 18th Street/I Street (AM)
- 15th Street/H Street (PM)
- 19th Street/H Street/Pennsylvania Avenue (AM and PM)

Right-turning movements were restricted at 17th Street (W) and 17th Street (E) on I Street to improve the traffic operation with the bus-only lane.

The 2030 Build Alternative 2 model assumes the same bus-only lane operation as in the 2012 Build Alternative 2 model. Signal timing was optimized for the following intersections:

- 13th Street/I Street (AM/PM)
- 14th Street/I Street (PM)
- 17th Street (W)/I Street (PM)
- 15th Street/H Street (PM)
- 13th Street/H Street/New York Avenue (AM and PM)
- 19th Street/H Street/Pennsylvania Avenue (AM and PM)

Exclusive transit signal phase was provided at the intersections of 13th Street/ H Street/ New York Avenue and 19th Street/ H Street/

Pennsylvania Avenue to allow buses to enter and exit the contra-flow bus-only lane on I Street.

The 2030 Build Alternative 3 model assumes the same bus-only lane operation as in the 2012 Build Alternative 3 model. Signal timing was optimized for the following intersections:

- 13th Street/I Street (AM/PM)
- 14th Street/I Street (PM)
- 15th Street (E)/I Street (AM)
- 17th Street (W)/I Street (PM)
- 15th Street/H Street (PM)
- 13th Street/H Street/New York Avenue (AM and PM)
- 19th Street/H Street/Pennsylvania Avenue (AM and PM)
- 21st Street/I Street/Pennsylvania Avenue (AM and PM)

Exclusive transit signal phase was provided at the intersections of 13th Street/ H Street/ New York Avenue, 19th Street/ H Street/ Pennsylvania Avenue and 21st Street/ I Street/ Pennsylvania Avenue to allow buses to enter and exit contra-flow bus-only lanes.

Simulation Results

The following section provides the results of the alternatives simulation. The alternatives were evaluated based on the following quantitative performance metrics: Bus Travel Time Changes; Auto Travel Time Changes; Person Delay Changes; Bus Reliability; and Intersection Level of Service.

In order to conduct an apple-to-apple comparison of bus travel time among three build alternatives which shows different bus alignments/operations and scopes of the network, bus travel time between 13th Street and 19th Street in the westbound direction and 17th Street to 13th Street in the eastbound direction was collected regardless of the roadways where the buses are running. The same segment was selected to conduct the auto travel time comparison. Eastbound (EB) and westbound (WB) directions mentioned below refer to the travel directions of buses and autos either on H Street or I Street.

The 2012 Existing serves as the basis for the 2012 alternative comparisons and the 2030 Optimized No-Build serves as the basis for 2030 alternative comparisons. Build Alternative 3 assumes bus lane on I Street starts from 21st Street to 13th Street. To understand the traffic impacts at the intersections of 21st Street and I Street, and 20th Street and I Street, which are two intersections not included in the 2012 existing or 2030 No Build models, extended models (so called “Full Network” models) were developed to include these two intersections as part of the study area. The Full Network models are used as base models to be compared with Build Alternative 3. The existing and No Build models, which are the Non Full Network, are compared with Build Alternatives 1 and 2.

Due to the stochastic nature of VISSIM, the bus and auto travel time results from Non Full Network models and Full Network models are slightly different. The Full Network includes a larger study area and more study intersections as compared to the Non Full Network. The study team ran both models multiple times to reduce the impacts from statistical variation. Nonetheless, a slight variation between the two models remained in that the Non Full Network was slightly more congested than the Full Network model. Therefore, vehicular travel times are shorter with the Full Network.

To understand the travel time changes from no build to build alternatives, travel times in Build Alternatives 1 and 2 are compared to Non Full Network models while Build Alternative 3 is compared to Full Network models. Due to the difference of travel time results between the Non Full Network and Full Network models, we predict that the travel time savings of Build Alternative 3 may be somewhat undervalued as compared to the travel time savings in Build Alternatives 1 and 2. A factor could be applied to the Alternative 3 results; however, one was not used in this study.

Other qualitative information on pedestrian/bicycle safety, enforcement, and curbside impacts used to evaluate the alternatives will be discussed in later sections. Detailed simulation results can be seen in **Appendix F.**

Bus Travel Time Changes (AM/PM)

Bus travel-time changes were documented for eastbound and westbound buses for each alternative. Changes were determined by comparing existing bus travel times in mixed traffic to bus travel times in bus-only lanes for each alternative. Note that Alternative 2 does not include an eastbound bus-only lane and that these results reflect buses traveling in mixed traffic for the eastbound direction. See **Table 5** and **Figure 8** for the bus travel-time changes for both the AM and PM peak-periods for 2012 and 2030.

As seen in the results table, all three bus-only lane alternatives outperform current mixed-traffic operations in the westbound direction. The bus travel time savings in Optimized No-Build are attributed to signal timing optimization and right-turn restrictions at the 17th Street intersections. The dedicated bus-only lane operation in three Build alternatives improves travel time. The eastbound direction generally experiences marginal loss or savings (+/- 30 seconds), except for Alternative 3 which experiences approximately 35% time savings in the PM period in 2012 and in 2030 due to the contra-flow bus-only lane operation. However, the concurrent flow bus-only lane along H Street (in Alternative 1) does not show much savings for bus travel time.

Compared to Optimized No-Build in 2012, bus-only lane Alternatives 2 and 3 show substantial travel time savings in the westbound direction. In 2012, the more bus travel time savings are shown in the PM on the westbound than in the AM in Optimized No-Build models. This is because the right-turn restriction at 17th Street (W) and 17th Street (E) has more benefits in the PM model than in the AM model due to higher right-turn volumes in the AM.

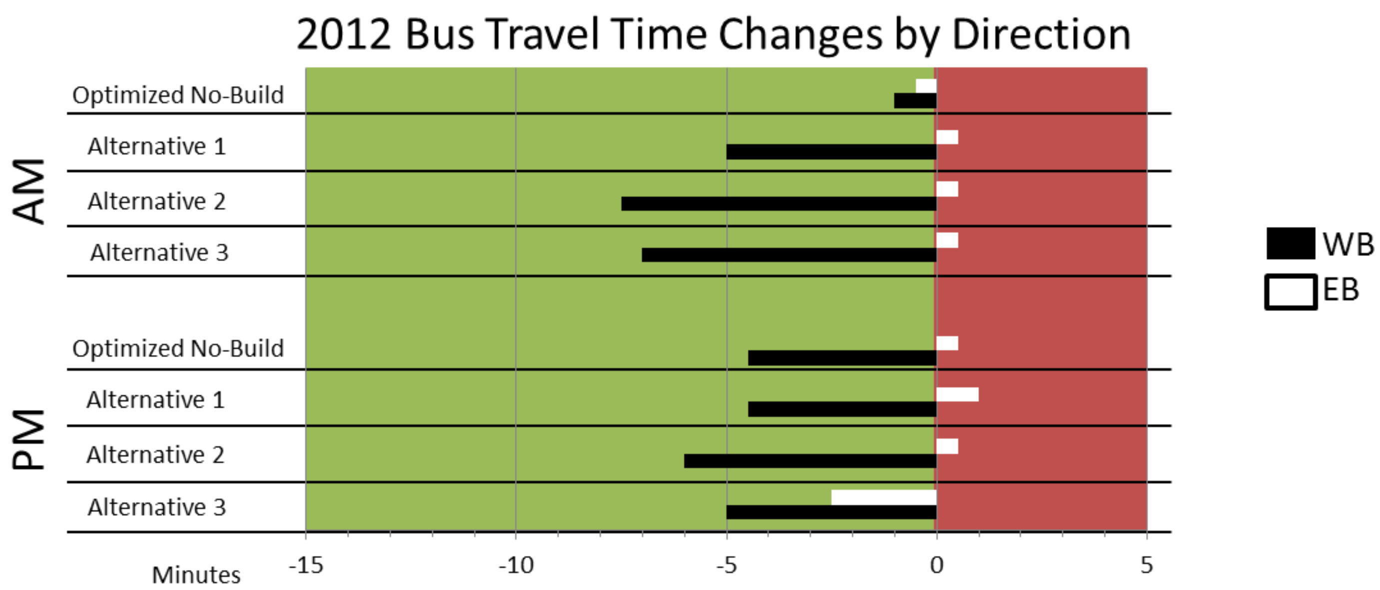
As explained earlier as to the difference of travel time results, Alternative 3 –2030 PM results may be somewhat underestimating bus travel time changes in the westbound direction. We predict that the travel time changes would be closer to the results seen in Alternative 2 (-4.5 seen in Alternative 3 vs. -7.5 seen in Alternative 2), as the model simulates the same westbound contra-flow bus-only lane on H Street.

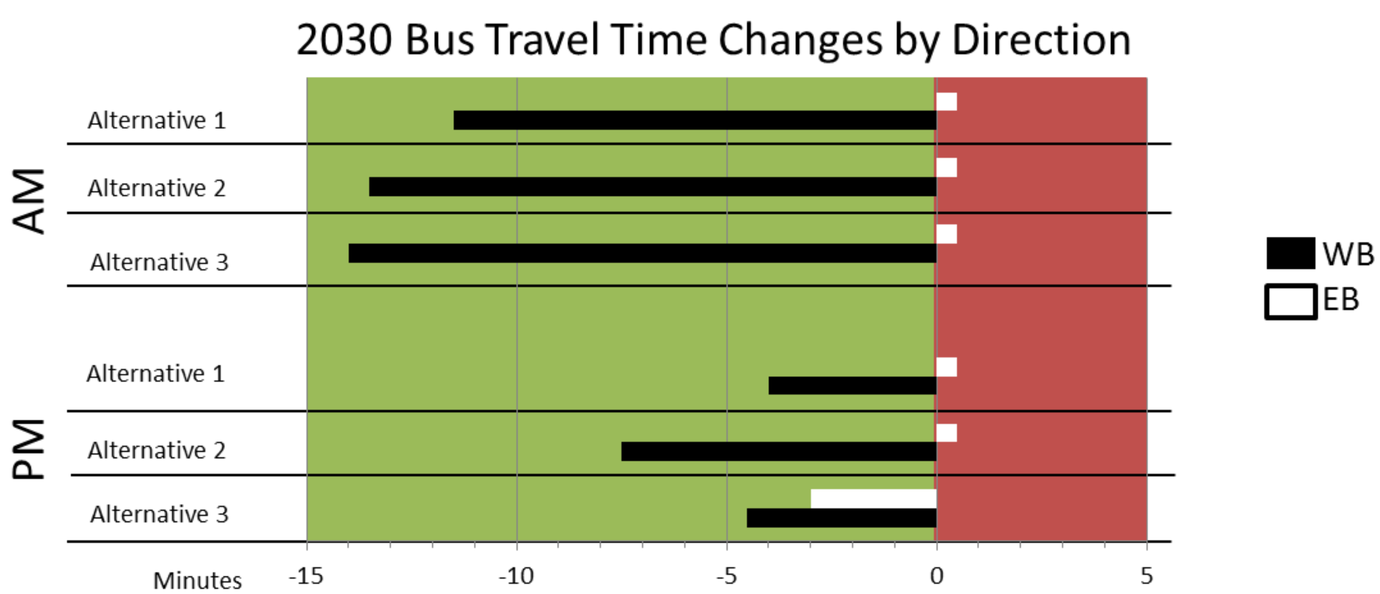
Table 5: Bus Travel-Time Changes

2012 Bus Travel Time Changes by Direction				
	WB		EB	
AM	**Time (Min)**	**% Change**	**Time (Min)**	**% Change**
Optimized No-Build	-1.0	- 6%	> - 0.5	- 1%
Alternative 1	-5.0	- 39%	< 0.5	6%
Alternative 2	-7.5	- 57%	< 0.5	5%
Alternative 3	-7.0	- 56%	0.5	11%
PM				
Optimized No-Build	-4.5	-33%	< 0.5	3%
Alternative 1	-4.5	-32%	0.5	10%
Alternative 2	-6.0	-44%	< 0.5	1%
Alternative 3	-4.5	-37%	-2.5	- 36%

2030 Bus Travel Time Changes by Direction				
	WB		EB	
AM	**Time (Min)**	**% Change**	**Time (Min)**	**% Change**
Alternative 1	-11.5	-60%	0.5	10%
Alternative 2	-13.5	-70%	0.5	11%
Alternative 3	-14.0	-72%	0.5	13%
PM				
Alternative 1	-4.0	-26%	< 0.5	3%
Alternative 2	-7.5	-50%	< 0.5	2%
Alternative 3	-4.5	-36%	-3.0	-36%

Figure 8: Bus Travel Time Changes by Direction





Auto Travel-Time Changes (AM/PM)

Auto travel-time changes were also documented for eastbound and westbound travel for each alternative. Changes were determined by comparing existing mixed-traffic travel times to the mixed-traffic travel times in the three alternatives. Note that in Alternatives 2 and 3, the mixed-traffic travel times also include buses that were not re-routed into the bus-only lanes.

Generally, auto travel time savings are due to (1) the separation of bus operations with automobile traffic, and (2) signal timing optimizations at sever major intersections such as 17th Street and 13th Street. As seen in **Table 6** and **Figure 9**, auto travel times experience marginal negative or positive changes (+/- 30 seconds) due to the addition of a bus-only lane in all three alternatives in the AM peak-period. However, auto travel times in the PM experience significant travel time savings in the westbound direction. Eastbound travel times experience marginal positive and negative changes.

In 2012, the Optimized No-Build provides the most auto time travel savings in the westbound direction in the PM peak, which is attributed to signal timing optimization and right-turn restrictions at 17th Street (W) and 17th Street (E) along I Street. Alternative 3 experiences the least travel time savings as compared to other alternatives due to the reduced lane capacity along I Street; this offsets the benefits from signal timing optimization and right-turn restriction, and results in more traffic congestion. Alternative 1 also shows some traffic impacts from lane reduction; however the impacts are not as significant as Alternative 3 as in Alternative 1 right-turning vehicles are allowed to share the bus-only lane. Alternative 2 shows comparable travel time savings as Alternative 1 even though there is no lane reduction in Alternative 2. However, Alternative 2 does not assume right-turn restrictions at any intersection which would slightly offset the travel time savings.

Westbound auto travel time does not gain much benefit in the AM as compared to PM.

Table 6: Auto Travel Time Changes

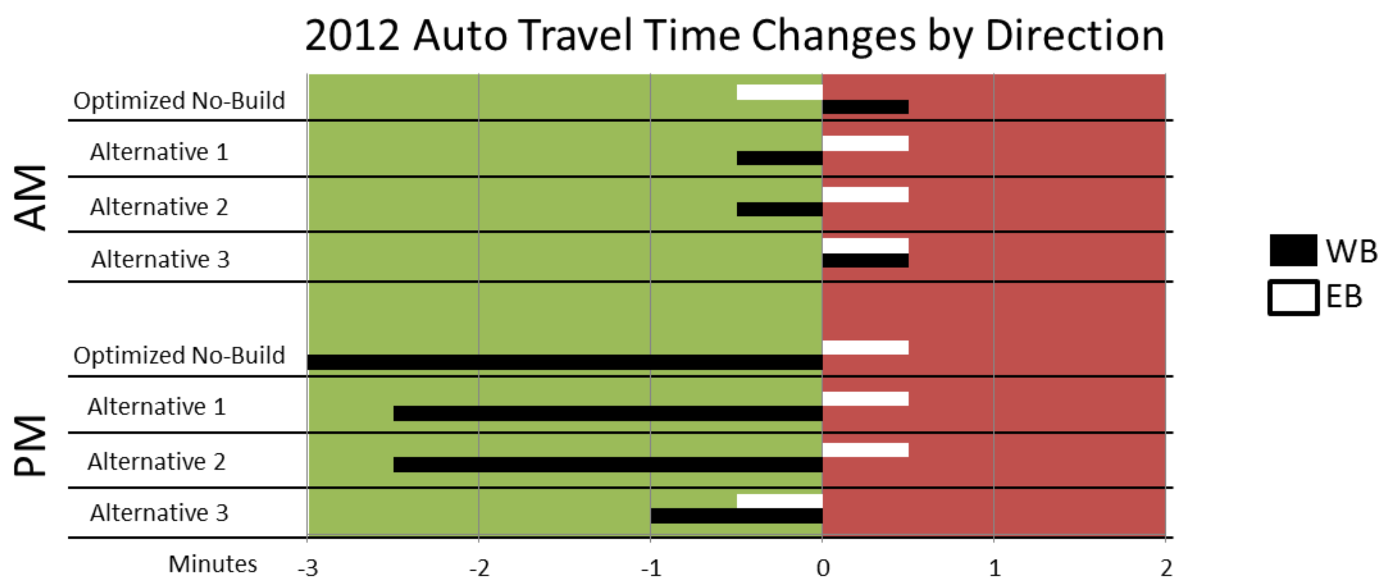
2012 Auto Travel Time Changes by Direction				
	WB		EB	
AM	**Time (Min)**	**% Change**	**Time (Min)**	**% Change**
Optimized No-Build	< 0.5	0%	> -0.5	-1%
Alternative 1	> -0.5	-5%	< 0.5	4%
Alternative 2	> -0.5	-10%	< 0.5	14%
Alternative 3	0.5	16%	< 0.5	1%
PM				
Optimized No-Build	-3.0	-45%	< 0.5	1%
Alternative 1	-2.5	-35%	< 0.5	2%
Alternative 2	-2.5	-38%	0.5	15%
Alternative 3	-1.0	-21%	> -0.5	-1%

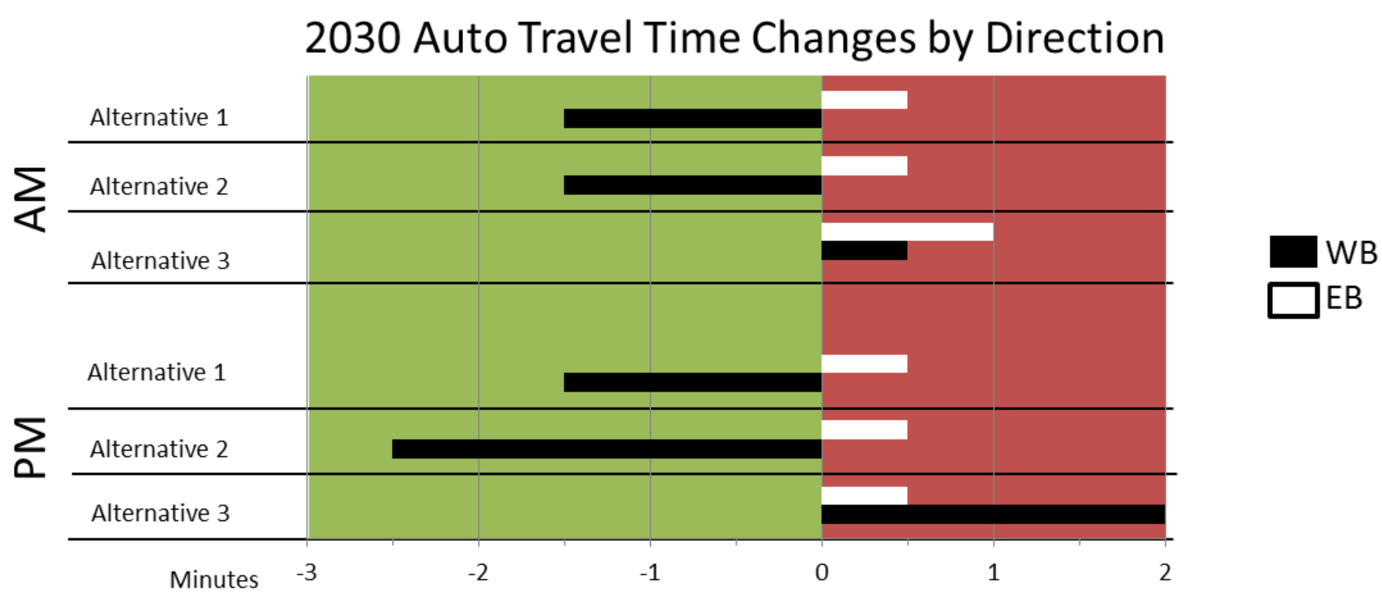
2030 Auto Travel Time Changes by Direction				
	WB		EB	
AM	**Time (Min)**	**% Change**	**Time (Min)**	**% Change**
Alternative 1	-1.5	-28%	< 0.5	6%
Alternative 2	-1.5	-31%	0.5	28%
Alternative 3	0.5	12%	1.0	42%
PM				
Alternative 1	-1.5	-25%	< 0.5	1%
Alternative 2	-2.5	-40%	0.5	19%
Alternative 3	2.0	44%	< 0.5	13%

This is because AM has higher right-turn volumes on I Street than in the PM. When right-turn vehicles at 17th Street (W) and 17th Street (E) reroute to other intersections, vehicles experience more delays at those intersections. This can also be seen in Alternative 3 where there is a right turn restriction at 17th Street (W).

2030 results follow the same pattern as 2012, with moderate automobile travel time savings in the westbound direction and marginal gains in travel time in the eastbound direction, with the exception of Alternative 3. Alternative 3 shows the most delay in travel time in the westbound direction in both the AM and PM peak-periods with 0.5 and 2.0 minutes respectively. This delay in travel time in the westbound direction is caused by the reduced lane capacity for automobiles and the expected growth in automobile volumes by 2030 on I Street. Alternative 2 shows the highest travel time savings in the westbound direction in 2030.

Figure 9: Auto Travel Time Changes by Direction





Person Delay Changes (AM/PM)

Person delay (person hours/hour) measures time required to move individuals, rather than time required to move vehicles. Measuring person delay rather than vehicle delay is an analysis approach that captures the overall impact of transportation improvements.

For this study, the changes in travel time were applied to the person throughput for bus-only lanes and mixed traffic for the three alternatives for 2012 and 2030 conditions.

Bus person throughput was determined using existing average loads per trip by roadway segment multiplied by the number of trips per segment for each alternative. Existing average loads per trip by segment were determined by dividing the total person throughput by the total number of existing bus trips for each roadway segment.

Bus person throughput for each alternative included both buses using the bus-only lanes as well as buses traveling in mixed traffic. Traffic volumes were used to determine the mixed traffic person throughput. See **Appendix F** for the detailed calculation worksheets for person delay changes including person throughput tables.

The following assumptions were used:

- For 2012, all bus trips carry the existing average load for each of the segments in each alternative. 2030 average loads were determined using the 36% ridership growth rate as previously noted;

Table 7: Changes in Person Delay

2012 Change in Person Hours/Hour

		Westbound		Eastbound	
	Peak-period	**Mixed Traffic**	**Bus-only lane**	**Mixed Traffic**	**Bus-only lane**
Opt. No-Build	AM	0	-4	0	0
	PM	-60	-43	0	2
Alternative 1	AM	-4	-50	2	1
	PM	-47	-53	1	6
Alternative 2	AM	-9	-65	7	1
	PM	-61	-42	10	1
Alternative 3	AM	15	-56	0	2
	PM	-29	-30	0	-21

2030 Change in Person Hours/Hour

		Westbound		Eastbound	
	Peak-period	**Mixed Traffic**	**Bus-only lane**	**Mixed Traffic**	**Bus-only lane**
Alternative 1	AM	-34	-166	3	4
	PM	-34	-64	1	3
Alternative 2	AM	-43	-159	16	5
	PM	-68	-97	14	2
Alternative 3	AM	16	-145	27	5
	PM	56	-46	11	-37

Net Change in Person Hours/Hour

	2012	**2030**
Opt. No-Build	-106	--
Alternative 1	-143	-286
Alternative 2	-158	-330
Alternative 3	-119	-112

- Commuter bus trips were included in Alternative 1 bus-only lane calculation, but were assigned to mixed traffic for Alternatives 2 and 3; and
- Autos in mixed traffic carried 1.2 persons/auto.

As seen in **Table 7**, all three alternatives provide significant westbound person hour savings for bus-only lanes during both the AM and PM peak-periods in 2012. In the PM, mixed traffic experiences improved westbound travel time as the conflicts between buses and automobiles and right-turning vehicles and pedestrians are reduced. Increases to bus-only lane and mixed traffic person delay are minimal in the eastbound direction.

In 2030, all the alternatives continue to experience westbound person hour savings for bus-only lanes. Increases are especially evident in the AM peak-period as the bus-only lanes experience over three times the reduction of person hours from 2012. Alternatives 1 and 2 also experience person hour savings for mixed traffic in the westbound direction. Alternative 3, however, experiences increased person hour delay as a result by the increased automobile volumes and decreased lane capacity on I Street. Eastbound travel delay also continues to increase from 2012. Alternative 3 is the only alternative which provides eastbound person hour savings for bus-only lanes.

All three alternatives provide net person delay improvements. In 2012, Alternative 2 provides the most improvement in net person delay, followed by Alternatives 1 and 3, respectively. However, in 2030, Alternative 3 does not experience any additional person delay improvements whereas Alternatives 1 and 2 experience over two times more reduction in net person delay. This is due to a number of factors including the difference in the VISSIM simulation (as discussed previously on Page 20) and the increased delay experienced by automobiles (increased auto travel time) offsetting the person delay improvements experienced by buses. The combination of increased travel time savings and increased person throughput for both mixed traffic and in the bus-only lanes contribute to the dramatic increase in net person delay for Alternatives 1 and 2.

Bus Reliability

Improving bus reliability is one of the main goals of any bus priority treatment. Improved bus reliability, meaning maintaining the bus on schedule with uniform headways and consistent travel times, has positive effects for both bus passengers and transit operators. Bus passengers experience enhanced service quality and punctuality. The increased passenger satisfaction may lead to increased ridership and farebox revenues for the agency. Improved bus reliability also provides bus operators efficiencies in vehicle usage time and reduced operating costs.

The bus travel time reliability is reflected by travel time standard deviation. A low standard deviation indicates the travel times tend to be close to the average; a high standard deviation indicates the travel times are more spread out over a large range of values. As the bus travel time standard deviation becomes smaller, the more reliable and constant the bus operations. The results show that all three alternatives provide smaller bus travel time standard deviation than in the mixed traffic, which means implementing the bus-only lanes will help improve the bus travel time reliability and runtime consistency. Alternative 3 provides the greatest reduction of travel time standard deviation.

The box plot is a straight-forward way of showing the variation of data set. It displays the range and distribution of data based on five number summary – minimum, first quartile, median, third quartile and maximum. The spacing between the different parts of the box helps indicate the degree of dispersion (spread) and skewing in the data. The smaller the space is the more converged the data is.

The box plots in **Figure 10** take Metrobus Route 32/36 as an example. The results shown here use the same travel time segments as the previous travel time results: WB from 13th Street to 19th Street and EB from 17th Street to 13th Street. **Table 8** provides a summary of the worst, average and best travel time scenario under each alternative.

The results for the westbound direction indicates that the bus runtime in the three build alternatives are more converged than in the existing condition, indicating less variability and more reliability of bus travel time. Under the exiting conditions, Route 32/36 could take up to 15 minutes to travel the corridor in the AM and 20 minutes in the PM in the westbound direction. Under all three build scenarios, the maximum time to travel the westbound corridor decreases and the variability becomes more constant in both the AM and PM peak periods.

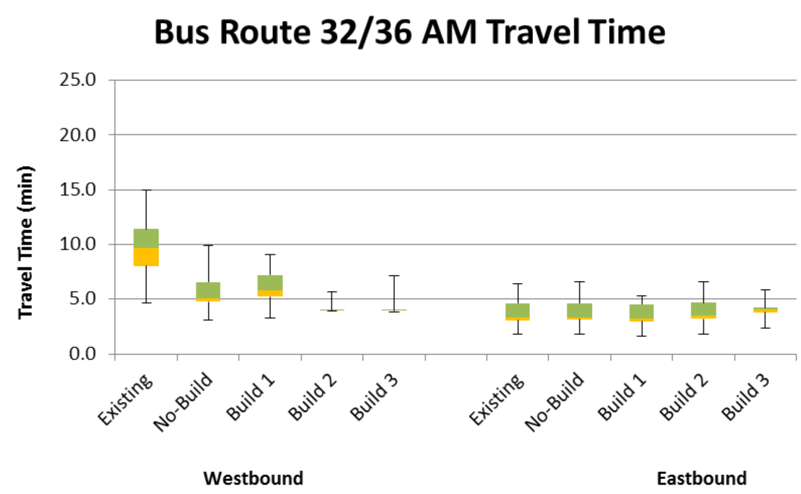
In the eastbound direction, the variability of bus travel time shows marginal improvement or similar runtime reliability in all build alternatives.

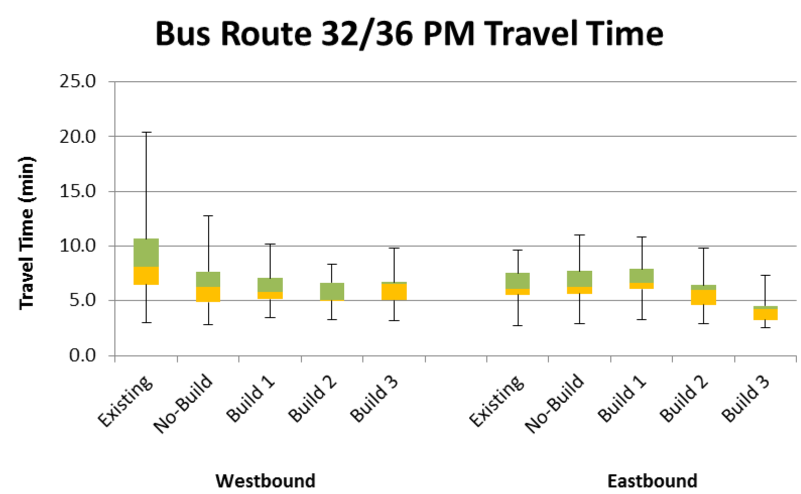
The Benefit Cost Analysis (BCA), in a later section, describes the benefits associated with improved reliability for both the transit user and transit operator.

Table 8: Bus Reliability Summary (Route 32/36) (2012)

	AM			PM		
Travel Time (Minutes)	Best Travel Time	Average Travel Time	Worst Travel Time	Best Travel Time	Average Travel Time	Worst Travel Time
Westbound						
Existing	4.6	9.7	15.0	3.0	8.9	20.4
Opt. No-Build	3.1	5.8	9.9	2.8	6.5	12.8
Alternative 1	3.3	6.1	9.1	3.5	6.2	10.2
Alternative 2	3.9	4.3	5.7	3.2	5.9	8.4
Alternative 3	3.9	4.3	7.2	3.1	6.1	9.8
Eastbound						
Existing	1.8	3.6	6.4	2.7	6.3	9.6
Opt. No-Build	1.8	3.7	6.5	2.9	6.6	11.0
Alternative 1	1.6	3.5	5.3	3.3	7.0	10.9
Alternative 2	1.8	3.7	6.6	2.9	5.9	9.8
Alternative 3	2.4	4.1	5.9	2.5	4.2	7.3

Figure 10: Bus Reliability Box Plots (Route 32/36) (2012)





Intersection LOS

Intersection Level of Service (LOS) analysis provides a measure of delay and service condition for all approaches to the intersection. Analysis of intersection LOS informs whether the congested intersections on H/I Streets will likely improve or worsen with the provision of bus-only lanes, signal optimizations and right-turn restrictions at key locations.

The Highway Capacity Manual 2010 edition uses LOS as a qualitative measure to describe the operating conditions at signalized and unsignalized intersections based on control delay per vehicle (seconds). The LOS range of A through F represents driving conditions from best to worst, respectively. LOS A represents free-flow conditions with no congestion, and LOS F represents severe congestion, significant delays, queues, and stop-go conditions. For the purpose of this study, LOS D or better was assumed to be acceptable at intersections for urban conditions. **Table 9** presents the LOS thresholds for signalized intersections per the HCM 2010.

The LOS analysis examined the AM and PM peak hour LOS conditions at the corridor intersections for the existing year 2012 conditions, 2012 Optimized conditions, 2012 proposed build conditions, 2030 no-build conditions, and the 2030 proposed build conditions.

Under the existing conditions analysis (see **Appendix A**), three intersections in the study area were determined to be failing in either the AM or PM periods: I Street and 17th Street (E); I Street and 13th Street; and H Street and 17th Street.

As seen in **Table 10**, the analysis showed that in 2012 and in 2030, all three bus-only lane alternatives preserve the same LOS or provide LOS improvements at existing failing intersections on H/I Streets.

At I Street and 17th Street, high delays and long queues are observed for the traffic traveling westbound in the PM peak period in the existing condition. Under Alternative 1 and Alternative 2, these high delays and long queues are still present in the PM for mixed traffic; however, due to the bus-only lanes, bus travel does not experience these delays at this intersection.

Table 9: LOS Thresholds for Signalized Intersections

Control Delay at Signalized Intersections	
Delay (sec/veh)	**LOS**
<= 10	A
> 10 – 20	B
> 20 – 35	C
> 35 – 55	D
> 55 – 80	E
> 80	F

Source: HCM 2010

Table 10: Failing Intersection Analysis

Scenarios	I and 17 (E)	I and 13	H and 17
2012 Existing	D/F	E/E	E/C
2012 Optimized No-Build	B/D	D/D	E/C
2012 Alternative 1	B/F	D/D	E/C
2012 Alternative 2	C/F	D/D	D/C
2012 Alternative 3	C/D	D/D	E/C
2030 Optimized No-Build	F/F	F/E	E/C
2030 Alternative 1	C/F	F/E	E/C
2030 Alternative 2	C/E	F/E	E/C
2030 Alternative 3	E/F	F/E	E/C

Sensitivity Analysis on Right-Turn Restriction Compliance

Right-turn restrictions were proposed and tested in westbound I Street at the intersections of 17th Street (W) and 17th Street (E) in both 2012 Optimized No-Build and 2012 Build Alternative 1. To further understand if the right-turn restrictions at these intersections would be effective in high traffic corridors in DC and if the corridor traffic would be sensitive to the violation of the restriction, the team developed a sensitivity analysis for the compliance of right-turn restriction. The analysis could also help agents identify the enforcement efforts needed in the field. Right-turn restriction was also proposed at 17th Street (W) and I Street in Build Alternative 3 during the PM peak period only. Due to the less enforcement efforts needed in this alternative, sensitivity analysis was not conduced for this alternative.

The study team tested 100%, 50% and 0% compliance rate of right-turn restrictions at the intersection of 17th Street (W) and 17th Street (E) on I Street for the PM models in both 2012 Optimized No-Build and 2012 Build Alternative 1 scenarios. 100% compliance refers to the condition where all vehicles obey the right-turn restriction rules at both sides of Farragut Square and reroute to other roadways such as 16th Street, 18th Street, 19th Street and 20th Street. 0% compliance refers to the condition where none of drivers obey the turning restriction at 17th Streets. 50% compliance means half of the drivers obey the rules. **Table 11** shows the number of violators per signal cycle in the PM peak corresponding to each compliance rate. The number of violators with 0% compliance also indicates the total number of right-turning vehicles per cycle at two intersections in 2012.

Table 11: Number of Violators per Signal Cycle in the PM

Intersection	50%	0%
17th St W	2-3	4-5
17th St E	1-2	3-4

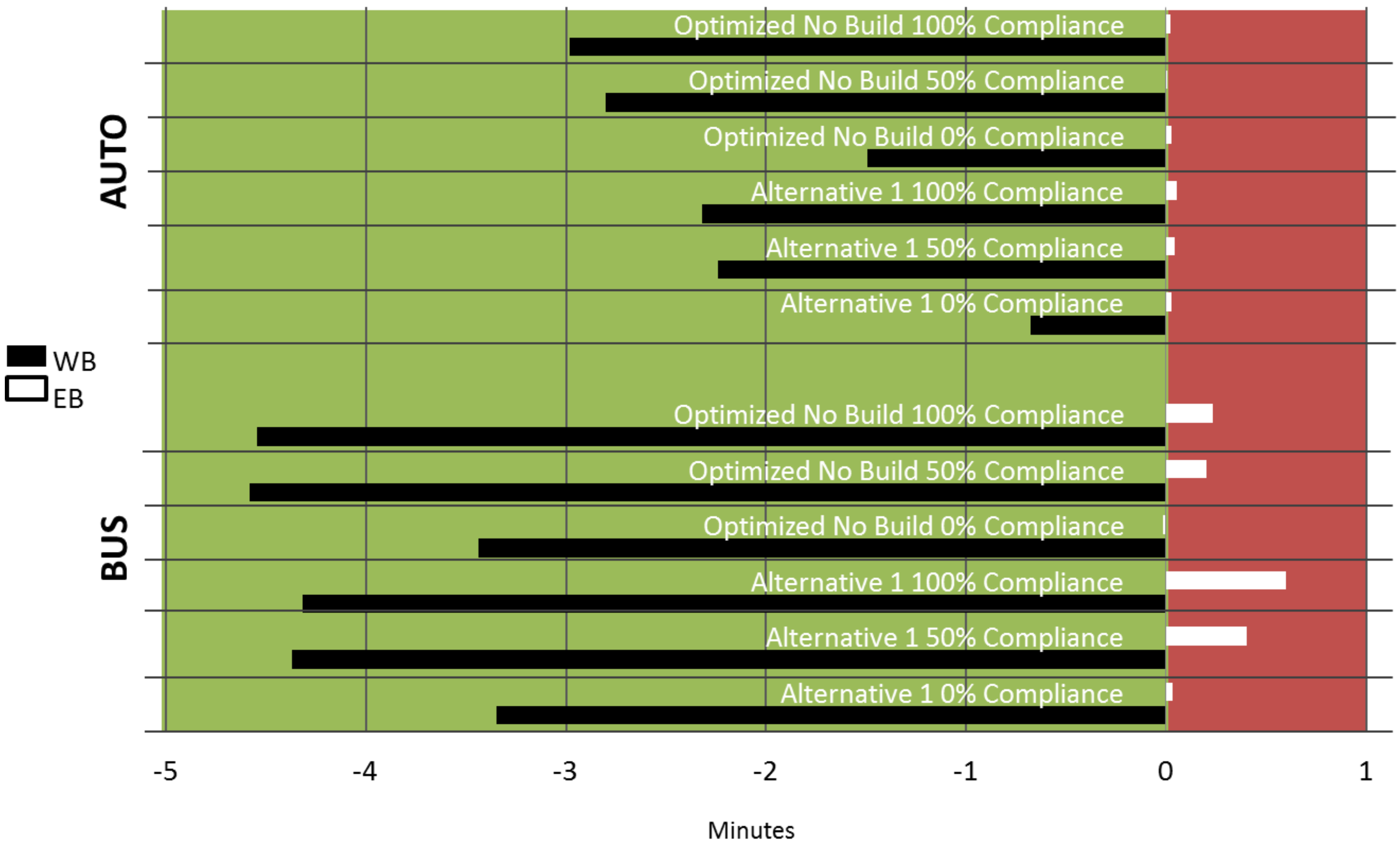
Figure 11 presents the bus and auto travel time change in 2012 Optimized No-Build and Build Alternative 1 scenarios with three compliance rates as compared to the existing travel times. Negative numbers mean the travel time savings while the positive means the travel time loss.

The figure indicates that due to the signal timing optimization and right-turn restriction, buses gain approximately 1.5 minutes to 2.0 minutes more travel time savings than auto drivers in both No-Build and Build Alternative 1 conditions with all compliance rates tested. The figure also helps differentiate traffic improvements from signal timing optimization and right-turn restriction in No-Build and Build Alternative 1. The auto and bus travel time savings of approximately 1.5 minutes and 3.5 minutes in the westbound direction are attributed to signal timing optimization in 2012 Optimized No-Build (see Optimized No Build 0% compliance; i.e. no turn restrictions), while the additional auto and bus travel time savings of 1.5 minutes and 1.0 minutes, respectively, are attributed to turning restriction (see the difference between Optimized No Build 0% and 100% compliance).

Auto and bus gains similar travel time savings with 50% compliance and 100% compliance while experience 1.5 minutes and 1.0 minutes of travel time delay, respectively, with 0% compliance as compared to 100% compliance. The results indicate that the traffic condition on I Street is not very sensitive to the compliance rate of right-turn restriction at 17th Streets.

Moderate enforcement efforts may be sufficient in order to limit right-turn violations without significant negative impacts to the operations of the bus-only lane in Alternative 1. However this level of enforcement does not actively monitor the behavior of automobiles violating the restrictions of driving and parking in the bus-only lanes, including making through movements in the bus-only lanes (where right-turns are allowed). Alternative 1 is more dependent on compliance of these restrictions than the right-turn restrictions. Alternatives 2 and 3, due to the contra-flow design, provide a level of self-enforcement that limit these violations.

Figure 11: 2012 PM Bus and Auto Travel Time Changes by Compliance Rate Scenario



Summary of Simulation Results and Conclusions

Bus Travel Time Changes:

- Westbound concurrent and contra-flow bus-only lanes provide significant travel time savings for buses and passengers in the peak-periods, resulting in a reduction of bus travel time by 30-70% or a maximum of 5 to 7.5 minutes, respectively. Contra-flow bus-only lanes on H Street provide the most westbound bus travel time savings.
- Alternatives 1 and 2 do not provide any benefits from the existing condition in the eastbound direction. Alternative 3, with a contra-flow bus lane on I Street, is the only alternative that provides eastbound bus travel time benefits.
- Bus travel time savings will increase in future years as traffic continues to grow on H and I Streets.
- All alternatives assumed full compliance of turning and operating restrictions in the bus-only lanes.
- In 2012,
  - Contra-flow bus-only lane on H Street (Alternatives 2 and 3) provides the most westbound travel time savings among all alternatives, with buses operating in the bus-only lane consistently saving 6 – 7.5 minutes in the morning and evening rush hours, about half of today's travel time in the westbound direction.
  - Build Alternatives 1 and 2 experience marginal negative or positive change (+/- 30 seconds) in the eastbound direction.
  - Build Alternative 3 is the only alternative that provides significant eastbound bus travel time savings due to the contra-flow bus-only lane.
- In 2030,
  - Build Alternatives 2 and 3 provide approximately equal net bus travel time savings in the westbound direction.
  - Build Alternative 2 only provides

Table 12: Simulation Results Matrix

	Bus Travel Time Changes (Minutes Change)		Auto Travel Time Changes (Minutes Change)		Person Delay Changes (in Person Hours/Hour)		Reduction in Travel Time Standard Deviation (Minutes)(Route 32/36)*	
	2012 (AM/PM)	2030 (AM/PM)	2012 (AM/PM)	2030 (AM/PM)	2012	2030	2012 (AM/PM)	2030 (AM/PM)
Optimized No Build EB	-0.5 / 0.5	NA	-0.5 / 0.5	NA	-106	NA	0.1 / 0.1	NA
Optimized No Build WB	-1.0 / -4.5		0.5 / -3.0				-0.8 / -1.2	
Alternative 1 EB	0.5 / 0.5	0.5 / 0.5	0.5 / 0.5	0.5 / 0.5	-143	-286	-0.1 / -0.3	-0.1 / -0.2
Alternative 1 WB	-5.0 / -4.5	-11.5 / -4.0	-0.5 / -2.5	-1.5 / -1.5			-1.0 / -1.4	-2.5 / -2.1
Alternative 2 EB	0.5 / 0.5	0.5 / 0.5	0.5 / 0.5	0.5 / 0.5	-158	-330	0.0 / 0.0	0.0 / -0.8
Alternative 2 WB	-7.5 / -6.0	-13.5 / -7.5	-0.5 / -2.5	-1.5 / -2.5			-1.7 / -1.8	-2.4 / -1.5
Alternative 3 EB	0.5 / -2.5	0.5 / -3.0	0.5 / -0.5	1.0 / 0.5	-119	-112	-0.5 / -0.9	-.04 / -0.3
Alternative 3 WB	-7.0 / -4.5	-14.0 / -4.5	0.5 / -1.0	0.5 / 2.0			-2.2 / -1.3	-2.6 / -0.7

Note: Green = Condition Improves; Orange = Marginal Change (+/-); Red = Condition worsens

*Route 32/36 used as a proxy to show bus reliability results due to the route using the entire length of the corridor in existing conditions as well as in all three alternatives.

savings in the westbound direction as buses are in mixed traffic in the eastbound direction.
    - Build Alternative 3 provides bus travel time savings for both the east- and westbound directions due to the bus-only lane.

Auto Travel Time Changes:

- In 2012 and 2030, the bus-only lanes in all three alternatives have marginal effects on the eastbound traffic. Eastbound auto travel time experiences +/- 30 seconds change in the rush hours.
- Westbound bus-only lanes provide auto travel time savings of up to 2.5 minutes. In 2012, an eastbound contra-flow bus lane on I Street shows auto travel time increase due to reduced auto capacity and projected traffic demand growth on I Street traffic in the future condition.
- In 2012,
    - Build Alternatives 1 and 2 results in significant travel time savings for vehicular traffic in the westbound direction in the PM peak period. Savings are attributed to signal timing optimization, right-turn restrictions, and reduced friction between buses and autos.
- In 2030,
    - Build Alternative 2 shows the highest auto travel time savings in westbound direction in 2030 as traffic continues to grow in the H/I corridor.
    - Build Alternatives 1 and 2 provide westbound auto travel time savings in both the AM and PM peak-periods with marginal increases in travel delay in the eastbound direction.
    - Build Alternative 3 experiences increased auto travel delay due to the reduced lane capacity for automobiles and the expected growth in automobile volumes by 2030 on I Street.

Person Delay Changes:

- Person delay changes are a function of person throughput and bus and auto travel time changes.
- All three alternatives provide net person delay improvements. Build Alternative 2 provides the most person delay improvements in both 2012 and 2030.
- All three bus-only lane alternatives provide significant person hour savings for buses in the westbound direction for both AM and PM. Build Alternatives 1 and 2 provide westbound person hour savings for mixed traffic in the westbound direction with minimal person hour delays experienced for the eastbound direction.
- Build Alternative 3 experiences increased person hour delay for mixed traffic as a result of the increased automobile volumes and decreased lane capacity on I Street.

Bus Reliability:

- All three alternatives provide bus reliability improvements from the existing condition. The maximum time to travel the westbound corridor decreases and the variability becomes more constant in both the AM and PM peak periods. In the eastbound direction, the variability of bus travel time shows marginal improvement or similar runtime reliability in all alternatives.
- Alternative 3 provides the best bus reliability results in terms of potential reduction of travel time standard deviation the westbound direction.

Intersection Level of Service (LOS):

- Under the existing condition, three intersections in the study area were determined to be failing in either the AM or PM peak periods: I Street and 17th Street (E); I Street and 13th Street; and H Street and 17th Street.
- In 2012 and 2030, all three bus-only lane alternatives preserve the same LOS or provide LOS improvements at existing failing intersections on H/I Streets, under the assumption that there would be no traffic diversion or reduction resulting from the implementation of bus-only lanes.

Effects of Turning Restrictions and Signal Optimizations:

- Signal timing optimization contributes to auto and bus travel time savings of approximately 1.5 and 3.5 minutes respectively in the westbound direction for all alternatives.
- While Alternative 1 could accommodate occasional violations (1 to 2 vehicles per signal cycle) of restricted right-turns in the rush hours without negating the bus-only lane performance, any increase in violations will quickly lead to the breakdown of the bus-only lane operations.

Conclusions from Traffic and Transit Simulations:

- Generally, both mixed traffic and bus travel experience benefits in the westbound direction. Eastbound mixed traffic and bus travel is marginally affected (both positively and negatively varying on alternative).
- As a result of bus travel time savings and bus reliability improvements, WMATA would experience operational benefits in terms of fleet savings under all three alternatives by 2030.
- All bus passengers waiting downstream on the routes using the bus-only lanes would experience improved bus service due to more reliable travel times under all alternatives. Passengers would experience more predicable travel times and uniform headways, resulting in reduced waiting time at bus stops.
- Intersection LOS is not negatively affected due to the addition of bus-only lanes in any alternative and improves at existing failing intersections on H/I Streets.
- Enforcement of right-turn restrictions are needed to ensure the desired bus-only lane performance as simulated (100% compliance), with the recognition that occasional violators could be tolerated by the bus-only lane, which is highly likely to happen even under diligent enforcement.
- Signal timing optimizations and right-turn restrictions improve westbound traffic flow on I Street from the existing condition.

BENEFIT COST ANALYSIS

A Benefit Cost Analysis[1] (BCA) was conducted to help with the evaluation of bus-only lane alternatives (see **Appendix B**). The purpose of the BCA is to compare three bus-only lane alternatives quantitatively in terms of the individual project costs and the associated benefits. The results of the BCA, in conjunction with other qualitative factors, provide WMATA and DDOT with information on how each alternative would affect bus operations and the overall system.

This section describes the long-term benefits generated by the alternatives. The stream of anticipated benefits and costs for the alternative capital investments have been estimated over a 20-year analysis horizon, starting the first full year each alternative is in operation. The 20-year analysis horizon is based on the useful life of asphalt pavement, which will be used for the bus-only lanes.

Each alternative's benefits are summed and then divided by its associated costs to yield the BCA ratio. The benefits outlined in this analysis are based on peak hour traffic simulations and include peak and off-peak period benefits. Build Alternative 1 is a peak period only facility and will not have any off-peak benefits. However, Build Alternative 2 and Build Alternative 3 are all day facilities and will have some off-peak benefits.

Since simulation models were only developed for analyzing weekday conditions during the AM peak hour and PM peak hour within the study area, the off-peak benefits (midday, early night, weekends) for Alternative 2 and Alternative 3 were derived from peak period benefits. These derivations were based on on-time performance (OTP) and speed data for certain bus routes that traverse the study area. Average bus speed and OTP data from the field were used as the basis for estimating the bus travel time benefits and passenger reliability benefits, respectively. For these reasons, the off-peak benefits presented reflect order of magnitude estimates.

Table 13 summarizes the BCA results for the three alternatives analyzed (discounted at a 7% rate). The tables have two costs: capital and enforcement.

Benefits include travel time savings (for auto and bus), bus reliability savings and bus emission savings (value of bus emissions avoided). In addition to the aforementioned benefits, fleet savings and an operating cost reduction have also been included.

The benefits for this scenario are listed below:

- Build Alternative 1 – $75 million
- Build Alternative 2 – $84 million
- Build Alternative 3 – $57 million

Compared to a similarly discounted cost estimate, the Benefit Cost Ratio for:

- Build Alternative 1 – Ranges from 22 to 32 (depending on enforcement scenario), an excellent return on investment;
- Build Alternative 2 – 28, an excellent return on investment; and
- Build Alternative 3 – 9, a good return on investment.

[1] A BCA is a ratio that compares the sum of a project's benefits to the cost of constructing and operating the project. Typically, a BCA ratio of 1.0 says that the benefits and costs are equal over the analysis period, and a BCA ratio over 1.0 shows that there are more quantifiable benefits than costs for the project. Alternately, a BCA ratio of less than 1.0 may indicate that there are not enough benefits to outweigh the costs, or that all of the benefits are not quantifiable. The difference between a BCA of 0.99 and 1.01 does not amount to a meaningful difference and could amount to nothing more than rounding error in the long term. Given the risks associated with forecasting costs and benefits, a successful project or program generally has a BCA ratio well over 1.0. The greater the ratio is over 1.0, the more downside risk the project or program can absorb. The qualitative benefits should also be considered when comparing project alternatives.

Table 13: BCA Ratios for the Bus-only Lane Alternatives: Base + Fleet Savings + Bus Operating Cost Reduction Scenario

	Alternatives Discounted at 7%			
	Values stated in Millions of 2013 dollars			
	Alternative 1	Alternative 1	Alternative 2	Alternative 3
	Concurrent (H/I) – Periodic Enforcement	Concurrent (H/I) – Dedicated Enforcement	Contraflow on H	Contraflow Couplet
20-year Analysis Period	2014 - 2033			
	Costs			
Capital Costs	$ 0.84	$ 0.84	$ 3.37	$ 7.68
Enforcement Costs	$ 1.53	$ 2.63	$ 0.11	$ 0.87
Total Costs	***$ 2.36***	***$ 3.46***	***$ 3.48***	***$ 8.55***
	Benefits			
Weekday Peak Period Benefits (directly based on simulation results)				
Travel Time Savings				
Bus Travel Time Savings	$ 23.03	$ 23.03	$ 24.26	$21.57
Bus Travel Time Savings (In Mixed Operations)	$ -	$ -	$2.31	$ (1.18)
Auto Travel Time Savings	$ 8.81	$ 8.81	$8.26	$ (5.58)
Bus Passenger Reliability Savings	$ 37.98	$ 37.98	$42.01	$33.70
Bus Emission Savings (CO, NO_X, PM)	$ 0.05	$ 0.05	$0.07	$0.07
Bus Emission Savings (CO_2)*	$ 0.07	$ 0.07	$0.11	$0.10
Bus Fleet Savings + Operating Cost Reduction				
Capital Cost Savings	$1.23	$1.23	$2.10	$2.88
Operating Cost Savings	$1.73	$1.73	$3.52	$3.76
Bus Operating Cost Reduction	$1.71	$1.71	$2.26	$2.02
Total Benefits	***$74.61***	***$74.61***	***$84.90***	***$57.33***
Pedestrian Walk Time Disbenefits	--	--	$0.90	$0.10
Net Benefits	***$74.61***	***$74.61***	***$84.01***	***$57.24***
Weekday Off-Peak Benefits (order of magnitude estimates)**				
Bus Travel Time Savings	--	--	$2.96	$2.86
Bus Passenger Reliability Savings	--	--	$6.93	$10.00
Weekend Benefits (order of magnitude estimates)**				
Bus Travel Time Savings	--	--	$0.47	$0.48
Bus Passenger Reliability Savings	--	--	$2.16	$3.15
Benefits (Weekday + Weekend))	**$74.61**	**$74.61**	**$96.53**	**$73.72**
BC Ratio	**31.59**	**21.55**	**27.74**	**8.62**

Notes: *Climate Change benefits are only discounted at 3% per Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon, Feb 2010

**Off-peak and weekend benefits presented for Alt 2 and Alt 3 are derived from peak period benefits. Per guidance from WMATA, these are based on On-time performance/Speed data for certain bus routes and thus reflect order of magnitude estimates. Realizing these benefits assumes that the bus-only lane is made available all the time during off-peak and weekends.

Elements of a Benefit Cost Analysis

The general framework and specifics of each cost and benefit is described in this section.

Costs

There are two aspects of costs calculated in the BCA – capital costs, and enforcement costs. It is assumed that no annual operations and maintenance costs will be incurred on the capital investment.

Based on enforcement requirements, annual enforcement costs were allocated over the analysis period and discounted. The capital and enforcement costs for the alternatives over the 20-year analysis period were discounted at 7% and expressed in millions of 2013 dollars.

CAPITAL COSTS

Capital costs are distributed over time according to the project schedule for expenditures. This stream of costs is then discounted to a net present value. Discounting to the net present value allows the future costs to be directly comparable because they represent the value at one common point in time.

The preliminary capital cost estimates for the three build alternatives are shown in **Table 14**. For the purpose of this analysis all capital costs are allocated in year 2014. The preliminary capital cost estimates consist of bus-only lane signage, pavement overlay, lane striping and markings, new bus shelters and landing pads, and signal modifications. The detailed cost calculations are included in **Appendix G**. The preliminary estimates assume 10% Plans, Specifications, & Estimates Design Fee; 12% Maintenance of Traffic; 15% Construction Management; and 40% Contingency. As the design of the project progresses, this contingency can be reduced.

Table 14: Preliminary Capital Cost Estimates (2013 Dollars)

		Bus-only lane Features*				
Alternatives	**Capital Cost Estimates**	**Bus-only lane Signage**	**Pavement Overlay**	**Lane Striping and Markings**	**New Bus Shelters/ Landing Pad**	**Existing Signal Modification**
Unit Cost		$35/sf	$4/sf	$2/sf; $250/ea	$10K/ea $10K/ea	$180K/ea
Alternative 1	$890,000	$10	$450	$40	--	--
Alternative 2	$3.6M	$3	$170	$13	$80	$1,600
Alternative 3	$8.2M	$7	$430	$27	$220	$3,600

*Shown as $1,000

As seen in the table, Build Alternative 1 has the lowest amount of capital costs as it requires the least amount of physical construction and modification. Build Alternatives 2 and 3 require new bus stop locations and modification of existing signals that make up the majority of the capital costs. Alternative 2 assumes modification to 9 existing signals and 4 new bus stops. Alternative 3 assumes modification to 20 existing signals and 11 new bus stops. The 15% design plans in **Appendix C** show the intersections where modifications to existing signals are needed for Alternatives 2 and 3. Existing signal modification is estimated at approximately $180,000 for each intersection.

ENFORCEMENT COSTS

Enforcement costs include the cost of providing enforcement for bus-only lane restrictions and corresponding right-turn restrictions required as a result of the implementation of the alternatives. The annual cost of hiring full time equivalents (FTE) for this purpose is assumed to be $113,900[2], starting in 2014 (opening year of the bus-only lane operations).

Build Alternative 1 would require periodic enforcement for the entire duration of the project. Enforcement will be required to enforce right turn restrictions on the east and

[2] FTE cost assumed is based on communication from DDOT

Table 15: Enforcement Requirements by Alternative

Alternative	Short-Term Enforcement – mid-block (1st Year)	Short-Term Enforcement - Intersections (1st year)	Long-Term Enforcement - Intersections (Years 2-20)
Alternative 1	2 FTE	2 FTE	1 FTE (periodic) 2 FTE (dedicated)
Alternative 2	1 FTE	0 FTE	0 FTE
Alternative 3	2 FTE	1 FTE	0.5 FTE (periodic)

Annual cost of hiring Full time equivalent (FTE) is assumed to be $113,900 (2013 dollars)

west side of Farragut Square. Additional enforcement at mid-block locations will be required during the first year to accelerate the learning curve of traffic to the modified operations along the corridor. In a meeting with DDOT traffic control, the project team was made aware that due to staffing constraints, it is unlikely that the intersections at I Street and 17th Street (E) and I Street and 17th Street (W) would receive full-time enforcement for the right-turn restriction. Since the benefits under Alternative 1 are highly contingent on enforcement, Alternative 1 is evaluated as two variations – periodic enforcement and dedicated enforcement – in order to test the sensitivity of the results to assumptions about enforcement.

Build Alternative 2 would only require short-term enforcement at mid-block locations to educate drivers, bicyclists, and pedestrians of the contraflow lane and accelerate the user's learning curve towards the modified operations along the corridor.

Build Alternative 3 would require some periodic enforcement for the entire duration of the project. Enforcement will be required to enforce right turn restriction on the west side of Farragut Square. Additional enforcement at mid-block locations will be required during the first year to accelerate the learning curve of traffic to the modified operations along the corridor.

Table 15 summarizes the short-term and long-term enforcement requirements for each of the alternatives.

Benefits

The benefits of the alternatives include the travel time savings (for auto and bus), bus passenger reliability savings, bus emission savings (value of bus emissions avoided), fleet savings and bus operating cost reduction. The analysis also includes pedestrian walk time disbenefits as a result of the modified bus alignments. The benefits are accrued over the 20-year analysis period and discounted to the present value.

TRAVEL TIME SAVINGS

Based on VISSIM simulation results for years 2012 and 2030, travel time savings for both buses and autos were used to estimate the overall travel time savings due to bus-only lane operations. Simulation outputs analyzed for the calculations include bus travel time savings for both WMATA bus routes and commuter bus routes in the study area.

BUS RELIABILITY SAVINGS

Implementation of bus-only lanes along H Street and I Street will alleviate congestion for buses, improving bus running times along the corridor. Smoother operations of buses along the corridor will help buses adhere to schedules, thereby providing more reliable service for bus passengers. Improved bus reliability will reduce waiting time for transit users at bus stations, translating into travel time reliability savings for bus passengers.

BUS EMISSION SAVINGS

Implementation of bus-only lanes along H Street and I Street will alleviate congestion for buses, improving bus running times and bus speeds along the corridor and reducing the amount of stopping/starting for buses. This bus travel time savings could improve bus interlining and potentially result in saved buses. A reduction in the number of buses on the corridor will result in lower bus emissions.

FLEET SAVINGS

Implementation of bus-only lanes along H Street and I Street will alleviate congestion for buses, improving bus running times along the corridor. Bus capital costs and maintenance costs are saved when an improvement reduces the total running time and yields time savings greater than bus headway.

Furthermore, slack time is typically built into the schedule of a bus route to account for variability in bus running times. The slack time provides bus operators with a break and ensures that the next trip starts on time. Thus, with an increase in bus running time variability (i.e., decrease in reliability), the slack time built into the bus schedule tends to increase. Implementation of bus-only lanes reduces bus running time variability, which in turn leads to lower built-in slack time for bus routes and potentially greater fleet savings.

In reality, if a bus is saved due to bus priority, WMATA could redeploy that bus to other areas that need better service. This benefit can be quantified with better service provisions on another corridor. Alternatively, this could also be simplified by quantifying the amount WMATA will not have to spend to purchase another bus to provide the new level of service. In order to accomplish this, bus travel time savings from VISSIM simulations were analyzed to determine routes/instances when time saved is greater than a bus route's headway.

For each alternative, route-level bus travel time savings for 2012 and 2030 (from model outputs) were analyzed. Reduced variability in bus running times was also included in the analysis to estimate fleet savings as a result of the potential decrease in scheduled slack time. **Table 16** summarizes the estimated fleet savings during the AM and PM peak for bus routes that are likely to experience fleet savings.

Table 16: Fleet Reduction Due to Improved Bus Reliability and Bus Travel Time Savings (Total Vehicle Savings in 2030)

Alternatives	AM		PM	
	Routes Affected	Fleet Reduced	Routes Affected	Fleet Reduced
Alternative 1	42, G8, X2	2	--	0
Alternative 2	11Y, 42, G8, S9, X2	5	42, X2	2
Alternative 3	42, G8, P17, S9, X2	6	42, X2	2

Note: *Alternative 3 saves two G8 buses in the AM peak: The first saving starts in 2015 and the second one in 2030

BUS OPERATING COST REDUCTION

Implementation of bus-only lanes along H Street and I Street will alleviate congestion for buses, improving bus running times along the corridor. Bus operating cost reductions are realized when an improvement reduces the total running time and yields time savings lower than bus headway. Bus travel time savings less than a full headway could improve bus interlining and potentially result in saved buses.

PEDESTRIAN WALK TIME DISBENEFITS

In existing conditions, westbound buses run on I Street and eastbound buses run on H Street. Build Alternative 1 involves no major changes in bus alignments and hence will not result in associated pedestrian walk time disbenefits. In Build Alternative 2, most of the westbound WAMTA bus routes will operate on H Street (using the westbound contraflow bus-only lane), while eastbound buses will continue to operate on H Street. The modified bus alignments will result in increased walk times for passengers using westbound buses, specifically for those transferring to and from metro (rail) stations north of H Street.

Similarly, in Build Alternative 3, most of the westbound WMATA bus routes will operate on H Street, while eastbound buses will operate on I Street, using the contraflow bus-only lane on H Street and I Street respectively. When compared to existing conditions, the bus direction on H Street and I Street is swapped. The modified bus alignments will result in a small increase in walk times for bus passengers, specifically for those transferring to and from metro stations. Changes in walk time experienced by transit riders depend on the metro station location and the corresponding bus alignment. For example, transit riders transferring from Metro stations along or north on I Street to westbound buses will experience an increase in walk time while those transferring to eastbound buses will experience a decrease in walk time.

OPERATIONAL MANAGEMENT AND POLICY

There are several operational management and policy considerations that are vital to the successful implementation of bus-only lanes on H/I Streets. These operational management and policy considerations include the hours of operation, vehicle access policy, and impacts to on-street parking and other curbside uses.

Bus-Only Lane Hours of Operation

Designating the hours of bus-only lanes operations is a key decision in the establishment of bus priority. Bus-only lanes hours of operations can either be at all times (24 hours a day) or during peak-periods only.

Due to the physical design of contra-flow lanes, Build Alternatives 2 and 3 will require a bus-only lane operation policy of 24 hours a day and 7 days a week.

For Build Alternative 1, a review of the traffic peaking pattern was done for the H/I corridor and found the peak-period was between the hours of 7:30 – 10:00 AM and 4:00 – 6:30 PM. Traffic enforcement personnel has stated in a previous study for the Crystal City-Potomac Yard Transitway with WMATA and Arlington County, that the hours of restriction should consider a buffer period around the actual hours of operation. For example, if the lanes are to be cleared for transit use by 7:30 AM, the posted restriction time should be 7:00 AM. The hours of restriction should also be clearly signed so that drivers can easily recognize the restriction. It is also recommended that the bus-only lanes hours of restriction should also be standardized among the other areas of city where vehicular operations on streets are restricted. The recommended posted bus-only restriction for Build Alternative 1 will be 7:00 – 10:00 AM and 3:30 – 6:30 PM Weekdays Only. Outside of these restricted hours, the lane may be used for general traffic, parking, and commercial deliveries; when blocked, buses can take over or switch to other lanes during off-peak periods.

Bus-Only Lane Access Policy

The purpose of the bus-only lanes is to provide reliable and efficient bus service in the region's most heavily traveled bus corridor and to alleviate Metrorail core congestion through surface transit improvements. Defining bus-only lane access is critical to ensuring smooth operations of bus-only lanes and eliminating unnecessary frictions with other users coming into the bus-only lane. This access policy designates which transit services, in addition to WMATA and DC Circulator services, will have access to the bus-only lanes. In summary:

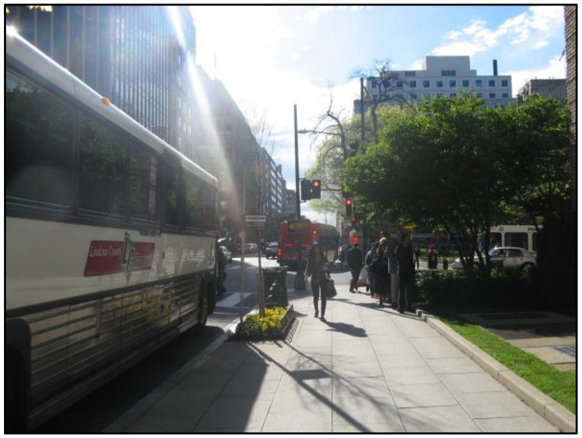
- Bus-only lanes are for the exclusive use of WMATA Metrobus and DC Circulator services.
- Publicly operated commuter bus providers (PRTC, Loudoun County Transit, MTA) will be permitted to use the bus-only lanes in Build Alternative 1 as Metrobus and DC Circulator buses will be able to overtake commuter buses often with longer dwelling time at stops up to 2 minutes. Commuter bus operators will also be permitted to use the bus-only lanes in Build Alternatives 2 and 3 for through buses only. In coordination with these three publicly operated commuter bus services, both Alternatives 1 and 2 were favored as the alternatives offer benefits to commuter buses. A slightly higher preference was given for Alternative 1 as it allows commuter buses to remain on their current routings in drop-off/pick-up mode. Alternative 2 provides benefits to commuter buses remaining on I Street as it moves the majority of bus traffic off of I Street onto H Street in the westbound direction. This allows traffic to move more freely on I Street and opens up the curb lane for commuter bus operations without conflict with Metrobus vehicles.
- All other transit operators, including private long distance providers, private employment shuttles, and motorcoach/tour

buses are not permitted to use the bus-only lanes and must operate in mixed traffic.

- Taxi and Pick-up/Drop-off Activity is not permitted in the bus-only lanes during the posted hours of operation. In Build Alternative 1, the lane may be used for pick-up/drop-off activity outside of the restricted hours. In New York City, along the First and Second Avenue bus-only lanes, taxis are permitted to "expeditiously" make pick-ups and drop-offs within the bus-only lanes. However, it has been noted that this additional "traffic friction" slows down the bus service as buses weave into general traffic lanes to avoid stopped taxis.
- In coordination with DDOT Bicycle Program planners, it is recommended that bicycles will be allowed access to bus-only lanes in Build Alternative 1 but not in Build Alternatives 2 and 3. Bicycle planners did not see the bus/bicycle interaction as a problem in concurrent flow lanes as bicyclists will be able to weave in and out of the bus-only lane and general traffic lanes to avoid the leap-frogging interaction between buses and bicycles. Bicyclists will not be able to perform this maneuver in contra-flow lanes as the lane adjacent will be traveling in the opposite flow direction. Shared bicycle/bus-only lanes have been implemented in Tucson, AZ; Madison WI; and Philadelphia, PA. However, due to the combination of high bicycle and bus volumes seen in the H/I Streets corridor as well as limited roadway widths, a shared contra-flow facility is not recommended.

Other Operational Considerations

- Protocols and standard operating procedures for maintaining or returning to service in a bus-only lane during and after an emergency operation must be researched and discussed further with appropriate District personnel.
- Accessibility issues related to MetroAccess service in the corridor must be considered further.
- Special events, including parades, races, and festivals, that close portions of the proposed bus-only lanes will continue to be scheduled through the existing coordination forums so that agency representatives can inform service providers of upcoming road closures and related service detours.
- One potential benefit of Alternative 2 is the removal of buses from busy I Street. Bus route modifications move 23 buses off I Street onto the westbound contra-flow bus-only lane on H Street during the PM peak hour.



Loudoun County commuter bus picking up passengers on I Street in the PM peak.

Curb Lane Uses Effects

An inventory of curb lane uses was done to document the varying uses and users of the curb lanes within the H/I Streets corridor. Effects to these curb lane uses differ by Build Alternative. **Table 17** provides a summary of the effects. Overall, all three bus-only lane alternatives effect current curbside uses with Build Alternative 1 providing the least amount of negative effects. The Optimized No-Build preserves the current operating environment for curb lane uses.

The area of impact for Alternative 1 (Concurrent on H/I Streets) is the north curb on I Street from 13th Street to 18th Street (east to west) and on the south curb on H Street from Pennsylvania Avenue to 13th Street (west to east). Approximately 132 parking spaces (124 Off-Peak, 8 All-Day), 6 loading/valet areas (approximately 350 feet), and 14 driveway access points are impacted. These impacts, however, are limited only to the peak-hour operations of the bus-only lanes. Curbside uses will be preserved during the off-peak hours.

Build Alternative 2's (Contra-flow on H Street) area of impact is limited to the north curb of H Street from Pennsylvania Avenue to 13th Street (west to east). Approximately 120 parking spaces (115 Off-Peak, 5 All-Day), 3 loading/valet areas (approximately 130 feet), and 12 driveway access points are impacted.

Build Alternative 3 (Contra-flow on H/I Streets) impacts the south curb on I Street from 13th Street to 21st Street (east to west) and on the north curb on H Street from Pennsylvania Avenue to 13th Street (west to east). Approximately 266 parking spaces (248 Off-Peak, 18 All-Day), 9 loading/valet areas (approximately 738 feet), and 25 driveway access points are impacted.


On-street off-peak period parking on I Street

Impacts to curb lane uses as well as their potential traffic impacts remain to be discussed with the public and businesses.

Table 17: Curb Lane Uses Inventory and Impacts Summary

Alternatives	Parking Spaces Removed* (Off-Peak / All-Day)	Loading Areas	Driveway/Alley Access
Alternative 1	0/8	6 (350 ft)	14
Alternative 2	115/5	3 (130 ft)	12
Alternative 3	248/18	9 (740 ft)	25

*Assumes 20 feet per parking space

Potential Parking Revenue Loss

As previously noted, parking will be impacted or eliminated along the curb lanes in all three alternatives. Build Alternative 1 assumes the bus-only lane restrictions will only be applied during the peak-periods of 7:00 – 10:00 AM and 3:30 – 6:30 PM, and that on-street parking will be preserved during the non-peak-periods. Build Alternatives 2 and 3 assume that contra-flow bus-only lanes will operate 24 hours a day, 7 days a week and will require the elimination of on-street parking.

An analysis of potential parking revenue loss was done for each of the three alternatives using a similar methodology used to assess parking revenue loss for the L and M Streets bicycle lanes. As seen in

Table 18, Build Alternative 3 has the highest amount of potential parking revenue loss at about $5,000 per weekday. Build Alternative 1 experiences marginal potential parking revenue loss (approximately $100/day) due to off-peak on-street parking being preserved; the only revenue loss is due to the conversion of all-day parking to off-peak parking. The policy level implications of parking revenue loss needs to be discussed further.

Table 18: Potential Parking Revenue Loss

Alternatives	Areas of Impact	# of Parking Spaces	Off-Peak Parking Spaces	Off-Peak Metered Hours	All-Day Parking Spaces	All-Day Metered Hours	Meter Rate/Hour	Potential Daily Weekday Maximum Revenue Loss
Alternative 1	I St - North Curb; H St - South Curb	Preservation of 132 Off-Peak parking spaces; Conversion of 8 All-Day Parking Spaces to Off-Peak Parking						$99
Alternative 2	H St - North Curb	120	115	9	5	15	$2.00	$2,220
Alternative 3	I St- South Curb; H St - North Curb	266	248	9	18	15	$2.00	$5,015

Assumptions:
- 20 feet per parking space
- $2.00/hour parking rate for Downtown DC
- Build Alternative 1 assumes Bus-only lane Restrictions only for the Peak-periods of 7:00 - 10:00 AM and 3:30 - 6:30; On-street parking available during non-peak hours; All Day parking is converted to off-peak parking
- Build Alternatives 2 and 3 assumes 24/7 operation and elimination of on-street parking
- Off-Peak Metered Hours from 10:00 AM - 3:30 PM; 6:30 PM - 10 PM (9 Hours)
- All Day Metered Hours from 7:00 AM - 10:00 PM (15 Hours)

Mitigation Strategies

Loss of On-Street Parking: Loss of on-street parking can be mitigated by promoting the use of existing parking garages in the study area. According to the Downtown BID and Golden Triangle BID, there are approximately 4,000 – 5,000 existing daily parking spaces in an inventory of 199 garages. DDOT can post more signs directing cars to off-street parking facilities or negotiate with downtown businesses to provide inexpensive parking validation. The District can also mitigate the potential parking revenue loss and decreased parking supply by implementing a performance parking strategy. Performance based parking works by adjusting the rates and/or the time restrictions on metered blocks as to balance the parking supply. Performance based meter rates and time limits are designed to encourage brief curbside parking with high turnover while discouraging long-term parking. Visitors that require longer-term parking are encouraged by the higher meter rates to utilize off-street parking facilities. Performance-based parking is currently used in two District neighborhoods: Columbia Heights and the Capitol Hill/Ballpark District.

Loading Activity: The delivery of goods and services are essential to the District economy and the H/I Street corridors, along with K Street, are among the most important commercial areas in the entire city. Currently, illegal parking, both double parking and parking during peak hours, for delivery and loading activity causes traffic congestion and bus delay on these corridors. Implementation of any of the three bus-only lane alternatives will have impacts to current loading activities, including the elimination of loading zones.

Build Alternative 1 preserves off-peak loading zones as the curb uses will remain open to existing uses during the off-peak hours. Build Alternatives 2 and 3, however, will result in the elimination of 3 (130 feet) and 9 (740 feet) loading zones, respectively. I Street has more loading zones and a higher daily level of loading activity due to more street level retail and office uses than H Street.

To mitigate the loss of loading zones in Alternatives 2 and 3, loading activities may be relocated to adjacent cross streets or along the opposite curb of the bus-only lane. Relocating or expanding loading zones may come at the expense of on-street parking or increase delay for delivery vehicles. Any relocation of loading activities should be coordinated with the Downtown and Golden Triangle BIDs, and may require additional analysis. Relocation and potential consolidation of loading areas to adjacent streets as well as their potential traffic impacts remain to be discussed with public stakeholders.

Rigorous enforcement for bus-only lane violations by freight delivery carriers is also required; Alternative 1 would more heavily rely on enforcement than Alternatives 2 and 3 as contra-flow is generally self-enforcing. Freight delivery carriers are often willing to risk paying fines for parking violations in order to conduct their business. Fines must be high enough to discourage illegal parking behavior. Additional details on enforcement policy is discussed a later section.

Metered loading zones and performance parking strategies may also be a strategy that will encourage turnover of loading zones or the use of off-street loading docks.

Driveway Access: Preliminary designs for all three bus-only lane alternatives do not create any physical barriers between general traffic and bus-only lanes, allowing vehicles to continue to access driveway entrance points under current driving norms and traffic laws. Low-impact curbs or flex posts may offer additional enforcement, but would be designed to allow for driveway access. For the concurrent flow alternative, drivers will be able to enter into the bus-only lane to access driveways. For contra-flow, drivers will have to yield to oncoming bus traffic before crossing over the bus-only lane to access driveways. For drivers exiting driveways, signage or other visual or audible warning devices will be necessary to alert drivers of the bus-only lanes and to exercise caution when entering into general traffic.

Pedestrian and Bicycle Crossing Safety: Due to the unfamiliarity of bus-only lanes, particularly contra-flow lanes, pedestrians, bicyclist, and drivers may require behavioral adjustments during the early stages of implementation. During this time, it is recommended that a public education campaign introduce the concept of the bus-only lanes as well as raise awareness of the potential safety issues. The use of design elements may also be incorporated to reduce pedestrian or bicycle conflicts. Design elements, such as fencing or other barriers, can discourage dangerous behavior, such as jay-walking, and encourage more predictable behavior at intersections. Crosswalks can also be signed or equipped with visual or audible warnings to remind pedestrians to look both ways.

Prominent displays along the street remind pedestrians of oncoming buses in Wellington, New Zealand.

Examples of signage for drivers, bicyclists, and pedestrians to increase safety for bus-only lanes. New York City has stenciled pedestrian warnings at 110 of the most dangerous intersections in the city (right); photo credit *The Associated Press*.

ENFORCEMENT ISSUES AND STRATEGIES

Dedicated Lane Enforcement Best Practices

This section presents a summary of best practices in bus-only lane enforcement based on a literature review of the following sources:

- Shared-Use Bus Priority Lanes on City Streets: Case Studies in Design and Management;
- TCRP Report 90 – Bus Rapid Transit Volume 2: Implementation Guidelines;
- TCRP Synthesis 38: Electronic Surveillance Technology on Transit Vehicles; and
- TCRP Synthesis 83: Bus and Rail Transit Preferential Treatments in Mixed Traffic.

Enforcement can be classified as either passive or active. Signage, markings, or other design-based designations are considered as passive. Employing enforcement personnel patrols or camera technology is considered as active.

Signage and Markings Enforcement

Signage and markings play an important role in communicating bus-only lanes rules and regulations. Comprehensible, bold, and consistent markings all help provide a clear message to drivers that bus-only lane restrictions are meant to be taken seriously. Distinctive lane separation lines designate bus-only lanes from general traffic lanes. Most cities use a solid white line for this separation with dashed lines to indicate where other traffic may enter or exit the lanes, for example for right-turns. The length of marking allowing passage into the bus-only lane should reflect queuing conditions at the intersection. In addition to bus-only lane line separation, colored pavement is also used to raise the lane's visibility as well as "BUS" or "BUS-ONLY" text painted on the pavement to clarify the lane's purpose.

Signage is used to complement the pavement markings in order to clearly communicate the bus-only lane restrictions. Most cities place at least one sign alerting drivers of the bus-only lane on every block. Los Angeles and San Francisco also use warning signs a block before to alert drivers ("BUS-ONLY LANE AHEAD"). Typically, signage indicates the bus priority lanes hours of operation and may also include fine amounts, other types of vehicles permitted in the lanes, or loading/unloading activity windows.

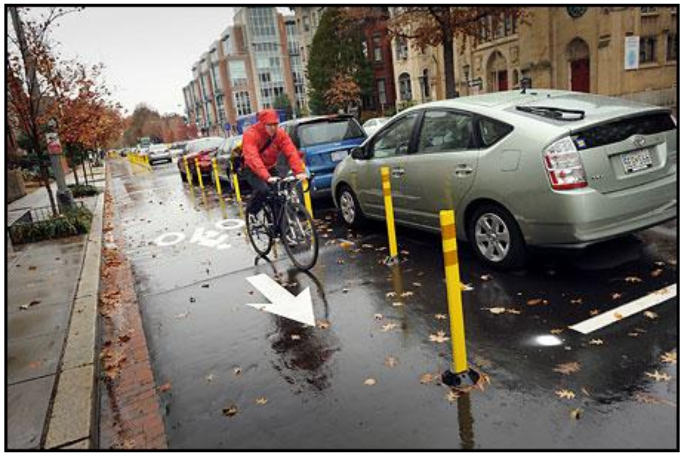
"BUS-ONLY" lane markings in New York City.

Typical bus-only lanes signage indicating hours of restriction and permissible users.

Design-based Enforcement

Design-based enforcement can achieve self-enforcement though design elements. For example, in Paris, the city uses a slightly raised curb or barrier to separate the lanes the bus-only lanes from general traffic. While the lanes do experience violations, the presence of the small barrier does deter most illegal blocking. Other examples of low-impact barriers include plastic/rubber lane impediments, or flexible pylon stanchions. Contra-flow lanes are typically self-enforcing due to the transit operations running in the opposite flow direction of general traffic.

A slightly raised concrete curb provides separation of bus-only lanes in Paris. The barrier keeps vehicles from driving in the bus-only lane, but is low enough to allow emergency vehicles to drive over if necessary. Source: www.humantransit.org



Flexible pylon traffic stanchions provide traffic separation for bike lanes in DC and could be used for bus-only lanes on H/I Streets. Stanchions come in varying heights and the flexible posts allow for emergency responders access through the barrier. Source: www.washingtonpost.com

Patrol-Based Enforcement

Patrol-based enforcement for bus-only lane driving violations are generally conducted by local police. Moving violations typically result in points that are recorded against an operator's license. Although dedicated patrol-based enforcement for driving infractions are difficult to sustain due to other pressing needs of the police force, London and San Francisco have been able to establish dedicated police units for the continuous enforcement of bus-only lanes. Since parking violations are considered minor civil infractions, they are typically handled by civilian personnel and do not require involvement of deputized officers. Parking violations are not treated as moving infractions and do not result in points on an operator's license.

Studies have shown that overall, the costs associated with continuous enforcement produced net benefits due to the revenues the fines brought in as well as the operational productivity gains enabled by the bus-only lanes.

A sweep or blitz style enforcement is typically used as an alternative to continuous enforcement. This involves intensive enforcement activities for a brief period of time. This strategy helps raise the public awareness of the bus-only lane restrictions but the residual enforcement effects may be limited if no visible enforcement effort is maintained between sweeps. In the District, traffic control officers have suggested that this approach be used at the onset of the bus-only lanes and then repeat periodically. DDOT traffic control officers (TCOs) used this approach for other enforcement efforts including during the implementation of the L Street bike lane.

Photo Enforcement

Automated camera based enforcement is a strategy that is emerging as an alternative to patrol-based enforcement. Similar to red light or speeding cameras, bus-only lane camera enforcement allows for the personnel resources for the overall enforcement effort to be shifted from in the field to more manageable and cost effective office work. Photo enforcement is used in London, New York, and Sydney. In all cases, stationary cameras are located at key locations along the bus-only lane corridor. London also uses cameras on mobile units and New York, Paris and San Francisco are piloting on-board bus cameras.

In most cities, personnel review raw footage to identify where violations occur and should be prosecuted. In New York, personnel review video from two camera angles in order to observe the violation as well as the surrounding conditions in order to validate a violation has occurred. Sydney's bus-only lane cameras are fully automated as cameras are stationed at intervals along the bus-only lane and violations notices are automatically issued to vehicles that are detected by consecutive cameras.

Enforcement is critical for the proper operations of bus-only lanes. Delivery trucks stopped in bus-only lanes are common violators. Dedicated enforcement personnel or an intensive periodic show-of-force is required to effectively maintain bus-only lane operations. London, New York City, and other cities have started to use camera enforcement strategies in order to better manage enforcement efforts in a cost effective manner.

Administrative Issues and Penalties

In general, the enforcement of bus-only lanes is governed by laws concerning the operation of motor vehicles. The enforcement of such laws is a police responsibility, and the civilian transportation agency does not have the authority to regulate or enforce these laws. Cities have dealt with this challenge in various ways. Some have passed laws reclassifying bus-only lane violations as civil infractions that can be enforced by civilian agents and/or by automated cameras. Others have developed contractual or supervisory relationships between police and transportation agencies to ensure that there are personnel directly responsible for bus-only lane enforcement.

Fine amounts vary depending on whether the bus-only lane infraction was a parking or moving violation. Fines for unauthorized vehicles should be high enough to discourage illegal use and should also be advertised to act as a deterrent. Fines for bus-only lane violations range from $50 - $214, with parking/stopping in a bus-only lane being slightly higher than traveling in the bus-only lane (see **Table 19** for examples from other cities).

Additionally, there should be an aggressive towing program for illegally parked vehicles in bus-only lanes. Immediately towing and impounding violating vehicles has proven effective.

Table 19: Penalties for Bus-only lane Violations

Penalty	London	Los Angeles	New York City	Paris	San Francisco	Sydney
Fine for parking/stopping in bus-only lane	$90-180	$88+	$115	$176	$103	$173
Fine for driving in bus-only lane	$90-180	$50+	$115-150	$176	$60	$214
Points against driving license		◆	◆			◆
Towing of illegally parked cars	◆	◆	◆		◆	◆

◆ - Additional enforcement penalties besides fines

Source: Shared-Use Bus Priority Lanes on City Streets: Case Studies in Design and Management. Mineta Transportation Institute. 2012.

Summary of Current District of Columbia Enforcement

Current District of Columbia Traffic Enforcement and Management Responsibilities

The Transportation Operations Division within the Transportation Operations Administration (TOA) is responsible for the management of the day-to-day traffic operations for the District of Columbia, including the deployment of traffic control officers and roadway operations patrols. The traffic control officers (TCOs) prevent congestion through enforcement and traffic control services at intersections throughout the District. Roadway operations patrols respond to traffic incidents, emergencies and roadway activity in the city.

The Department of Public Works (DPW) provides parking enforcement, including the removal of abandoned and dangerous vehicles, ticketing, towing, and booting and impoundment of vehicles that are in violation of parking regulations.

The Metropolitan Police Department (MPD) is the primary law enforcement agency for the District of Columbia with duties including improving the safety on the streets for pedestrians, bicyclists, and drivers. MPD operates automated cameras for traffic, red light, and speed enforcement. The automated photo enforcement program uses technology to enforce the law fairly and consistently, with the goal of reducing violations, preventing crashes and injuries, and saving lives. Intersection safety cameras catch red light runners and photo radar cameras, both stationary and in police vehicles, focus on aggressive speeders. Locations for stationary cameras are selected by MPD based on crash statistics, officer observations, and citizen complaints. Cameras automatically photograph vehicles that violate the law and no photos are taken of the driver or passengers. Photos are reviewed and citations are verified by a MPD officer and the ticket is mailed to the registered owner of the vehicle. No points are assessed for photo-enforced tickets.

The Department of Motor Vehicles (DMV) provides adjudication services, including administrative hearings and payment services for parking, minor traffic, and photo enforcement tickets issued in the District of Columbia. The current fine amount in DC for parking in a bus zone or bus-only lane is $100. There is no current law against driving in bus-only lanes. See **Appendix H** for current District traffic laws and fines related to operating/parking in restricted lanes or areas.

Lessons Learned from Enforcement Programs

In coordination with DDOT TCO personnel, it was noted that TCOs have difficulty with enforcement of right-turn restrictions in other areas of the city. The problem arises as it is difficult to pull violators over to issue citations during the peak hours. There is often limited or no room for cars to stop without interrupting traffic.

The MPD photo enforcement programed has shown to improve traffic safety and change driver behavior in the District. At intersections equipped with automated cameras, red light running has been reduced by two-thirds or more. Aggressive speeding has also been reduced from 1 in 3 drivers at the beginning of the program to 1 in 40 today. Additionally, average speeds for all vehicles traveling in the District have been reduced significantly. Fines collected from violators have been able to pay for all program expenses.[3]

[3] DC Photo Enforcement, MPD, Traffic Safety and Special Enforcement Branch. http://mpdc.dc.gov/sites/default/files/dc/sites/mpdc/publication/attachments/dcphoto_english.pdf

New York City MTA Enforcement Case Study

MTA New York City Transit and the New York City Department of Transportation (NYCDOT) have piloted three different types of bus-only lane camera enforcement: static cameras mounted on poles, cameras on board the buses themselves, and cameras in cars traveling along the streets (i.e., "mobile units"). Presently, NYCDOT uses cameras at fixed locations; however, the mobile units on buses and other vehicles may be used more in the future.

At each of the locations where a bus-only lane camera is located, there is a tightly focused higher resolution camera to capture license plate numbers, as well as a lower resolution camera that captures the overall view of the street and bus-only lane area. It is this latter camera that identifies a violation of the bus-only lane has occurred (i.e., someone drives in the bus-only lane without making the next available right turn, or parks/stands in the bus-only lane), and then the time stamp from this camera is compared to the image from the former camera to identify the vehicle. The potential bus-only lane violations are reviewed (as the same vehicle must be in the bus-only lane for an extended amount of time and not solely for an expeditious pick-up or drop-off, or for a right turn, or in case there is some other extenuating circumstance such as utility work or a motor vehicle accident in an adjacent lane) before a citation is issued. The fine is $115.00 for either a camera-captured or parking violation, and $150.00 for a moving violation issued by a traffic enforcement officer (i.e., should an officer observe the motorist in the bus-only lane illegally). NYCDOT has indicated that the number of tickets issued is relatively high, although they have recently started to observe a very slight downward trend.

NYCDOT has found that with red light cameras, it takes a couple of years before drivers' behavior really changes; thus, it is premature to be able to discern if driver behavior has been modified as a result of the bus-only lane cameras. However, NYCDOT indicated that bus-only lane cameras have allowed them to deploy the traffic enforcement officers more effectively, since they can focus on locations that do not have bus-only lane cameras.

NYC bus-only lanes ticket video playback.

There were some privacy concerns related to the use of the bus-only lane cameras, which is why the higher resolution cameras capture an image of the vehicle's license plate, but not an image of the vehicle's driver. As a result, the bus-only lane camera-captured violations are issued to the vehicle owner, and not to the driver. NYCDOT also does not store recorded video for any length of time, so the video cannot be used other than for bus-only lane violations.

Proposed H/I Bus-only lane Enforcement Strategies

Based on the enforcement best practices research and coordination with DDOT TCOs, the following enforcement strategies are proposed for the H/I Bus-only lanes.

Passive Enforcement

Signage and pavement markings are proposed for the bus-only lanes. Signage would clearly communicate the restrictions of the bus-only lanes, including the hours of operation, vehicles permitted, and fines for violations. Signage would be placed at an interval of at least every block, with longer blocks having two. Signage would also be placed at the block before the beginning and at the end of the bus-only lane in order to warn auto and bus drivers when bus-only lanes convert between mixed traffic operations.

Pavement markings would also be used to identify the bus-only lanes. "BUS-ONLY" text would be placed in the lanes. Lanes would also be painted a contrasting color to general traffic lanes to make identification of the bus-only lane simple. For the contra-flow alternatives, double yellow lines would be used to identify the contra-flow traffic flow.

Active Enforcement

In coordination with DDOT TCO personnel, it is recommended that TCOs be placed at intersections where "No Right-Turn" restrictions would be required to enforce the restrictions. In Alternative 1, two TCOs will be stationed at the I Street and 17th Street East and West intersections. In Alternative 3, a single TCO would be required at the I Street and 17th Street (W) intersection during the PM Peak only. Additionally, DPW Parking Enforcement personnel would be required to actively enforce peak-period parking restrictions for Alternative 1, including aggressively towing illegally parked vehicles in order to keep the bus-only lanes clear. The contra-flow nature of Alternatives 2 and 3 should be self-enforcing; however, illegally parked vehicles must be cleared from the bus-only lanes if violations occur.

A sweep or blitz style of enforcement activity would be used at the onset of the bus-only lanes in order to raise awareness of the new restrictions. Future sweeps will be scheduled if deemed necessary based on the level of compliance seen in the field.

Automated camera enforcement strategies would be examined based on the performance of the bus-only lanes and if an additional level of enforcement is necessary.

Concurrent flow bus-only lane sign for H/I Streets.

Contra-flow bus-only lane sign for H/I Streets

COORDINATION WITH OTHER DDOT OFFICES

The joint project team, led by WMATA and DDOT, established early coordination between the two agencies. Specific coordination efforts included internal DDOT stakeholders involved in the Union Station to Georgetown Waterfront AA, Bicycle program, Traffic Control Officers, and Commuter bus operators. Below is a summary of the key findings and coordination discussions of these internal stakeholders.

Union Station to Georgetown Waterfront AA:

The project team met with the Union Station to Georgetown Waterfront AA team with the purpose of coordinating between the two projects. The H/I bus-only lanes project shares a similar study area with the AA project in Downtown DC. The H/I team gave an update of the progress and results of the simulation runs.

It was discussed how the H/I project will affect the AA project. Concerns over the "taking of lanes" within the greater downtown area (H/I Streets, K Street, L and M Streets) for multimodal purposes are valid, however, the project teams believe that any decreases in lane capacity will be offset by the segregation of modes and the reduced "friction factor" that is seen today between the modes. All alternatives will be able to accommodate transfer of bus routes off K Street if necessary and will also be able to help offset negative effects on K Street bus routes during construction on the K Street transitway.

DDOT Bicycle Program:

The purpose of the coordination meeting with the DDOT bicycle program planners was to provide an update of the project as well as to obtain feedback on issues regarding bicycle interaction and the lessons learned from the L and M Bicycle Lanes project. The bicycle planners believed that the concurrent flow (Build Alternative 1) will be best for bikes as bicyclists can access the concurrent flow bus-only lane. The bicycle planners did not see bus and bike interaction as a problem in concurrent bus-only lanes. Buses and bikes will leap frog, but bikes will have the freedom to weave in and out of the bus-only lane and general traffic lanes. For the contra-flow bus-only lanes alternatives (Build Alternatives 2 and 3), bicycles will not be permitted to access bus-only lane.

Lessons learned from implementation of the L Street bicycle lanes can be applied to the bus-only lanes project, including curbside management and impacts due to loss of parking. The L Street bicycle lane project also found new loading and parking locations to replace those curbside uses.

DDOT Traffic Control Officers:

The purpose of the coordination meeting with the DDOT TCOs was to provide an update of the project as well as to obtain feedback on issues regarding enforcement of bus-only lanes and turn restrictions. TCOs stated that to be able to enforce the right-turn restrictions in Alternatives 1 and 3 (I and 17th Streets), TCOs would need to be stationed at those locations. Additionally, it is difficult to pull people over to hand out citations during peak hours, as there is no room for cars to stop without interrupting traffic. TCOs would provide a "show of force" early on in the implementation then decrease the level of enforcement personnel with follow-up periods of increased enforcement. Department of Public Works (DPW) parking enforcement personnel will need to enforce parking restrictions in the bus-only lanes. Additionally, Metropolitan Police Department (MPD) is currently responsible for camera enforcement and speed camera. MPD will need to be involved for camera enforcement and a process will also need to be developed to administer/check violations like in New York City.

COORDINATION WITH COMMUTER BUS OPERATORS

The purpose of this coordination meeting was to have an initial discussion with relevant commuter bus operators including Loudoun County Transit (LCT), PRTC (OmniRide), and Maryland Transportation Authority (MTA). The briefing was oriented towards describing the study's purpose, alternatives and the benefits and trade-offs associated with each. The meeting was intended to identify early conflicts as well as areas of common ground and begin a dialogue that leads to wide spread support and understanding.

Overall, the commuter bus operators were in favor of implementing bus-only lanes in the District and see the benefits in all of the Alternatives presented. Both Alternatives 1 and 2 were favored as the alternatives offer benefits to commuter buses. A slightly higher preference was given for Alternative 1 as it allows commuter buses to remain on their current routings in drop-off/pick-up mode. Alternative 2 provides benefits to commuter buses remaining on I Street as it moves the majority of bus traffic off of I Street onto H Street in the westbound direction. This allows traffic to move more freely on I Street and opens up the curb lane for commuter bus operations without conflict with Metrobus vehicles.

TECHNICAL REPORT CONCLUSIONS AND FINDINGS

Optimized No-Build:

- Lowest cost solution with good benefits
- Lowest level of impacts to traffic and curb uses
- Turning restrictions enforcement needed to ensure benefits

Optimized No-Build: Traffic Signal Optimizations and Right-Turn Restrictions (2012)

H Street Contra-Flow Bus-Only Lane:

- Medium cost solution with nearly all the possible benefits
- Benefits not contingent on enforcement

Alternative 2: Westbound Contra-Flow on H Street

Concurrent Flow Bus-Only Lanes:

- Low cost solution with good benefits
- Turn and operating restrictions enforcement needed to ensure benefits

Alternative 1: Concurrent Flow on H and I Streets

Contra-Flow Bus-Only Lane Couplet:

- Highest cost solution
- Marginal increase in benefits
- Turn restriction enforcement required for congestion management

Alternative 3: Contra-Flow on H and I Streets

Performance:	Best	Moderate	Least

Technical Report Conclusions (cont.)

Table 20 and the text below illustrate the overall performance of each bus-only lane alternative and the general conclusions of this Technical Report.

Transit Performance: Alternative 3, the contra-flow bus-only lanes couplet, provides better travel times with exclusive bus lanes in both travel directions, however when bus person throughput is measured Alternative 2 performs the best.

Traffic Impacts: Alternative 2 provides the best results in terms of traffic impacts including improved automobile travel times and no significant impacts to intersection LOS.

Curb Lane Impacts: With the preservation of off-peak on-street parking, Alternative 1 performs the best in terms of curb lane impacts.

Capital and Enforcement Costs: Alternative 1 has low upfront capital costs compared to the other two alternatives. However, Alternative 1 has the highest enforcement costs.

BCA Standard Benefits: Alternative 2 provides the most monetary benefits as determined by the BCA in terms of travel time savings (bus and automobile), bus reliability savings, and bus emission savings.

All three alternatives provide good to excellent returns on investment. Alternative 1 and 2 provide excellent returns on investment, whereas Alternative 3 provides a good return.

BCA Operating Cost Reduction Benefits: Alternative 3 provides the most monetary benefits as determined by the BCA in terms of operating cost reduction benefits.

Other Major Findings:

- Generally, both vehicular traffic and buses gain benefits in the westbound direction. Eastbound mixed traffic and buses are marginally affected (both positively and negatively varying on alternative).
- As a result of bus travel time savings and bus reliability improvements, WMATA would experience operational benefits in terms of fleet savings under all three alternatives by 2030.
- Because bus service is cyclic, bus-only lane improvements would benefit the entire route under all alternatives. Passengers would experience more predicable travel times and uniform headways, resulting in reduced waiting time at bus stops.
- Intersection LOS is not negatively affected due to the addition of bus-only lanes in any alternative. All alternatives improve or maintain LOS at existing failing intersections on H/I Streets.
- Enforcement of right-turn restrictions are needed to ensure the desired bus-only lane performance as simulated (100% compliance), with the recognition that occasional violators could be tolerated by the bus-only lane. Occasional violations are highly likely to happen even under diligent enforcement.
- One potential benefit of Alternative 2 is the removal of buses from busy I Street without dedication of a general purpose lane to bus operations. Bus route modifications move 23 peak-hour bus trips off of I Street onto the westbound contra-flow bus-only lane on H Street during the PM peak hour.
- Signal timing optimizations and right-turn restrictions improve westbound traffic flow on I Street from the existing condition.

Optimized No-Build:

- Applying traffic management improvements without bus lanes, such as signal timing optimizations and right-turn restrictions, can improve westbound traffic flow on I Street from the existing condition in the near-term.

Table 20: Bus-Only Lanes Alternatives Performance Summary Matrix

Alternative	Transit Performance	Traffic Impacts	Curb Lane Impacts	Capital and Enforcement Costs	BCA Standard Benefits	BCA Operating Cost Reduction Benefits
Alternative 1: Concurrent Flow Bus-Only Lanes on H/I Streets	○	◐	●	●	◐	○
Alternative 2: Contra-Flow Bus-Only Lane on H Street	●	●	◐	◐	●	◐
Alternative 3: Contra-Flow Bus-Only Lanes on H/I Streets	◐	○	○	○	○	●

Performance: Least to Best ○ → ●

Technical Report Findings and Next Steps

The Technical Report analyzed and evaluated bus operational improvements and bus lane alternatives through a combination of quantitative operational measures and policy considerations, including travel time savings, curb lane impacts, enforcement strategies, and costs. This study found that all bus improvement alternatives provide good to excellent returns on transit investment, and identified a technical preference for the H Street contra-flow bus-only lane (Alternative 2).

In consideration of the ongoing land use development and transportation improvement initiatives in Downtown, a short-term traffic management option, as seen in the Optimized No-Build scenario, could provide immediate benefits to the existing traffic and transit operations in the east-west corridor of H/I and K Streets and allow flexibility for a later determination of transit investment.

This Technical Report recommends further analysis of the bus-lane alternatives in order to understand the overall benefits and effects to the downtown transportation network, including traffic diversion and reroutings due to turn restrictions. While the technical report assumed auto traffic would remain on the H and I Streets, the proposed operational changes including turning restrictions could potentially induce traffic diversion to other streets.

If a bus-lane alternative were selected for implementation, DDOT would require NEPA & Section 106 approval. Therefore, subsequent studies could include the recommendations and findings of this study, which would also allow for the determination of the benefits and impacts at the network level.

Relocation and potential consolidation of loading areas to adjacent streets as well as their potential traffic impacts remain to be discussed with public stakeholders. Additionally, the policy level implications of parking revenue loss needs to be discussed further.