

**Technical Memorandum 2:
Existing Conditions: Signal Systems and
Operations on Corridors
Rapid Transit System (RTS) Transit Signal
Priority**

For:

Montgomery County
Department of Transportation



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Technical Memorandum 2:**Existing Conditions: Signal Systems and Operations on Corridors
for Rapid Transit System (RTS) Transit Signal Priority****Sabra, Wang & Associates, Inc.****For:****Montgomery County Department of Transportation****18 December 2013****I. INTRODUCTION**

The Rapid Transit System (RTS) Transit Signal Priority (TSP) Concept Study was commissioned by the Montgomery County Department of Transportation (MCDOT) in March 2013 in order to assist in determining how TSP and its operations may be integrated and operate within the overall RTS system. One of the study's primary goals is to "define the appropriate metrics for the implementation of TSP systems on each RTS corridor, building on what was developed for TSP for local bus operations". The purpose of the study is to:

- Define:
 - Current state of traffic signal control & TSP systems used in Montgomery County.
 - Key measures of effectiveness and range of functional attributes for TSP within RTS Corridors
 - Qualitative impacts associated with TSP system operations within RTS Corridors
 - Systems Engineering Approach to TSP planning, design, and implementation within RTS Corridors
- Recommend:
 - Approach to coordinate implementation of planned countywide and RTS TSP
- Establish:
 - Guidelines for TSP systems on RTS study corridors and the degree/need for consistency with TSP systems used on other county and state highways in Montgomery County.
 - Proposed guidelines for agency coordination regarding implementation of TSP on RTS corridors.

This technical memorandum is the second of three deliverables associated with the RTS TSP Concept Study. The first deliverable provided: foundational concepts for TSP; proposed a purpose, goals, objectives, and measures for TSP within RTS within Montgomery County; and then described stakeholders and their needs along with potential policy issues to resolve. This document, Technical Memorandum 2, describes the existing conditions of signal systems and traffic/transit operations on the proposed RTS corridors within Montgomery County including:

- Within each proposed corridor:
 - Characteristics (length, number of bus stops, number of signals, current traffic and transit characteristics)
 - Proposed RTS Priority ROW and stations
 - Potential for TSP
- Overall Transportation System Operations
 - Signal system characteristics and technologies (Montgomery County, SHA, City of Rockville)



- Transit systems and technologies (RIDE ON, WMATA, MTA)
- An assessment of existing components with respect to potential TSP within RTS.

Four sections follow. First, the proposed RTS corridors as described in the Countywide Transit Corridors Functional Master Plan approved by the Maryland National Capitol Park and Planning Commission (MNCPPC) Planning Board in July 2013 and their current operating conditions are described. Second, the overall traffic and transit systems within the County that may operate or influence TSP are examined. Third, the existing components and proposed types of priority right-of-way treatments within the RTS corridors are assessed concerning potential TSP options and desired features within the Rapid Transit System. Last, the next steps are laid out.

II. RAPID TRANSIT SYSTEM CORRIDORS: CURENT OPERATIONS

The genesis and evolution of the plans for RTS in Montgomery County was discussed in Technical Memorandum 1 (Sabra, Wang & Associates, Inc., September 2013). The initial idea proposed by Councilman Elrich has (through several exploratory efforts) led to the Countywide Transit Corridors Functional Master Plan which was approved by the Maryland National Capitol Park and Planning Commission (MNCPPC) Planning Board in July 2013, and is now being considered by the Montgomery County Council. This study therefore uses the Planning Board Functional Master Plan as the basis for its assessment and analysis. As shown in Figure 1, the Plan as approved by the Planning Board includes 81 miles of RTS Right of Way (ROW) within 10 corridors. Table 1 shows the types of ROW treatment the plan recommends. These were determined based upon ROW constraints, potential ridership, traffic impacts, public input, and other factors. The Plan provides for over 27 miles of RTS 2 way guideway (median and side running), 16.8 miles of 1 lane (one way) guideway, 6.2 miles of 1 lane bi-directional guideway, 4 miles of dedicated curb lanes, 0.9 miles of managed curb lanes, and 25.9 miles of service in mixed flow. Both the specific corridors and ROW treatments are now being considered by the County Council and may change based on their inputs or during the facility planning phase of each corridor.

As discussed later, the appropriate TSP strategies to implement and their potential benefits depend both on the ROW treatment and the traffic and transit characteristics at each intersection along the proposed corridors. The detailed characteristics of each corridor are provided in Table 2 and in the Appendix 1 corridor maps which show the recommended alignment and ROW treatments, signalized intersections that the RTS service will cross (at grade), the RTS and Metro stations and the current bus stops. Each corridor is further described in the sub sections that follow¹. **The 10-route RTS network is proposed to have 116 stations, which would overly on top of 284 existing traffic signals and 820 existing bus stops.**

¹ The descriptions are derived from those found in the Planning Board's plan (MNCPPC, July 2013) with special attention on issues related to Transit Signal Priority.

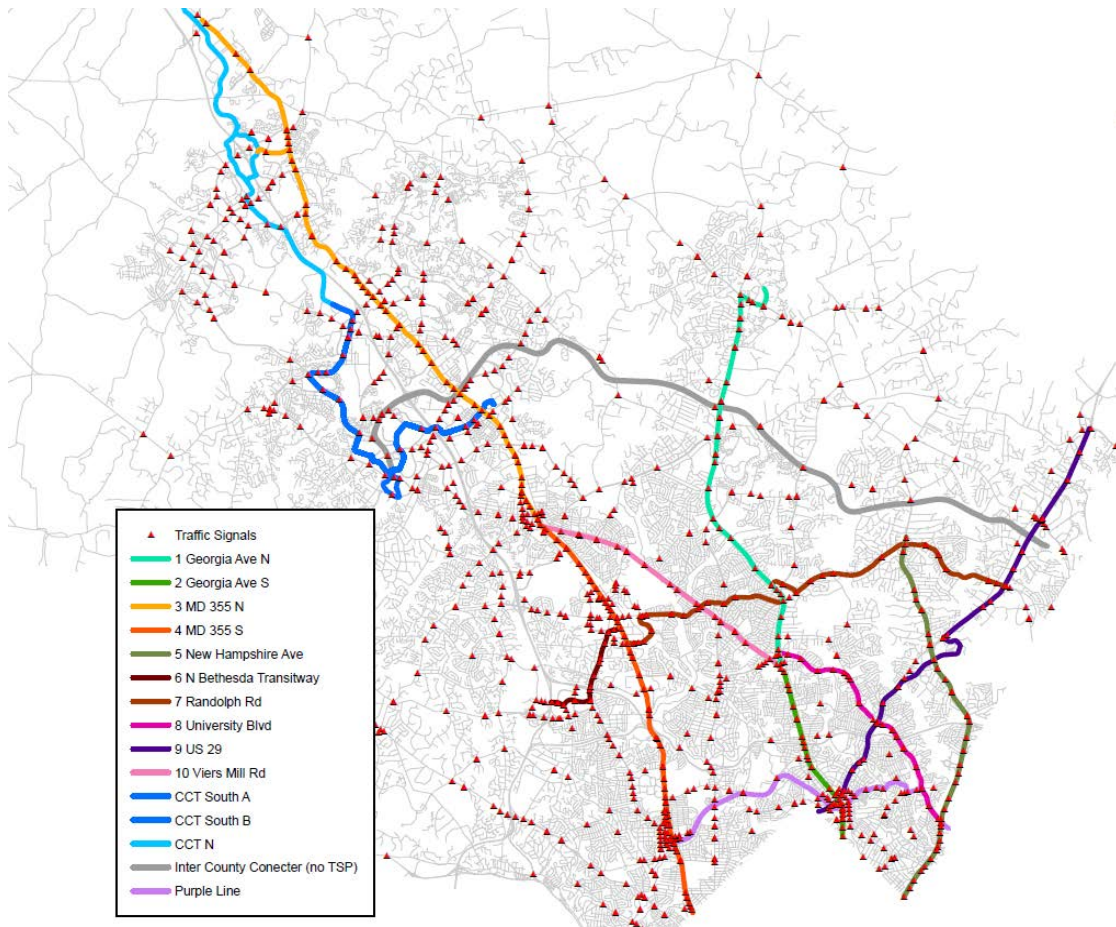


Figure 1 Priority Transit Corridors and Montgomery County Signals

Table 1 MNCPPC Functional Master Plan
Proposed RTS Corridors,

						Miles									
Corridor		From	To	Stations (RTS & Metro)	Signals	Length (Miles)	Mixed Flow	Mixed Flow w Queue Jump	Dedicated Curb Lanes	Managed Lane (dedicated 1 way Pk)	1 Lane Median Busway (bi-dir)	1 Lane Median Busway (1 way)	2 Lane Side Busway (2 way)	2 Lane Median Busway (2 way)	2 Lane New ROW Busway (2 way)
MNCPPC Funtional Master Plan Planning Board Draft															
1	Georgia Avenue North	Montgomery General Hospital	Wheaton Metrorail station	13	30	9.6	1.0					8.6			
2	Georgia Avenue South	Wheaton Metrorail Station	District of Columbia line	8	24	3.9	2.2		1.7						
3	MD 355 North	Corridor Cities Transitway	Rockville Metrorail station	20	37	14.1	3.5							10.6	
4	MD 355 South	Rockville Metrorail Station	District of Columbia line	14	47	9.3	0.0		1.2					8.2	
5	New Hampshire Avenue	Colesville Park & Ride	District of Columbia line	12	34	8.5	2.8					3.8		1.8	
6	North Bethesda Transitway	White Flint Metrorail Station	Montgomery Mall Transit Center	7	14	2.7	0.3					1.5	0.9		
7	Randolph Road	US 29	White Flint Metrorail Station	11	30	10.1	10.1								
8	University Boulevard	Wheaton Metrorail Station	Takoma/Langley Transit Center	9	21	5.5	2.7					2.8			
9	US 29	Burtonsville Park & Ride	District of Columbia line	11	22	11.0	3.4		1.1	0.9				5.6	
10	Veirs Mill Road	Rockville Metrorail Station	Wheaton Metrorail Station	11	18	6.2					6.2				
Totals				116	277	81.0	25.9	0.0	4.0	0.9	6.2	16.8	0.9	26.2	0.0

Table 2 RTS Corridor Characteristics by ROW Treatment

Corridor	Alignment	From	To	Stations (RTS & Metro)	Signals	Signals with V/C > 0.95	Bus Stops	AM		PM		Length (Miles)	Mixed Flow	Mixed Flow w Queue Lump	Dedicated Curb Lanes	Miles					
								peak direction busses / hour*	Peak direction Autos / Hour	peak direction busses / hour*	Peak direction Autos / Hour					Managed Lane (dedicated 1 way Pk)	1 Lane Median Busway (bi-dir)	1 Lane Median Busway (1 way)	2 Lane Side Busway (2 way)	2 Lane Median Busway (2 way)	2 Lane New ROW Busway (2 way)
1	Georgia Avenue North	Montgomery General Hospital	Wheaton Metrorail station	13	30	5	114					9.6	1.0					8.6			
	Prince Phillip Drive /Olney Sandy Spring Road	Montgomery Gen Hosp	Georgia I-97	2	4	0	8	5	1498	7	1928		0.9								
	Georgia Ave.	Sandy Spring Rd.	Reedie Rd	10	25	5	105	11	3898	11	4967							8.6			
	Reedie	Georgia Ave.	Viers Mill Rd	1	1	0	1	-	410	-	565		0.1								
2	Georgia Avenue South	Wheaton Metrorail Station	District of Columbia line	8	24	3	48					3.9	2.2		1.7						
	Georgia Ave.	Viers Mill Rd	16th Street	4	10	3	26	12	4380	12	5076		2.0								
	Georgia Ave.	16th Street	US 29	2	4	0	15	10	2548	10	2836				1.0						
	Wayne Ave.	US 29	Georgia Ave.	2	4	0	1	70	800	59	1110		0.2								
	Georgia Ave.	Wayne Ave.	DC Line	2	6	0	6	31	2804	28	3399				0.7						
3	MD 355 North	Corridor Cities Transitway	Rockville Metrorail station	20	44	23	120					14.1	3.5							10.6	
	MD355	Redgrave Place	Shakespeare Blvd	6	7	2	27	5	2162	5	2665		3.5								
	Seneca Meadows Pkwy /Shakespeare Blvd /MD 355	Corridor Cities Transitway	Game Preserve Rd	4	7	2	32	4	2882	8	3265									3.3	
	MD 355 (assumes 2 way Median through cities)	Game Preserve Rd.	Just S. of O'Neil Dr.	5	14	5	29	8	2588	9	2980									3.8	
	MD 355	Just S. of O'Neil Dr.	S. of Shady Grove Rd.	1	1	1	3	10	2437	10	3393									0.4	
	MD 355 (assumes 2 way Median through cities)	S. of Shady Grove Rd.	Ridgemont Ave.	0	1	1	4	10	2677	10	3173									0.2	
	MD 355	Ridgemont Ave.	Indiananola Rd.	1	3	1	7	10	2685	10	3170									0.7	
	MD 355 (assumes 2 way Median through cities)	Indiananola Rd.	1,000 ft. S. of Indianola Rd.	0	0	3	0	7	2685	8	3170									0.2	
	MD 355	1,000 ft. S. of Indianola Rd.	N. of Campus Dr	1	3	2	6	10	2696	8	3388									0.6	
	MD 355 (assumes 2 way Median through cities)	N. of Campus Dr	Church Street	2	8	6	12	16	2534	16	3140									1.4	
4	MD 355 South	Rockville Metrorail Station	District of Columbia line	14	47	22	106					9.3	0.0		1.2					8.2	
	MD 355 (assumes 2 way Median through cities)	Church Street	Twinbrook Pkwy	3	10	6	23	6	2657	6	3353									2.2	
	MD 355	Twinbrook Pkwy	Bradley Blvd	10	32	16	67	21	2888	24	3758									6.0	
	MD 355	Bradley Blvd	Western Ave.	1	5	0	16	4	2324	4	2896				1.2						
5	New Hampshire Avenue	Colesville Park & Ride	District of Columbia line	12	34	4	89					8.5	2.8					3.8		1.8	
	New Hampshire Blvd	Colesville Park & Ride	Lockwood Dr	5	9	0	28	7	2981	6	3664		2.8								
	New Hampshire Blvd	Lockwood Dr	Northhampton Dr	4	8	2	23	17	3539	19	3941							2.5			
	New Hampshire Blvd (One Lane Median)	Northhampton Dr	University Blvd	1	6	1	11	10	2928	11	3669							1.3			
	New Hampshire Blvd	University Blvd	D.C. Line	2	11	1	27	9	2617	12	3168									1.8	

Bus volumes derived from "Demand and Service Planning Report to Montgomery County DOT" and its databases (ITDP, December 2012)

Traffic Volumes derived primarily from the MWCOG Version 2.2 2010 base year traffic forecasting model (MWCOG, March 2008)



Table 2 RTS Corridor Characteristics by ROW Treatment (Continued)

Corridor	Alignment	From	To	Stations (RTS & Metro)	Signals	Signals with V/C > 0.95	Bus Stops	AM		PM		Miles									
								peak direction busses / hour*	Peak direction Autos / Hour	peak direction busses / hour*	Peak direction Autos / Hour	Length (Miles)	Mixed Flow	Mixed Flow w Queue Lump	Dedicated Curb Lanes	Managed Lane (dedicated 1 way Pk)	1 Lane Median Busway (bi-dir)	1 Lane Median Busway (1 way)	2 Lane Side Busway (2 way)	2 Lane Median Busway (2 way)	2 Lane New ROW Busway (2 way)
6	North Bethesda Transitway	White Flint Metrorail Station	Montgomery Mall Transit Center	7	14	1	23					2.7	0.3					1.5	0.9		
	Old Georgetown Road	Rockville Pike	Executive Blvd	1	3	0	2	7	1574	8	1925		0.3								
	Old Georgetown Road	Executive Blvd	Rock Spring Dr.	2	7	1	11	12	2788	14	3530							1.5			
	Rock Sping Dr /Fernwood /Westlake Terrace	Old Georgetown Rd	I-270	4	4	0	10	19	2515	22	2953								0.9		
7	Randolph Road	US 29	White Flint Metrorail Station	11	30	7	105					10.1	10.1								
	Randolph Rd	US 29	Glenallen Ave	3	13	2	55	6	3218	6	4155		5.1								
	Glenallen Ave.	Randolph Rd	Georgia Ave.	2	2	0	2	2	595	2	545		0.6								
	Randolph Rd	Georgia Ave.	Parklawn Dr.	5	10	5	37	9	3029	8	3611		3.1								
	Parklawn Dr /Nicholson Lane	Randolph Rd	MD 355	1	5	0	11	9	754	9	965		1.2								
8	University Boulevard	Wheaton Metrorail Station	Takoma/Langley Transit Center	9	21	5	76					5.5	2.7					2.8			
	University Blvd	Georgia Ave.	US 29	5	11	2	41	15	3074	19	3666							2.8			
	University Blvd	US 29	New Hampshire Blvd	4	10	3	35	24	2824	20	3118		2.7								
9	US 29	Burtonsville Park & Ride	District of Columbia line	11	22	7	70					11.0	3.4		1.1	0.9				5.6	
	US 29	MD 198	Stewart Ln	4	8	0	1	28	3795	25	4058									5.6	
	Stewart Ln /Lockwood Dr (thru W.O.)	US 29	US 29	3	2	0	29	16	594	12	596		2.0								
	US 29	Lockwood Dr	Southwood Ave	0	2	2	4	34	3099	32	3704				0.6						
	US 29	Southwood Ave.	Sligo Creek Pkwy	2	4	2	17	39	3523	36	4175		1.4								
	US 29	Sligo Creek Pkwy	Georgia Ave.	1	4	3	16	44 (68)	2811	41 (64)	3321					0.9					
	Colesville Rd	Georgia Ave.	16th Street	1	2	0	3	23 (41)	1554	26 (61)	2636				0.5						
10	Veirs Mill Road	Rockville Metrorail Station	Wheaton Metrorail Station	11	18	5	69					6.2					6.2				
	Vierns Mill Rd.	MD355	Meadow Hall Dr	3	5	1	20	8	1696	9	2013						1.8				
	Vierns Mill Rd.	Meadow Hall Dr.	Wheaton Metrorail station	8	13	4	49	20	2929	19	3629						4.4				
Totals				116	284		820					81.0	25.9	0.0	4.0	0.9	6.2	16.8	0.9	26.2	0.0

Bus volumes derived from "Demand and Service Planning Report to Montgomery County DOT" and its databases (ITDP, December 2012)

Traffic Volumes derived primarily from the MWCOG Version 2.2 2010 base year traffic forecasting model (MWCOG, March 2008)

II.1 1 GEORGIA AVENUE NORTH

Georgia Avenue North is a 9.6 mile commuter corridor, with most traffic flowing southbound in the morning and northbound in the evening. **Figure A 1** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops. The corridor includes the Georgia Avenue Busway, a long-planned transitway in the wide median between Glenmont and Olney.

The corridor has several activity nodes, notably the commercial centers at Wheaton and Glenmont, and their respective Metrorail stations. Aspen Hill and Olney are at the northern end, with residential uses in between.

Since congestion tends to occur in the peak direction of traffic, a single dedicated transit lane is sufficient for achieving a travel speed consistent with commuter BRT service.

Corridor treatment recommendations, from north to south include:

- Along Prince Phillip Drive and Sandy Spring Road from the Montgomery General Hospital to Georgia Avenue, 0.9 miles of mixed traffic transitway (2 RTS stations). There are 4 signalized intersections and 8 current bus stops in this section. There are only 5 to 7 busses per hour in the peak direction and less than 2,000 autos per hour along Sandy Spring Road
- Along Georgia Avenue from Olney-Sandy Spring Road in Olney to Reddie Drive in Wheaton, a 8.6 mile reversible one-lane median transitway (10 RTS stations). There are 25 signalized intersections and 105 bus stops through this heavily travelled section of the corridor. The part of the corridor also crosses major arterials such as Connecticut Avenue and Bel Pre Road. Five (5) of these intersections have volume to capacity (V/C) ratios greater than or equal to 0.95. There are approximately 11 busses per hour in the peak direction over the most used section of this segment. Auto volumes approach 5,000 vehicles per hour in the PM peak.
- Along Reddie Drive from Georgia Ave to Veirs Mill Road, there is 0.1 miles of mixed traffic service (1 signal) to provide connectivity to the last station. This is a connecting road with light traffic (400 to 500 vehicles/hour) in either peak, but it provides bus circulation around the Wheaton Metro Station.

II.2 2 GEORGIA AVENUE SOUTH

Georgia Avenue South is 3.9 mile commuter corridor from Wheaton to the Silver Spring Metro station and on to the District of Columbia line. **Figure A 2** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops. The corridor has several activity nodes, notably the Wheaton and Silver Spring CBDs with their respective Metrorail stations, the Forest Glen Metrorail station, and the Montgomery Hills commercial center, with residential uses in between.

Like the Georgia Avenue North most traffic (and congestion) flowing southbound in the morning and northbound in the evening. While travelers often complain of severe congestion especially outbound in the evening peak period, only three (3) intersections have V/C ratios greater than or equal to 0.95.

Corridor treatment recommendations, from north to south are:



- Along Georgia Avenue from Veirs Mill Road to 16th Street (4 RTS stations), 2.0 miles of mixed traffic transitway with 10 signals and 26 current bus stops. The most heavily used segment of this section typically sees 12 busses per hour in the peak direction during the peak periods. Near I-495 it also has some of the highest peak hour auto volumes in the system of around 4,400 vehicles per hour in the AM peak and close to 5,100 vehicles per hour in the PM.
- Along Georgia Avenue from 16th Street to Colesville Road (2 RTS stations), 1.0 miles of dedicated curb lanes are proposed. This segment has only 4 signals but 15 current bus stops. There are 10 Buses per hour in the peak direction during the peak period. Traffic volumes are less than the segment to the North but are still significant at around 2,500 vehicles per hour in the AM peak hour and 2,800 vehicles per hour in the PM peak hour.
- Along Wayne Avenue from Georgia Avenue to Colesville Road (2 RTS stations), 0.2 miles of mixed traffic service is planned. There are 4 signals but only 1 current bus stop along this segment. Because of the bus circulation in the CBD to the Silver Spring Metro this segment carries 60 to 70 busses per hour in the peak direction in the AM and PM peak periods.
- Along Georgia Avenue from Wayne Avenue to the DC line (2 RTS stations), 0.7 miles of dedicated curb lanes are planned. This section includes 6 signals and 6 current bus stops. It also has high bus volumes of around 30 busses per hour in the peak direction. Peak direction traffic volumes increase towards the District Line to approximately 2,800 vehicles per hour in the AM and 3,400 vehicles per hour in the PM.

II.3 3 MD 355 NORTH

MD 355 North is a 14.1 mile activity center corridor planned for a high level of development that will support all-day travel throughout the corridor. **Figure A 3** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops. The corridor extends from Redgrave place in Germantown to the Rockville metro Station and connects to the planned Corridor Cities Transitway at Shakespeare Boulevard along with several major existing and planned activity nodes, including Rockville and Gaithersburg.

It is also characterized by heavy congestion as shown by 23 (50%) signals with V/C ratios greater or equal to 0.95 during the peak periods. It has high transit ridership potential from providing connectivity between major transportation (Metro stations, CCT) and activity nodes.

Corridor treatment recommendations, from north to south are:

- A 3.5 mile mixed traffic transitway along MD355 from Redgrave Place to Shakespeare Blvd (6 RTS stations). This section encompasses 7 current signals and 27 bus stops. It only carries 5 busses per hour in the peak direction in both the AM and PM peaks. Peak hour peak direction autos per hour vary from 2,200 in the AM to around 2,700 in the PM.
- A 3.3 mile 2 lane median busway (4 RTS stations) along Seneca Meadows Parkway and Shakespeare Boulevard from the Corridor Cities Transitway to Observation Drive. This section includes 7 signals and 32 current bus stops. Again, there are only 4 busses per hour in the AM and 8 busses per hour in the PM (due to 1 way loops). The maximum auto volumes start to increase as one moves further South and are around 2,900 to 3,300 in the peak hour peak direction in this segment.
- A 7.3 mile 2 lane median busway (10 RTS stations) along MD 355 from Shakespeare Boulevard to Rockville Metro station. This section goes through Gaithersburg and Rockville city limits. It includes 30 signals and 52 current bus stops. The southern portion (South of Indianaola Drive) experiences significant congestion with 8 out of 11 intersections having V/C ratios greater than



or equal to 0.95. Busses per hour increase from 5 at Shakespeare Blvd in the North, to 16 approaching Church Street in the South. Traffic also increases to a maximum in the peak direction of around 2,700 vehicles per hour in the AM and 3,400 in the PM between Indianola Drive and North Campus Drive.

II.4 4 MD 355 SOUTH

MD 355 South is a 9.3 mile activity center corridor that will support all-day travel throughout the corridor. **Figure A 4** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops. The corridor has several planned or existing activity nodes, including Rockville, Twinbrook, White Flint, NIH/WRNMMC, Bethesda CBD, and Friendship Heights CBD. While the corridor is planned for a high level of development, it is characterized by shorter trips representing a wide variety of travel purposes (shopping and recreation, in addition to commuting). It also connects both outer suburban development and more dense inner neighborhoods just north of the District line (Friendship Heights).

It is also characterized by very heavy congestion and high transit ridership potential.

Corridor treatment recommendations, from north to south:

- A 8.2 mile 2 lane two-way median busway (13 RTS stations) from Rockville Metro station to Bradley Boulevard. This section is dense with 42 signals and 90 bus stops. There are 16 intersections with V/C ratios greater than or equal to 0.95 from Twinbrook Parkway to Bradley Boulevard. There are only 6 busses per hour in the peak direction in the peak periods North of Twinbrook Parkway. South of Twinbrook down to Bradley the maximum busses in the peak direction increases significantly to 21 in the AM and 24 in the PM. Traffic in the peak direction close to I-495 is also significant with vehicles per hour in the AM approaching 2,900 in the AM and 3,900 in the PM.
- A 1.2 mile curb lane transitway (1 RTS station) from Bradley Boulevard to Western Avenue. This section includes 5 signals and 16 current bus stops. This section does not have any intersections with V/C ratios as great as 0.95. In this segment there are only 4 buses per hour and traffic in the peak direction, while still noticeable, is at 2,300 vehicles per hour in the AM and 2,900 vehicles per hour in the PM.

II.5 5 NEW HAMPSHIRE AVENUE

New Hampshire Avenue is an 8.5 mile commuter corridor (12 RTS stations), with most traffic flowing southbound in the morning and northbound in the evening. **Figure A 5** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops. Activity centers are located at Fort Totten (just south of the District line), Takoma / Langley Crossroads and the emerging mixed-use center at White Oak. Traffic in the peak direction is significant across the entire corridor with maximum section volumes varying between 2,900 to 3,600 vehicles per hour in the AM and 3,200 to 3,900 vehicles per hour in the PM. The highest route to route bus transfers currently occur at the University Blvd and New Hampshire Ave intersection in Langley Park. The first priority bus service in the County also has recently been implemented on the K9 Metro Extra Service in the corridor and with reduced travel times and increased ridership.

Corridor treatment recommendations, from north to south are:

- A 2.8 mile mixed traffic transitway (5 RTS stations) from the Colesville park-and-ride to Lockwood Drive. This section has 9 signals (none over capacity) and 28 current bus stops. In this segment, there are 6 to 7 busses per hour in the peak direction in both the AM and PM.
- A 3.8 mile reversible one-lane median transitway (5 RTS stations) from Lockwood Drive to University Boulevard that includes 14 signals and 34 current bus stops. Three (3) of the signals have V/C ratios greater than or equal to 0.95 in the peak periods. As you approach University Boulevard peak direction busses per hour increase and are 17 in the AM and 19 in the PM between Lockwood and North Hampton.
- A 1.8 mile two-lane 2 way median transitway (2 RTS stations) from University Boulevard to the District line. This segment includes 11 signals (1 with a V/C ratio greater than or equal to 0.95) and 27 current bus stops. Note that the City of Takoma Park's *New Hampshire Avenue Corridor Concept Plan* outlines the use of curb lanes or mixed traffic treatments from Sligo Creek Parkway to the District line. Buses per hour along this segment (before the K9 Metro Extra) varied between 9 and 12 in the peak direction in the AM and PM peaks.

II.6 6 NORTH BETHESDA TRANSITWAY

The North Bethesda Transitway is a 2.7 mile corridor that serves as a connector from the Metrorail Red Line and White Flint to the Rock Spring office park area and Montgomery Mall. **Figure A 6** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops. Much of the right-of-way along Rock Spring Drive, Fernwood Road, and Tuckerman Lane is currently available through easements and dedications provided through the development review process.

Corridor treatment recommendations, from west to east are:

- A 0.3 mile mixed traffic transitway (1 RTS station) along Old Georgetown Road between Rockville Pike and Executive Boulevard. This section currently has 3 signals and 2 bus stops. This segment carries from 7 to 8 busses per hour in the peak direction in the AM and PM peaks. Peak direction traffic volumes are less than 2,000 vehicles per hour but are more in the PM.
- A 1.5 mile reversible one-lane median transitway (2 RTS stations) along Old Georgetown Road between Executive Boulevard and Rock Spring Drive. There are 7 signals (one with V/C ratio greater than or equal to 0.96) and 11 bus stops currently within this segment. Peak direction busses per hour increase in this segment to 12 in the AM and 14 in the PM. Maximum directional traffic volumes also increase along Old Georgetown Road to approximately 2,800 vehicles per hour in the AM and 3,500 vehicles per hour in the PM.
- A 0.9 mile two-lane side running transitway (4 RTS stations) along Rock Spring Drive, Fernwood Road, and Westlake Terrace, between Old Georgetown Road and the I-270 Spur. This section currently includes 4 signals and 10 bus stops. This portion has the highest directional buses per hour with 19 in the AM and 22 in the PM. Traffic is still noticeable at 2,500 vehicles per hour in the AM and 3,000 vehicles per hour in the PM.

The North Bethesda Transitway could become part of a significant transit link between Tysons Corner and White Flint which could include additional signals and potential TSP treatments as vehicles move to/from the Freeway/HOV system. This link should be studied as part of any new HOV or HOT lane project on I-270 and I-495 in Maryland.



II.7 7 RANDOLPH ROAD

Randolph Road is a 10.1 mile commuter corridor (11 RTS stations) with traffic and congestion in the westbound direction in the morning and the eastbound direction in the evening that connects the east and west parts of the county. **Figure A 7** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops. Major activity centers include White Flint, Glenmont, and the emerging mixed-use center at White Oak. Residential uses fill in the gaps between these areas.

The complete corridor is recommended to initially be a mixed traffic transitway. It includes 30 signals and 105 current bus stops along its length. Seven (7) of the signals are now operating during the peak periods with V/C ratios of 0.95 or greater. Five (5) of these are in between Georgia Avenue and Parklawn Drive. This is reflected in the high traffic volumes as well. Along Randolph from US 29 to Glenallan Avenue there are 3,200 vehicles per hour in the peak direction in the AM and 4,200 vehicles per hour in the peak direction (at the maximum load point). From Georgia Avenue to Park Lawn Drive the volumes are more balanced in the AM and PM, with 3,000 vehicles per hour in the AM and 3,600 in PM. During the peak periods there are from 6 to 9 buses per hour operating in the corridor in the peak direction.

The westernmost corridor segment would serve the planning White Flint MARC commuter rail station in addition to the Metrorail station. During project planning, an alternative alignment along Nebel Street rather than Parklawn Drive should be considered if the at-grade Randolph Road crossing of the CSX tracks is retained. This may require additional evaluation for TSP potential.

II.8 8 UNIVERSITY BOULEVARD

University Boulevard is a 5.5 mile commuter corridor providing an east west connection closer in than Randolph Road. **Figure A 8** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops. It connects activity centers in Wheaton, Four Corners, Long Branch, and Takoma/ Langley Crossroads as well as the New Hampshire, US 29, and Georgia Avenue RTS corridors.

Corridor treatment recommendations, from west to east are:

- A 2.8 mile one-lane median reversible transitway (5 RTS stations) along University Boulevard from Georgia Avenue to Lorain Avenue. This section includes 11 signals with 2 operating with a V/C ratio of 0.95 or greater during the peak periods. There are 41 current bus stops along this section. There are 15 Busses operating in the peak direction in the AM peak hour and 19 in the PM peak hour. This segment carries higher traffic with approximately 3,000 vehicles per hour in the AM peak direction and 3,700 vehicles per hour in the PM peak direction.
- A 2.7 mile mixed traffic transitway (4 RTS stations) along University Boulevard from Lorain Avenue to New Hampshire Avenue. There are 10 signals with 3 operating with a V/C ratio of 0.95 or greater during the peak periods along this section. It includes 35 current bus stops. There are more buses operating in this segment with 24 operating in the peak hour peak direction in the AM and 20 in the PM. However, there is slightly less traffic with 2,800 vehicles per hour in the AM and 3,100 vehicles per hour in the PM (peak direction).

One issue to address is allocating TSP resources and strategies between the Purple line and RTS service along the duplicated ROW between Piney Branch Road and New Hampshire Avenue. Allowing the RTS service to use the Purple Line exclusive ROW may also be considered.

II.9 US 29/COLESVILLE RD

The 11.0 mile US 29/Colesville corridor has different characteristics and roles along its length. It is an express corridor north of New Hampshire Avenue and a commuter corridor south of New Hampshire Avenue, with most traffic flowing southbound in the morning and northbound in the evening. **Figure A 9** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops.

US 29 north of the New Hampshire Avenue interchange is classified as a fully access-controlled major highway, with interchanges ultimately replacing all existing at-grade intersections. It has a wide median that can accommodate a busway, and the three existing interchanges —at Randolph Road/Cherry Hill Road, Briggs Chaney Road, and Spencerville Road (MD198)—can all accommodate a median busway. Activity centers in this corridor segment are located in Burtonsville and White Oak.

South of New Hampshire Avenue, US 29 is classified as a major highway and has a very different character, passing through very congested areas in Four Corners and the Silver Spring CBD with very limited opportunities to expand the right-of-way.

Much of the traffic in the corridor is long distance trips, passing through the corridor on the way to other places. There is routinely severe congestion along the corridor especially from north of Stewart Lane to I-495 in the morning. However, only 7 of the 22 signals along the ROW currently operate with a V/C ratio of 0.95 or greater during the peak periods.

Corridor treatment recommendations, from north to south:

- A 5.6 mile two-lane median busway (4 RTS stations) along US 29 from MD198 to Stewart Lane. This section operates mostly as a freeway or throughway with interchanges and only 8 signals. None of the signals in this section are currently over capacity. Because of its expressway characteristics there is only 1 current bus stop along this section. However, there are from between 25 peak direction buses per hour in the AM peak and 28 buses per hour in the PM peak. US 29 carries significant traffic with peak hour directional volumes (maximum load point) at 3,795 vehicles per hour in the AM and 4,058 vehicles per hour in the PM.
- A 2.0 mile mixed traffic operation (3 RTS stations) along Stewart Lane and Lockwood Drive to provide connections to the White Oak Shopping Center and New Hampshire Avenue. This section includes 2 signals and 29 current bus stops. Note that this does not inhibit the continuation of express bus service along US29 through the New Hampshire Avenue interchange which would alter the TSP assessment of Stewart Lane. This section today carries relatively few busses per hour in the peak direction (between 12 and 16) and around 600 vehicles per hour.
- A 0.6 mile segment of curb lanes via repurposing along US 29 from Lockwood Drive to Southwood Avenue. This includes 2 traffic signals that are already at a V/C ratio of 0.95 or greater during the peak periods. Busses per hour in the peak direction continue to increase as you approach downtown Silver Spring. This segment currently carries 32 to 34 peak direction busses in the AM and PM peak periods. Traffic volumes are at 3,100 peak vehicles per hour in the AM and 3,704 peak vehicles per hour in the PM.

- A 1.4 mile return to mixed traffic operation (2 RTS stations) along US 29 from Southwood Drive to Sligo Creek Parkway (crossing both 4 corners and I-495). This section is highly congested today with 2 of the 4 signals operating at a V/C ratio of 0.95 or greater. It also includes 17 bus stops. There are currently between 36 and 39 peak busses/hour crossing the beltway in the peak direction during the peak periods. Traffic volumes are also high at 3,500 peak direction vehicles per hour in the AM and 4,100 peak direction vehicles per hour in the PM.
- A 0.9 mile dedicated curb lane (1 RTS station) in the peak hour peak direction via managed lanes and lane repurposing along US 29 from Sligo Creek Parkway to Georgia Avenue. This segment has high local bus ridership today with 16 current bus stops. It is also heavily congested with 3 out of the 4 signals operating with a V/C ratio of 0.95 or greater. There is often congestion from curb side friction (bus stops, right turns, etc.) and left turns causing significant delay in the reverse peak direction as well. Within the Silver Spring Urban District the traffic volumes decrease slightly to 2,800 peak direction vehicles per hour in the AM and 3,300 peak direction vehicles per hour in the PM. However, peak direction busses per hour increase significantly from around 40 just south of the Beltway to 64 to 68 in the Downtown Silver Spring Area.
- 0.5 miles of curb lanes via lane-repurposing (1 RTS station) along Colesville Road (now MD 384) from Georgia Avenue to Sixteenth Street. This section provides connectivity to 16th Street and includes 2 signals (1 additional to start operations with the Silver Spring Transit center) and 3 current bus stops. Peak direction traffic volumes are approximately 1,600 vehicles per hour in the AM peak and 2,600 vehicles per hour in the PM peak. Within the downtown busses per hour remain high at 41 in the AM and 61 in the PM. As you move away from the Downtown are they drop to from 23 busses per hour in the AM and 26 buses per hour in the PM.

II.10 10 VEIRS MILL RD

Veirs Mill Road is a 6.2 mile commuter corridor, with the flow of traffic largely balanced in the eastbound and westbound directions between the two, large central business districts, Wheaton and Rockville. **Figure A 10** in Appendix I shows its alignment by recommended ROW treatment, RTS and Metro stations, signalized intersections, and bus stops. Smaller commercial districts exist at Randolph Road and just west of Twinbrook Parkway. Residential uses fill in much of the rest of the corridor. Service roads that provide access to residential properties and may also impact signal operations exist along many sections of the roadway.

A 1 lane bi-directional transitway (11 RTS stations) is recommended for the Veirs Mill corridor. The corridor includes 18 traffic signals, five (5) of which currently operate with a V/C ratio of 0.95 or greater during the peak periods. It also has 69 current bus stops along its length. Because of the bi-directional operation of this facility and the need to have very reliable headways and travel times, TSP may be an important component in operating this transitway.

There are 8 to 9 buses per hour operating in the segment from MD 355 to Meadow Hall Drive. As you approach Wheaton the maximum bus service currently operating increases to from 19 to 20 busses per hour.

Traffic volumes at the maximum load point in the peak direction are around 1,700 vehicles per hour in the AM and 2,000 vehicles per hour in the PM from MD 355 to Meadow Hall Drive. These increase to 2,900 vehicles per hour in the AM and 3,600 vehicles per hour in the PM between Meadow Hall Drive and Wheaton.



The corridor is also the subject of the MD 586 (Veirs Mill Road) Bus Rapid Transit (BRT) Study from Rockville Metrorail Station to Wheaton Metrorail Station being carried out by the Maryland SHA and MTA. This planning study is also looking at signal operations and queue jump opportunities along Veirs Mill and it will be important to coordinate closely with its findings as the RTS planning moves forward.

III. EXISTING SYSTEMS AND OPERATIONS

Transit Signal Priority by its very nature requires the interaction of: 1) the traffic signal system and its operations/communication systems; and 2) the transit system and its operations/technologies both on each vehicle and within the operations center. Both the traffic and transit system must work together if the promise of providing the benefits of TSP to transit (improved reliability and reduced delays at signals) without significantly impacting the traffic signal operations is to be fulfilled. As mentioned in Technical Memorandum 1, this requires agreements and coordination between operating agencies and across modes.

An understanding of the current existing and planned traffic signal and transit technologies, communications systems, and features/capabilities to implement different types of TSP strategies must also be developed. This provides the basis for the TSP policies and plans (Concept of Operations) and recommendations to be prepared in final stages of this project (Technical Memorandum 3) and ultimately the above agreements between agencies and modes. Consequently, overviews of the existing Traffic and Transit Systems and their operations are provided in the sub-sections that follow.

III.1 TRAFFIC SYSTEMS AND OPERATIONS

The existing traffic signals operating within Montgomery County or along its borders, who owns them, and who is responsible for their day to day operation and maintenance along with the potential TSP corridors identified in the Countywide TSP implementation study (see Technical Memorandum 1) are shown in Figure 2. Within the County, traffic signals are owned and operated by three main agencies/entities: The Montgomery County Department of Transportation, Division of Traffic Engineering and Operations; The Maryland State Highway Administration, and the City of Rockville. As stated in Technical Memorandum 1 any plans for TSP within the county must keep in mind that these agencies/entities have the ultimate decision authority over these systems and must agree with what is being proposed.

Montgomery County is somewhat unique in that the County operates the majority of the traffic signals as part of its Advanced Transportation Management System (ATMS) even though the Maryland State Highway Administration (MDSHA) owns the signals that are located along state routes. Of the 879 signalized intersections in the county shown in Figure 2, approximately 64% (557) are owned by the Maryland State Highway Administration, with the remainder owned by the County and the City of Rockville. The County owns and operates 274 signals and operates 522 of the MDSHA owned signals. It also operates 5 of the signals owned by the City of Rockville. The City of Rockville owns and operates 42 signals and also operates 6 of the MDSHA signals. Also shown in Figure 2 are the approximately 30 signals in the south east part of the County in and around Takoma Park and along New Hampshire Avenue that are not operated as part of the Montgomery County signal system. SHA owns and operates these signals, though it is expected that at least 10 will migrate to the Montgomery County

system in the near future (Some of these signals were not within Montgomery County when portions of Takoma Park were part of Prince George's County). Fifteen of these are along New Hampshire Avenue (4 outside the county but along the ROW), and one is on University Boulevard (at the shopping center entrance just NW of New Hampshire Avenue).

Note that the majority of the signals along the TSP (see Figure 2) and RTS (see Figure 1) corridors are along State Routes and are owned by MDSHA. However, the County and City of Rockville are also potentially impacted by RTS plans either through the system operations or as part of route diversions being considered in the Service Planning and Integration Study.

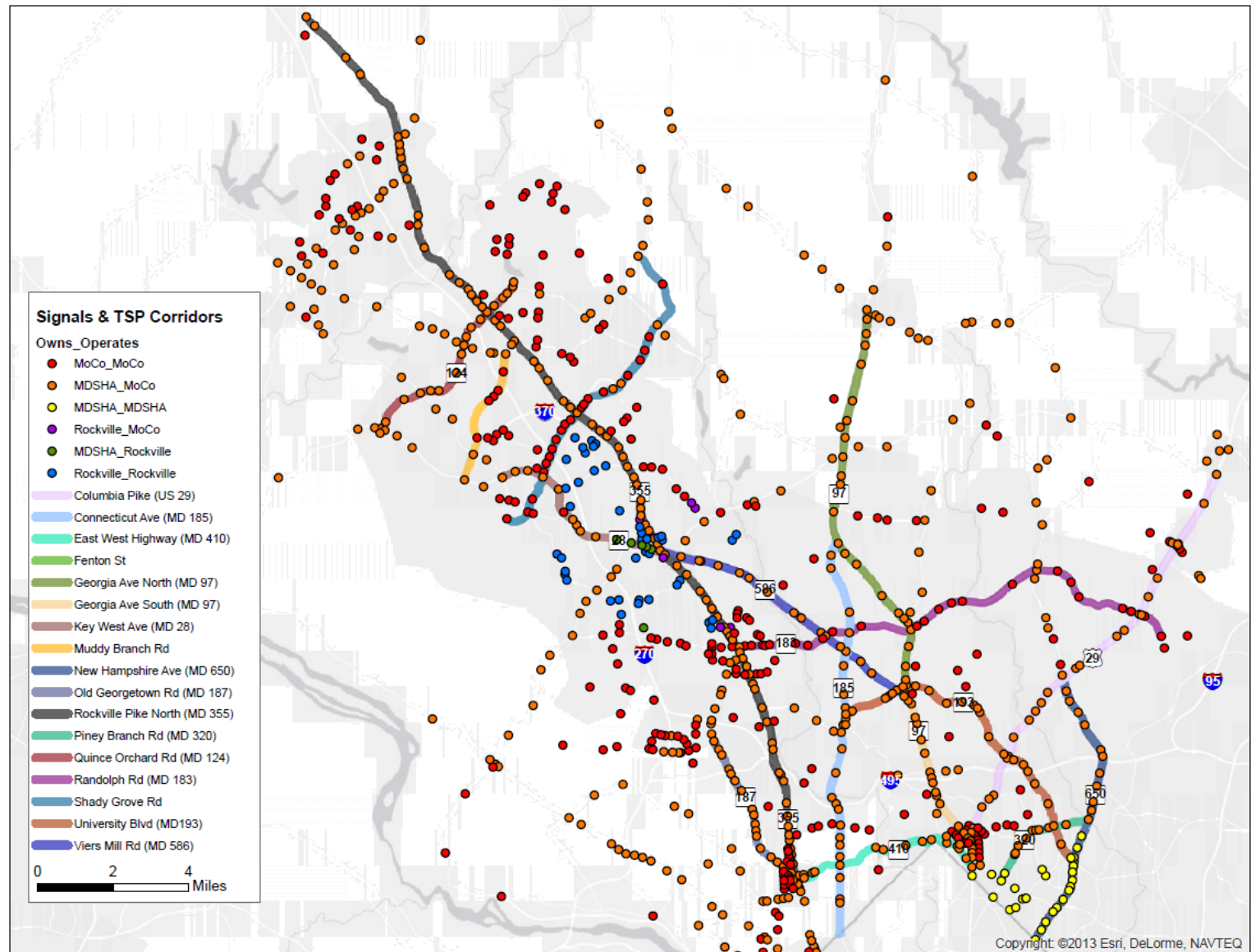


Figure 2 Traffic Signals in Montgomery County with Potential TSP Corridors

Montgomery County Advanced Transportation Management System (ATMS)

As discussed above, Montgomery County operates and maintains the majority of the traffic signals within its borders (91%) including those owned by itself and MDSHA. Signal operations are one component of the Montgomery County Advanced Transportation Management System (ATMS) which was recently upgraded as part of the Traffic Signal System Modernization (TSSM) project. Phase 2A of the TSSM project was completed in 2012. It included:

- Replacement of the central computer and servers
- Development and implementation of a new custom traffic operations and advanced transportation management software system.
- Upgrade and replacement of all (~800) traffic signal controllers to Econolite ASC/3 controllers.
- Installation of Uninterruptible Power Supplies/Battery Back-Up for County owned signals.
- Implementation of a new distributed signal control system utilizing the ASC/3 controllers
- Implementation of a new high speed communication network utilizing DSL and copper wire to distributed communications hubs throughout the county, and the FIBRENET fiber optic network from the hubs to the ATMS operations center.

The result is a modern traffic management system that can monitor and update the performance of any signal across the county in real time. The Econolite ASC/3 controller is TSP ready. Activation of TSP at a specific traffic signal only requires the purchase and installation of a TSP Data Key (a onetime cost of approximately \$400 per TSP intersection).²

MDSHA provides the signal design and initial phasing and reviews/approves modifications to operations for the signals that it owns.

Montgomery County DOT and the Maryland State Highway Administration (MDSHA) also have been working on a plan and implementation policy for TSP within the existing local transit environment and exploring transit signal priority systems on several highway corridors in the county in support of Ride On, WMATA, and MTA bus systems. The Countywide TSP Concept of Operations for implementing TSP within current operations and systems was developed as part of this effort. It proposes a distributed TSP system architecture utilizing the installed Econolite ASC/3 controllers and other improvements that were part of the TSSM. Figure 3 provides a diagram of the recommended TSP Architecture. Some major features are:

- Onboard equipment uses GPS and stored schedules to monitor the vehicle location and on time performance (the AVL/Dispatch system provided by ORBCAD). When the bus is late a Priority request is generated and broadcast using an onboard radio emitter.
- The request is received by the wayside antennae

² In addition to the TSP Data Key activation there is also roadside and bus equipment installation with associated costs. Unit costs per intersection are approximately \$13,000 and costs per bus are approximately \$6,000. This includes all hardware, contractors, engineering, and management (staff charges).



- The GTT Opticom Spread Spectrum GPS/TSP Priority Request Server (PRS) determines if the vehicle is in range and when it will arrive at the intersection. It then determines if priority is to be granted to a specific vehicle and if so notifies the ASC/3 controller. The PRS also resolves competing priority requests (currently first come first served).
- The ASC/3 controller checks to see if it is in lock out due to a previous request, determines which priority signal strategy to apply (currently extended or early green) and then implements the priority signal strategy if possible.

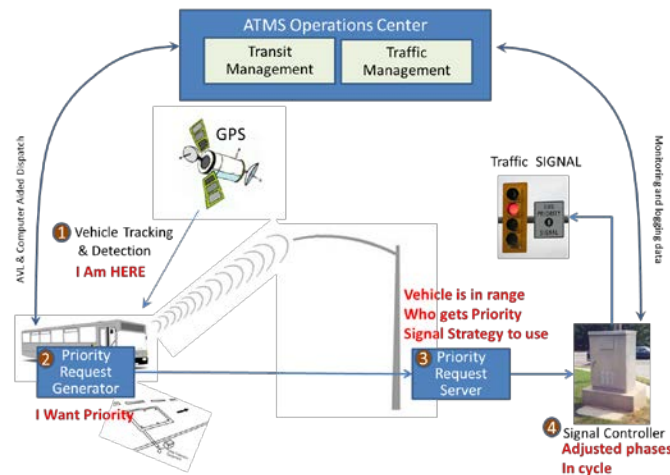


Figure 3 Montgomery Countywide TSP Architecture

- Both traffic and transit log information for later analysis. The controller logs that a request was received. This data can currently be viewed only via the front panel or by serial upload to a laptop in the street. Transit performance data on where the vehicles stopped and how long is stored within the ORBCAD automatic vehicle location/computer aided dispatch system.
- It is possible to verify which transit bus vehicle number made the priority request, and if that bus was late. Also based on the time stamp from the emitter request it can be determined if the signal was green or red during the priority call, or if the bus made a near side stop to board and alight passengers. However it is not possible to determine which TSP pattern was executed. Integrating these separate monitoring functions would be a necessary step to fully evaluate TSP operations.
- While colocated, real time information is not currently shared between the transit and traffic operations centers.

The Countywide TSP CONOPS also assumes within its operational scenarios that when implemented as part of current operations (see section II for an explanation of TSP concepts) (Sabra, Wang & Associates Inc. July 2013):

- TSP will be requested only when the buses are running more than 5 minutes behind schedule.
- A TSP request will be granted on a first come first served basis (no special consideration to direction, corridor, operator, or type of service).
- A TSP request will be granted only when it can be accommodated safely within the traffic signal controller phases at the intersection.
- TSP signal options include only green extension and early green.
- Once priority is granted at an intersection the signal cannot grant another request (i.e. the lockout period) until the system recovers coordination (currently assumed to be three cycles).

The Countywide TSP study has identified and ranked 18 corridors in the County (including 355 existing traffic signals) for potential TSP implementation assuming current traffic and transit operations. These were selected based upon inputs from WMATA, RIDE ON, the MTA, and transit and roadway operating characteristics.

The potential corridors are also shown in Figure 2. Note that many, but not all, of the corridors overlap with the MNCPPC Transit Functional Master Plan. The Countywide TSP effort is in the process of identifying the intersections along the TSP corridors to recommend for initial TSP deployment. . Intersections where TSP is feasible ($0.6 \leq \text{Volume/Capacity} < 0.95$ and available slack time where minimum walk and left-turn green times are met) are being identified first. The feasible TSP intersections are then being ranked by the potential effectiveness of TSP based upon:

- Their overall corridor ranking
- The cross street facility type
- If other priority treatment exists
- Bus Delay on Approach (Bus Speed)
- Bus passengers, and
- Bus frequency.

Preliminary analysis indicates that approximately 200 signalized intersections along these corridors will meet the criteria for TSP implementation.

City of Rockville

The City of Rockville also owns and operates its own traffic signal system. Figure 4 provides a detailed view of the traffic signals within the City of Rockville's Jurisdiction and which agency owns and operates them.

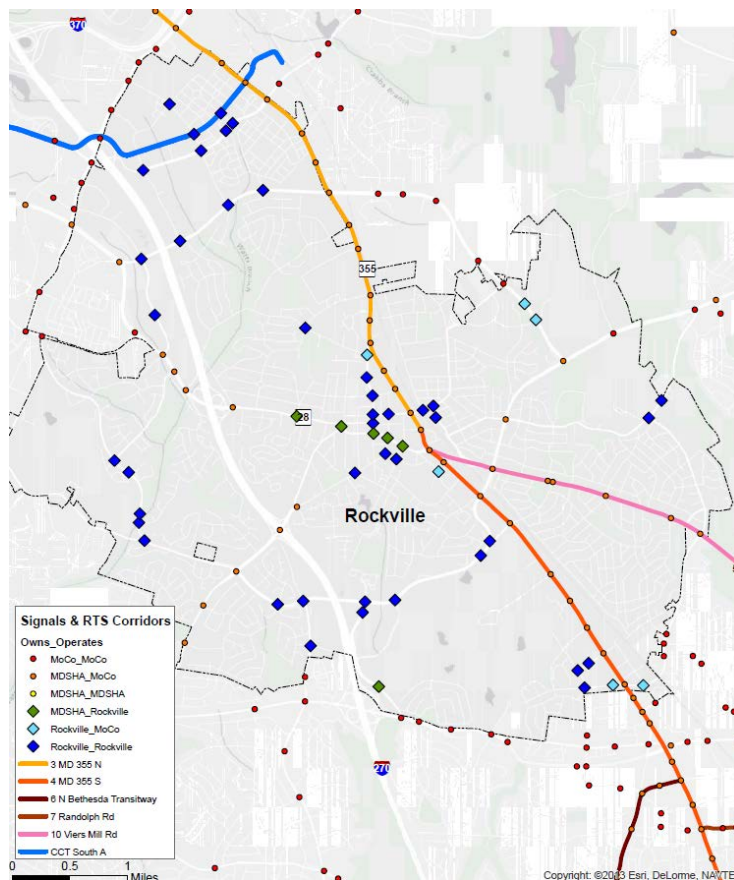


Figure 4 City of Rockville Traffic Signals and RTS Corridors

The diamonds represent signals owned or operated by the City. Of the 143 signals within or near its borders, the City owns 48 signals. It operates 42 of these and Montgomery County operates the remaining 6. However, the City also operates 6 of the signals owned by the MDSHA within its borders. The County also operates 48 signals owned by MDSHA and 42 of its own signals.

The majority of Rockville's traffic controllers are Econolite ASC/2 controllers. Their traffic engineer when asked also stated that they have "...upgraded a few signals with ASC/3 to be able to get information from the UPS system (battery backup) when it became active". The ASC/2 controllers do have limited TSP capabilities with the purchase of an extra software module, but are no longer supported by Econolite.

The City provides limited real time connectivity between their operations center and the traffic signals it owns and operates. It runs the Aires Closed Loop traffic system provided by Econolite. Traffic signal technicians can use a dial up modem to connect to the traffic signals and change timings, but it does not seem that the signals are directly tied into their operations center via a fiber or other network. It is likely that additional interfaces and equipment/software upgrades will be needed to fully integrate the City signals into any RTS TSP system, especially if performance monitoring is desired.

Note, that the MD 355 and Viers Mill are the main RTS corridors that travel through the City of Rockville. Neither of these directly interacts with the signals owned and/or operated by the City. However, the CCT South corridor along King Farm Boulevard crosses two (2) of the Rockville signalized intersections. Also, any diversions of RTS vehicles to or from major attractors within Rockville such as Montgomery College would go through City owned or operated signal intersections.

Other Cities and Towns

The incorporated cities and towns along RTS corridors also have important roles and responsibilities for their road system performance and operation. Gaithersburg, Takoma Park, Chevy Chase, Friendship Heights special tax district and other small jurisdictions do not operate or maintain signals but have a vested interest in the performance of their road/traffic system. As already mentioned there are for example approximately 30 signals in and around Takoma Park (see Figure 2) that are not operated as part of the Montgomery County signal system and ATMS. These mostly impact the New Hampshire and University Boulevard Corridors. It will also be important to coordinate with them as we move forward with RTS and TSP.

III.2 TRANSIT SYSTEMS AND OPERATIONS

Ride On Montgomery County Transit (Ride On)

The Montgomery County Department of Transportation Division of Transit Services provides Ride On transit service within Montgomery County. It currently provides weekday service on 78 routes and operates 289 vehicles in the peak periods³. Ride On provides service in every proposed RTS Corridor.

The Ride On transit and Montgomery County traffic operations centers are currently co-located at the County's transit management and traffic management and operations functions are co-located at the Transportation Management Center (TMC) in Gaithersburg Maryland. Ride On currently utilizes the Trapeze system from Trapeze for bus scheduling and run-cutting and the ORBCAD system for Automatic Vehicle Location (AVL) and Computer Aided Dispatch (CAD). As part of the overall ATMS they also provide a Smart Traveler Customer Information system, and are integrated into the regional smart card system. On board technologies include the Smart Card automated fair box collection, mobile data terminals, Security cameras (no real time monitoring), automated stop annunciation, and automatic passenger counters. Ride On also operates a (UHF 450-490 MHz) radio system for voice and data communications with its vehicles.

³ From the 2011 National Transit Database accessed on November 11, 2013:
http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2011/agency_profiles/3051.pdf

The transit technology systems were also updated as part of the ATMS system upgrades and move to a decentralized system that started in 2009. The upgrades to the transit system include integration with outside data sources such as route and scheduling data, and on-board automatic passenger counters (APC). Approximately 55% of the fleet is now equipped with APCs. Potential TSP functionality integrated into the CAD/AVL system includes the ability to query the real time on board passenger count to determine how many passengers are on the bus. The new system will allow the utilization of conditional TSP by determining priority based on passenger load and schedule adherence (Sabra, Wang and Associates, Inc. July 2013).

With the exception of Ride On Route 55 vehicles that participated in a TSP test along MD 355, the current Ride On fleet is currently not equipped with the on board Priority Request Generators and the GTT Opticom GPS/TSP and “Spread Spectrum” vehicle to wayside emitters (2.4 GHz) recommended to implement TSP county wide for existing service (pre-RTS) (see Sabra, Wang and Associates, Inc. July 2013). The Opticom wayside equipment is also only installed at the three test locations along MD 355 (Professional Drive, South Summit Ave., and Indianola Drive/Watkins Pond Boulevard). The previous test used Infrared emitters and detectors rather than the GPS TSP wide spectrum radios.

Washington Metropolitan Area Transportation Authority (WMATA)

WMATA operates approximately 140 Metrobuses during the weekday peak periods within Montgomery County. These provide primarily regional service along the major corridors within the County. WMATA provides service in every proposed RTS Corridor. The WMATA vehicles operating within Montgomery County are managed from the WMATA Carmen Turner Facility Bus Operations Center Landover Maryland.

In 2011 WMATA initiated a Consolidation of On-board Ancillary Bus Equipment (CoABE and Fixed-end System project to provide for its operations and maintenance systems “under one vendor, one warranty plan, and one maintenance contract” (Jonathan Walker, October 2013). Clever Devices was chosen as the vendor. Factory acceptance testing at Clever Device’s site was completed in October 2012, and full deployment and testing is expected to be complete on the Metrobus fleet by the end of 2013.

The new system consolidated the myriad of on-board equipment and ITS applications through the Clever Devices Intelligent Vehicle Network Unit (IVN), provided cellular communications to the operations center, and implemented new systems at the operations center. The applications include (Jonathan Walker, October 2013):

- Fixed End System Computer Assisted Dispatch/Automatic Vehicle Location (CAD/AVL)
- Bus radios to meet the FCC Narrowbanding mandate by December 2013
- Automatic Vehicle Location (AVL)
- Automated Voice Annunciation (AVA)
- Automated Passenger Counting (APC)
- Automated Vehicle Health Monitoring (AVHM)
- Supervisor Mobile Data Terminal (MDT)
- Yard Management System (YMS)

In a closely relate effort WMATA is designing and implementing TSP as part of its Priority Corridor Network (PCN) improvement plans. The initial development and implementation of TSP within the



WMATA bus system is part of a regional transit FTA TIGER program grant which included upgrading the Washington DC core signal system to include TSP and TSP along corridors in Maryland, the District, and Northern Virginia. The VA-7 Leesburg Pike corridor was chosen for an operational test of the WMATA System. An initial RFP for the WMATA TSP system including requirements was issued in 2011 but cancelled in order to closely coordinate with the CoABE system.

The current concept for the WMATA TSP implementation is to leverage the CoABE system by using the Clever Devices IVN as the Priority Request Generator and an OPTICOM GPS TSP system. The IVN has real-time schedule, route, location, passenger count and other information that may be used to determine when to request priority. The priority request is communicated to the wayside via a NTCIP 1211 (signal priority standard) cellular data call between the IVN on the vehicle and a cellular modem within the roadside cabinet. The modem then communicates an Opticom “764 Phase selector” also within the roadside cabinet (Young, October 2013). The request is then processed based upon the rules to grant priority within the various jurisdictions. The Opticom “764 Phase selector” equipment theoretically should be able to receive priority requests from both the WMATA cellular based systems on WMATA vehicles and the Spread Spectrum GPS/TSP systems anticipated for Ride On Vehicles. However, this requires both a cellular modem and a wide spectrum receiver within the cabinet.

It is important to point out that a number of issues need to be considered for WMATA TSP within Montgomery County including:

- The installation, recurring costs and maintenance of the cellular modems within the signal cabinets.
- Testing and reconciliation of technology requirements and operations when multiple agencies using different communications technologies between the vehicles and the signal cabinets are operating in a corridor.
- Communication and coordination between the WMATA operations center and the Montgomery County ATMS operations center for both traffic and Ride On real time performance monitoring and operations.
- Operational control protocols concerning which agency has authorization to monitor system performance and how to alter operational parameters in response to emergencies or other changing conditions. The procedures regarding how to make requests for changes to who gets priority when, or how much priority is granted need to be defined?
- How to prioritize and balance competing priority requests for priority at an intersection or within a corridor by time of day, direction, or type of service. When requests overlap or conflict which vehicle/service operated by which agency has its request granted?
- How are the requests for TSP, whether they are granted, and their impacts logged, monitored, and analyzed across the disparate systems.

Maryland Transit Administration (MTA)

The Maryland Transit Administration provides both MARC commuter train service and various commuter bus routes (from Frederick, Washington and Howard Counties) as well as newer routes along the ICC (MD 200) within Montgomery County. The commuter bus routes include:

- Route 201 Gaithersburg to BWI Marshall Airport
- Route 202 Metropolitan Grove to DOD/Ft. Meade



- Route 203 Columbia to Bethesda
- Route 204 Frederick to College Park
- Route 915 Columbia/Silver Spring to Washington, DC
- Route 929 Columbia/Silver Spring to Washington, DC
- Route 991 Hagerstown/Frederick to Shady Grove/Rock Spring Business Park
- Route 995 Clarksville/Ellicott City/Columbia to Washington, DC

The routes along the ICC may only have very little interaction with the signal system when they divert to serve park and ride lots and rail stations.

The commuter bus service is operated through contracts with private companies and currently there are no requirements to include onboard AVL, Computer Aided Dispatch, Transit Signal Priority, other on board technologies, or passenger information as part of the service they provide. These would have to be added to their operations if the MTA commuter bus service is to utilize TSP and operate within the RTS corridors or within Montgomery County in non-RTS corridors.

The MTA is also moving forward on fixed guideway projects within the County: the Purple Light Rail Line and the Corridor Cities Transitway (CCT). These MTA projects are exploring the use of TSP (and possibly preemption at some intersections) as part of their future operations. No decisions have been made to date though on how TSP will function in these corridors. If TSP or preemption is provided for the Purple Line or CCT, one question that needs to be addressed is the impact on the RTS system's ability to provide TSP if at all, and specifically which types of treatments when RTS corridors cross or run parallel to their alignments.

IV. EXISTING COMPONENT ASSESSMENT

IV.1 TRANSIT SIGNAL PRIORITY SYSTEM COMPONENTS

An important question in this effort is: What are the capabilities of the existing major components required for implementing TSP within an RTS system? These major components include: the Econolite ASC/3 traffic controller which controls the signal phasing, length of the priority phase, and time out periods. The GTT Opticom GPS/TSP system and equipment which provides the requests from the vehicles, receives the requests at the roadside, and determines which request will be forwarded to the ASC/3 traffic controller; and the OrbCad AVL/Cad system which monitors the transit vehicle performance and schedule adherence and provides communication between the transit vehicle and the transit operations center. Each is discussed briefly below.

Econolite ASC/3 Traffic Controller. The ASC/3 is a series of advanced system controllers offered by Econolite. It is designed to be fully compatible with the NEMA TS2 and NTCIP 1211 standards and account for up to 16 phases in an intersection's operation. The ASC/3 comes TSP ready, however, activation of TSP at a specific traffic signal requires the purchase and installation of a TSP Data Key (a onetime cost of approximately \$400 per TSP intersection).

The ASC/3 may use vehicle check in and check out or continuous monitoring to ensure that the priority request has been services. It only allows one TSP request to be addressed within each cycle. The firmware installed within the ASC/3 determines to a large extent what features and capabilities it has. Currently, Montgomery County has implemented version 2.45 within all of its controllers and will

upgrade to 2.49 in the near future (version 2.58 is the current release). The County has found that Econolite changed internal operating systems after version 2.50 which apparently changed how the NTCIP status data is reported making it incompatible with the County ATMS central software. Currently using firmware 2.45 (or 2.49) the County's ASC/3 controllers can be set to implement under coordinated operations:

- Extended Green
- Early Green (red truncation of the crossing movement)
- Leading green for clearance of queue jump or dedicated guideway transit vehicles (similar to transit only phase insertion)

Based upon the documentation advanced priority treatments may be possible with firmware versions 2.50 and beyond including:

- Vehicle movement phase skipping (allow or prevent phase skipping based upon user parameters) when signal coordination is relaxed
- Pedestrian phase skipping (The County does not plan to utilize this function due to concerns about pedestrian safety).

However, upgrading the County systems beyond 2.49 is a significant and costly undertaking and would have to be balanced against the likely benefits.

At this time it is assumed that even more advanced strategies such as phase rotation or true transit only phase insertion cannot be accommodated without customization.

GTT Opticom GPS/TSP. The GTT GPS/TSP Preemption/Priority system has been recommended for the Montgomery Countywide implementation of TSP under existing service conditions. As stated, it is also being chosen by WMATA, and is used in other areas of the State by the MDSHA for emergency vehicle preemption (calls transmitted from emergency vehicles). The Opticom system components are also on the State's procurement schedule. It provides the equipment and software to implement distributed preemption/priority on the vehicle and at the wayside. The system includes the on-vehicle equipment to send a request, the wayside antennae and receiver to receive the vehicle location, a phase selector to validate the vehicle position, determine if it is in range for priority, prioritize and resolve conflicts between competing requests (direction, eligible transit vehicles, emergency vehicle preemption calls), and send a request for priority (or emergency vehicle preemption) to the traffic signal controller.

The Opticom GPS/TSP Spread Spectrum system is recommended as part of an extended Ride On Route 55 /MD 355 TSP test now being considered to better understand the benefits of TSP within Montgomery County. It is clear from a limited 3 intersection test carried out as part of Phase II of the Countywide TSP assessment that the logic and equipment do work for isolated intersections with limited service frequency. An additional central software package from Opticom that provides for monitoring of all the phase selectors in the field much more efficiently and easily than is currently provided for may also be warranted. This addition would make it easier to provide reports on individual receivers and approaches.

Currently, the schedule and on time performance of each equipped Ride On vehicle is monitored individually by the ORBCAD system. The Opticom on vehicle priority request emitter is activated based upon the individual vehicle's performance and requests are granted on a first come first serve basis at

the intersection. What remains to be seen is how the system can be integrated across operating agencies (Ride On, WMATA, RTS) to allow for combined assessment of schedule adherence and resolution of conflicting priority needs. How the location and schedule adherence of nearby vehicles with conflicting requests can be accounted for remains to be seen. The ability to receive signals from and resolve conflicts between WMATA, Ride On, and RTS vehicles also needs to be verified.

OrbCad. OrbCad is the Automatic Vehicle Location (AVL) and Computer Aided Dispatch (CAD) software implemented by Ride On to manage its transit operations. During its lifetime its vendor has gone through several ownership transitions and it is currently provided by ACS Systems/Xerox. It provides the ability to provide real time vehicle location monitoring, monitor schedule and route adherence, communicate with operators via voice or data terminal messages, provide voice annunciation for stops along routes, count passengers automatically, and integrate with Transit Signal Priority Systems. Based upon the Montgomery County TSP test along 355 it has been proven that the on vehicle OrbCad system can monitor a vehicle's schedule adherence and notify the TSP system when a vehicle is not meeting schedule adherence thresholds and a request is warranted. It is presumed that the system can also be set to issue authorize requests by time of day and direction.

Additional capabilities to log, monitor, and analyze TSP requests and impacts may be needed to meet the full expectations of the RTS system.

IV.2 TRANSIT ROW PRIORITY TREATMENTS AND SIGNAL OPERATIONS

This section describes the most applicable signal operations and priority strategies for each type of right-of-way treatment identified in the RTS master plan. These strategies will serve as guidance for developing technical details regarding communication protocols, operational protocols, detection parameters, and system architecture, integration and monitoring framework in the third and final Technical Memorandum.

- **Non-RTS Corridor:** The type of priority recommended for corridors that are not part of the RTS network should be limited early green and extended green. This is consistent with policy developed for countywide deployment of transit signal priority under the current bus environment, and the screening and operational protocol should similarly follow the countywide TSP policy.
- **Mixed Flow:** For RTS vehicles operating in mixed flow, priority strategies should also be limited early green and extended green. The inability of the transit vehicles to separate from the general traffic flow in this configuration limits the variety of TSP strategies that can be utilized.
- **Mixed Flow with Queue Jump:** Where physical priority treatments are provided, in addition to early and extended green TSP operations, a phase insertion priority strategy would be applicable. The phase insertion would be a brief (less than 5 seconds) green 'bus-only' indication to allow the RTS vehicle to enter and clear the intersection in advance of the general traffic.
- **Dedicated Curb Lanes:** Where a semi-exclusive designated curb lane is provided for RTS vehicles, in addition early and extended green TSP operations, a passive transit priority strategy would also be applicable. Passive signal priority would entail adjusting the signal timing, specifically the offsets and arterial bandwidths, to be based on the anticipated RTS vehicle operating speeds rather than general vehicle traffic operating speeds. Under this strategy,

careful consideration of potential friction in the curb lane such as right turns and local non-RTS transit vehicles must be considered in developing signal timing plans.

- Managed Lane (dedicated one-way peak direction): Similar to dedicated curb lanes, in a semi-exclusive right-of-way, the applicable transit priority strategies would be early green, extended green and passive priority.
- One Lane Medan Busway (bi-directional): A one-way bi-directional busway would provide exclusive dedicated right-of-way to RTS vehicles. However, due to the complications of RTS vehicles operating two-way in a one-lane configuration, applicable priority strategies would be limited to early green, extended green and passive priority. This ROW treatment may also require additional turn restrictions along the corridor (e.g. protected left turns).
- One Lane Median Busway (one-way): With exclusive and dedicated right-of-way for RTS vehicles, and one-way operations, a more robust spectrum of transit vehicle priority strategies would be applicable. Basic strategies such as early green, extended green and passive priority are viable. Advanced strategies such as phase insertion, phase rotation, and phase suppression would also be applicable but their implementation must be balanced with the current system capabilities (see previous section). Phase insertion would provide brief 'bus only' signal indication to allow an RTS vehicle to enter and clear the intersection prior to any general traffic. ***(It should be noted that Phase insertion could be accommodated through standard vehicle detection and operate as part of the normal signal sequence)*** Phase rotation (requires traffic signal system upgrade) would re-order the standard phase sequence at a given traffic signal to provide the green indication to the approaching general traffic/ RTS vehicles to minimize stopped delay. Phase suppression (requires system upgrade) would skip non-RTS vehicle phases to minimize RTS vehicle stopped delay. Under these advanced strategies, careful consideration must be given to the presence of non-RTS transit vehicles in the RTS right-of-way, RTS vehicle turning movements, and TSP strategies available to non-RTS transit vehicles in the general purpose travel lanes.
- Two-Lane Side Busway (two- way operations): With exclusive and dedicated right-of-way for RTS vehicles, and two-way operations, the full spectrum of transit vehicle priority strategies would be applicable. Basic strategies such as early green, extended green and passive priority are viable. Again, advanced strategies that may require system upgrades such as phase insertion, phase rotation, and phase suppression would also be applicable.
- Two-Lane Median Busway (two-way operations): With exclusive and dedicated right-of-way for RTS vehicles, and two-way operations, the full spectrum of transit vehicle priority strategies would be applicable. Basic strategies such as early green, extended green and passive priority are viable. Again, advanced strategies that may require system upgrades such as phase insertion, phase rotation, and phase suppression would also be applicable.
- Light Rail Transit Right-of-Way (Purple Line): Priority strategies for light rail vehicles, although similar to the applicable strategies for RTS configurations with exclusive and dedicated right-of-way, will not be discussed in detail as the RTS vehicles will be a gas or electric bus technology but are noted for comparison purposes.

Table 3 summarizes the applicable TSP strategies by right-of-way and priority treatment. For the ROW treatments where advanced signal treatments may be considered, there are 57 current signals that are along 1 lane median (one way) busways, 4 that are along a 2 lane side busways, and 98 that are along 2 lane (2 way) median busways.

Table 3 RTS ROW Priority Treatments versus TSP Signal Operations

ROW Treatments	Current Signals	Potential Signal Treatments*					
		Passive	Extend Green	Red Truncate	Insert Transit Phase	Phase Rotation /Swap	Phase Suppression
Non-RTS Corridor	~595		✓	✓			
Mixed Flow	84		✓	✓			
Mixed Flow w Queue Jump	0	✓	✓	✓	Transit only Early Green		
Dedicated Curb Lanes	19	✓	✓	✓			
Managed Lane (dedicated 1 way Pk)	4	✓	✓	✓			
1 Lane Median Busway (bi-dir)	18	✓	✓	✓			
1 Lane Median Busway (1 way)	57	✓	✓	✓	✓	✓	✓
2 Lane Side Busway (2 way)	4	✓	✓	✓	✓	✓	✓
2 Lane Median Busway (2 way)	98	✓	✓	✓	✓	✓	✓
LRT ROW (Purple Line)	~14	✓	✓	✓	✓	✓	✓

Table 4 presents other corridor operation characteristics that should be considered in developing applicable TSP strategies. These include the permission of left and right turns, the permission of general traffic in the RTS lanes, and the permission of other transit vehicles in the RTS lanes. Each of these characteristics will not only have an impact on the applicability and effectiveness of the transit signal priority strategies, but also the basic RTS service planning and operations. Most of these decisions will need to be made within a more detailed facility planning (Fac Plng) level analysis.

Table 4 Other Corridor Operation Characteristics impacting TSP (Turns, Other Service)

ROW Treatments	Turns Permitted		Traffic Lane Use	Transit Service in Priority ROW			
	Right	Left		LRT	RTS	Express	Local
Non-RTS Corridor	Y	Y	Y		N	Y	Y
Mixed Flow	Y	Y	Y		Y	Y	Y
Mixed Flow w Queue Jump	Y	Y	Right Trn		Y	Y	Y
Dedicated Curb Lanes	Fac Plng	Y	Right Trn*		Y	Y	Y
Managed Lane (dedicated 1 way Pk)	Fac Plng	Y	Right Trn*		Y	Y	Y
1 Lane Median Busway (bi-dir)	Fac Plng	Fac Plng	N		Y	Fac Plng	N
1 Lane Median Busway (1 way)	Y	Fac Plng	N		Y	Fac Plng	N
2 Lane Side Busway (2 way)	Y	Y	N		Y	Fac Plng	N
2 Lane Median Busway (2 way)	Y	N	N		Y	Fac Plng	N
LRT ROW (Purple Line)	Fac Plng	Fac Plng	N	Y	Fac Plng	N	N
* If permitted							

Other factors that will influence what TSP strategy is recommended along each corridor and intersection include: Cross street facility type, Cross street transit service, Bus stop/station locations, Bicycle & Pedestrian treatments and priority areas, Available green time within the signal phasing, the intersection Level of Service, Service frequency and time between priority requests, and ridership.

How these are all balanced in order to produce: recommended TSP system parameters, policy, and operational guidelines is the focus of the remainder of this effort.

V. NEXT STEPS

Now that foundational knowledge and high level needs, goals, objectives and potential roles of TSP within RTS (Technical Memorandum 1) and existing conditions on signal systems, communications, and traffic & transit operations within the RTS corridors (this document) have been documented, the next step is to carry out the high level RTS TSP planning and policy development. This includes:

- Ongoing interaction with the RTS TSP stakeholders.
- Ongoing collaboration with the Service Planning and Integration Work Group and consultant team to incorporate their service recommendations and system design into the TSP recommendations.
- Develop a recommended Systems Engineering Approach to TSP implementation on the RTS study corridors, including integration with existing TSP programs in Montgomery County.
- Establish policy recommendations regarding TSP implementation both for the overall systems and by type of ROW priority treatment.
- Develop recommended guidelines for implementing TSP within the RTS system to the extent possible at this stage of the RTS system planning.
- Develop recommendations for inter-agency partnership and coordination with regard to TSP operation and signal coordination.
- Prepare and deliver the remaining deliverable.

A final Technical Memorandum 3: Transit Signal Priority Planning will summarize the current work efforts to date including identifying purpose and needs, and existing traffic and transit system conditions. In addition the concluding memorandum will focus on developing:

- TSP Policy and Corridor recommendations:
 - Recommended TSP policies and procedures
 - Preferred minimum criteria and Measures of Effectiveness (MOE) for selection and evaluation of TSP locations
 - Preliminary operational review of RTS study corridors
- Concept of Operations and System Control
 - High-level Concept of Operations for TSP integration with the RTS system
 - Integration of TSP with other transit ITS, traffic engineering, and EMS pre-emption systems
 - Recommended system architecture

This deliverable may change in order to incorporate results from the Service Planning and System Integration effort and ongoing decisions and recommendations on the RTS corridors, policies, and operations.

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