Technical Memorandum 3:
RTS Transit Signal Priority Findings and Recommendations
Rapid Transit System (RTS) Transit Signal Priority

For:

Montgomery County
Department of Transportation

SABRA, WANG & ASSOCIATES, INC.

9 May 2014

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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 components 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 last of three deliverables associated with the RTS TSP Concept Study. Technical Memorandum 1 (SWAI, October 2013):

- Provided foundational concepts for TSP
- Proposed a purpose, goals, objectives, and measures for TSP within RTS within Montgomery County
- Described stakeholders and their needs along with potential policy issues to resolve

Technical Memorandum 2 (SWAI, December 2013):

- Described the existing conditions of signal systems and traffic/transit operations on the proposed RTS corridors within Montgomery County
- Examined the overall transportation system operations:
  - Signal system characteristics and technologies (Montgomery County, SHA, City of Rockville)
  - Transit systems and technologies (RIDE ON, WMATA, MTA)
- Provided an assessment of existing components with respect to potential TSP within RTS

Note, that originally this TSP within RTS study effort included components that cannot be addressed at this point in the RTS planning process. These include: a detailed operational review and recommendations by corridor and intersection on equipment modifications/upgrades, detection parameters, active priority strategies, and traffic control system parameters for implementing. These depend on either system-wide operational decisions beyond TSP (e.g. separate or integrated operations control center, Transit AVL/CAD and APC systems selected) or details yet to be defined as part of facility planning (future traffic volumes, final guideway configurations, integrated transit service plans). What can be done at this time is to lay out some high level recommendations on the types of TSP treatments that should be considered within each type of right of way and the overall system for TSP, identify key decisions needed in facility planning, and identify next steps to facilitate TSP integration and deployment as a part of the RTS implementation.

Consequently, this document, Technical Memorandum 3, summarizes the findings and recommendations of the TSP within RTS concept to date. Recognizing that many decisions regarding TSP both at the system-wide and corridor/intersection basis can't be made until more detailed preliminary engineering and analysis is done, it then lays out a road map of key policy and system decisions that need to made as the RTS system development and related TSP implementation moves forward and what their key inputs are.

Five (5) sections follow. Section II summarizes the current status of TSP and RTS within Montgomery County focusing on developments and decisions that have taken place since the start of this effort. Recognizing that how and where to implement TSP within the RTS system cannot be determined independently, Section III provides a roadmap of the TSP policy and system decisions that need to be made and the additional inputs (from systems operational and facility planning), decision makers/stakeholders, and tradeoffs involved. Section IV then lays out a preliminary "Concept of Operations" including recommendations that can be made at this time on high level system architecture, technology and equipment, and operating scenarios and principles. Section V documents a preliminary cost assessment for TSP within RTS. Last, Section VI provides a summary and recommended next steps.

II. CURRENT STATUS OF TSP AND RTS WITHIN MONTGOMERY COUNTY

Since the start of this effort, the planning and decision making for: the Countywide Transit Corridors Functional Master Plan and RTS System; the Countywide TSP (current service and right of way); and other projects that may impact and influence TSP within the RTS system (WMATA TSP TIGER Grant, the CCT Systems Planning, the Purple Line, MD 97 Georgia Avenue North and Viers Mill MD 586 BRT Studies)[1] have continued to move forward. This section briefly summarizes the current status of these efforts highlighting their relevance to TSP within RTS as planning for the RTS system continues.

[1] These were discussed in more detail in Technical Memorandums 1 and 2.

II.1 COUNTYWIDE TRANSIT CORRIDORS FUNCTIONAL MASTER PLAN AND RTS SYSTEM

In November 2013, the Council formally adopted the Corridors Functional Master Plan. Of note in the adopting resolution is that the Council did not endorse any specific right-of-way treatments but deferred those decisions to the County Department of Transportation (DOT) and Maryland State Highway Administration to be determined during detailed facility planning. Consequently, since many of the decisions regarding TSP depend on the right of way, the details regarding TSP on a corridor by corridor and intersection basis must also be determined in facility planning. Slight changes were also made to some of the recommended corridor alignments that will impact the implementation of TSP including: the provision of direct service along US 29 that bypasses the White Oak Transit Center and service that diverts to the Transit Center for transfers to the New Hampshire Avenue service (and the FDA); and alternative alignments for the North Bethesda Transitway and Randolph Road. Last, the Corridor Cities Transitway is now included in the Recommended BRT Corridors and service of the overall RTS system.

The parallel effort of the RTS Service Planning and Integration Study developed proposed route structure, service characteristics (e.g. headways), and modifications to the existing local service in each corridor. Operating speeds were assumed based on a literature review as well as the material in the Functional Master Plan. The average speeds predicted in the report are based on the assumed infrastructure (e.g. priority treatments) and some type of traffic signal priority. There was no explicit calculation of potential operating speed with a specific TSP strategy. However, the extension (diversion) of service by RTS vehicles outside the RTS ROW of some corridors to serve transit and activity centers is included in the basic service concepts. This raises the potential for TSP to help facilitate access to the corridors and service along these extensions.

In order to develop preliminary cost estimates, the Service Planning and Integration Study also estimated the service frequency needed to carry the projected demand in each of the corridors. This resulted in very frequent service along some of the proposed routes (2.2 minutes on MD 355 south, 2.6 minutes on MD 355 north, 3.3 minutes on US 29 and 4 minutes on New Hampshire). Based on current service levels (combined headways of all routes) and ridership, the initial headways in the southern sections of the US 29/Colesville Road and MD 355 corridors and portions of other corridors may fall in the range of 5 to 6 minutes (or less).

Where there is very frequent service, other systems such as the Los Angeles Metro BRT have moved to headway versus schedule based service management. The CCT is also currently assumed to be headway based service with a vehicle every 6 minutes in the opening year. Frequent service and/or headway based management is an important factor in deciding how to implement TSP since it changes how conditional TSP can be applied. For example, if buses are operating at 5 minute headways using "5 minutes or more late" as a conditional TSP criteria would mean that buses would be queued up one behind the other before the conditional criteria is met. So, a different approach to conditional TSP for frequent service based upon headways may be warranted where frequent service is planned. This is discussed more in the Section IV Operational Scenarios.

II.2 Countywide Transit Signal Priority Assessment and Policy

The Countywide Transit Signal Priority Assessment and Policy Effort was initiated in 2011 by Montgomery County DOT in partnership with the Maryland State Highway Administration to accelerate and promote the implementation of TSP within current transportation systems so that shorter-term benefits could be realized while longer-term rapid transit systems advanced through planning and design. Its purpose was to recommend a policy and process for selecting locations and number of rolling stock fleet to deploy TSP components for the existing roadway and transit service in the County. The goal was to deliver a comprehensive analytical assessment of corridors and intersections where optimal traffic, transit and geometric conditions existed for signal prioritization to "improve ridership and provide for a higher quality ridership experience", and for the DOT to be clear and transparent in the decision making process by providing an "evaluation for these intersections that can be reviewed by residents"[2]. In addition, the effort also assessed the technology readiness of the County's Advanced Traffic Management System and related components to implement TSP.

The Countywide project forms the foundation for TSP within Montgomery County, as well as throughout the State. The final phase of the project was completed in December 2013. Significant recommendations include:

- **Distributed TSP Architecture**
- **TSP Technology Components**
  - *Signal Controller:* Econolite ASC/3 traffic controller which controls the signal phasing, length of the priority phase, and time out periods.
  - *TSP System:* 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.
  - *Transit AVL/Cad:* 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.
- **Operating Principles**
  - *Conditional Priority:* TSP will be requested when the buses are running more than 5 minutes behind schedule.
  - *Request Service:* A TSP request will be granted on a first come first served basis (no special consideration to direction, corridor, operator, or type of service).
  - *Safety Constraints:* 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*: Priority signal options are green extension and red truncation.
  - *Priority Lockout:* Once priority is granted at an intersection the signal cannot grant another request (i.e. the lockout period) until the system recovers coordination (currently three cycles).
- **Recommended corridor and selection process**
  - *Corridor selection:* Eighteen potential TSP corridors totaling 366 intersections were identified by transit agencies based upon their impressions of where there was sufficient transit service

[2] Letter from the County Council President and Transportation, Energy, Infrastructure & Environment Committee to the County Executive

to make TSP cost effective. They were then ranked based upon likely impact to existing traffic congestion levels and likely benefit to existing transit service/performance.

– *Intersection screening and weighting:* As shown in Figure 1, Intersections within each corridor were then screened based upon mandatory feasibility criteria (volume-to-capacity ratio and available slack time), and weighted based upon additional criteria indicating their likelihood to provide transit benefits and not cause roadway disruptions.

Building on the foundational process for Countywide TSP screening, an initial review of the 288 signals[3] along the RTS corridors (**shown in Figure 2 and summarized in Table 1**) shows that the Countywide study recommends that 136 implement TSP in the near term. These would provide immediate benefits to the county and also serve the RTS corridors once they are open. Eighty-seven locations that are in both the TSP and RTS corridors do not meet the criteria for early implementation prior to the RTS corridor development and would have to undergo additional analysis during RTS facility planning. An additional sixty-five locations were not evaluated under the Countywide TSP assessment as they did not fall under one of the eighteen identified TSP corridors. These would also have to be assessed as part of facility planning. The cost implications of deploying signals recommended in the Countywide study in the near term are discussed in Section V.

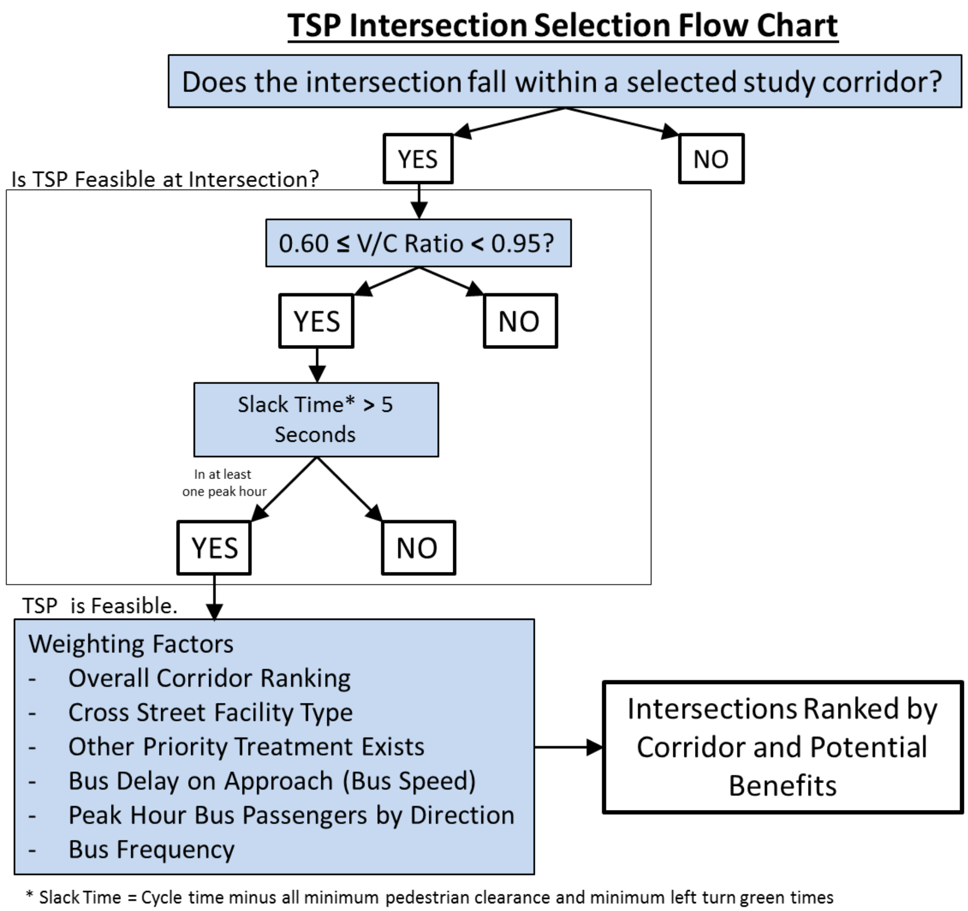

Figure 1 Intersection Selection TSP Flow Chart

[3] 273 unique signals with 15 counted in more than 1 corridor.

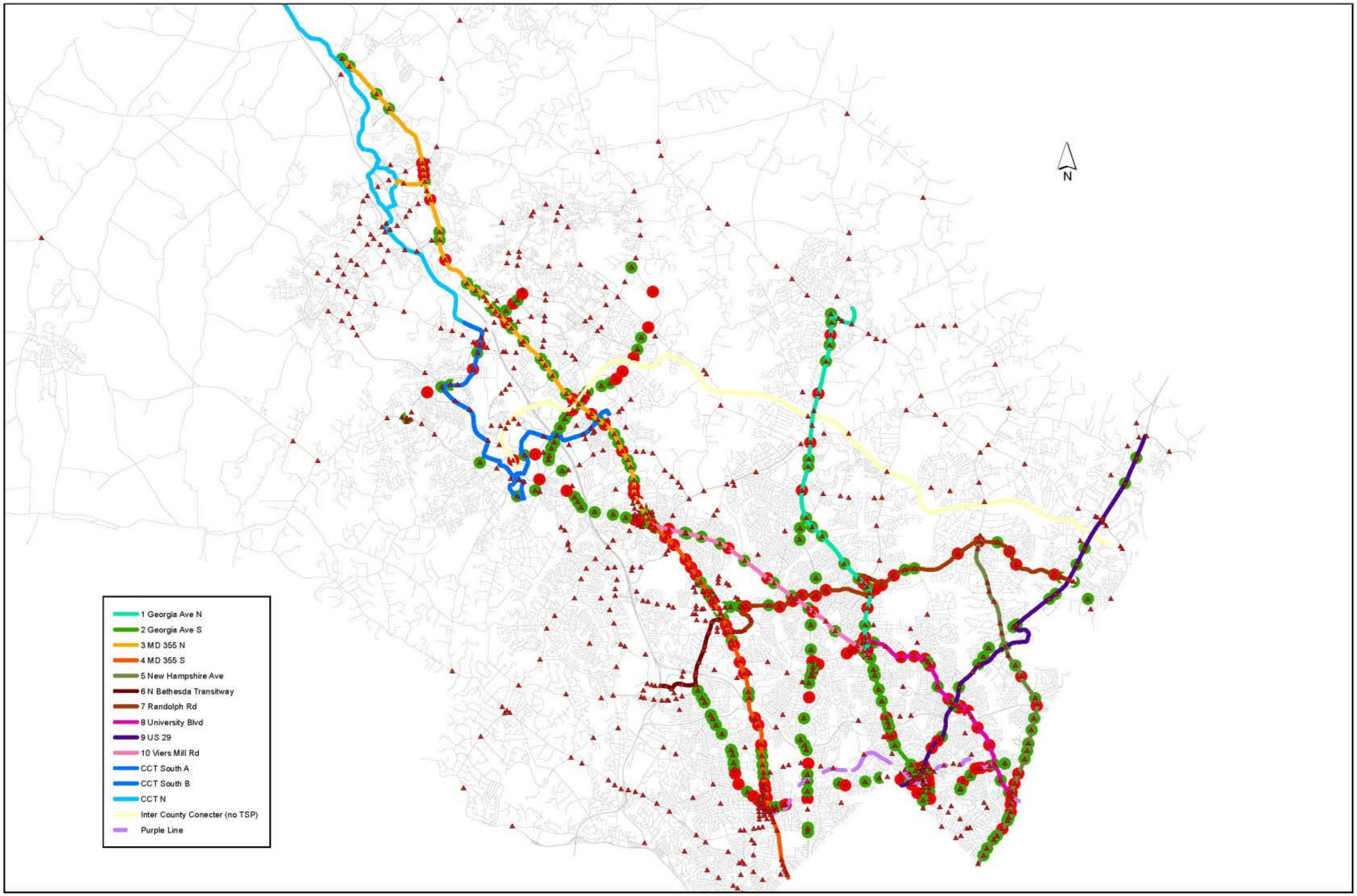

Figure 2 RTS Corridors Overlay of Countywide TSP Study Signals

Table 1 Summary of RTS Network Existing Signal Screening

	Corridor	From	To	Stations (RTS & Metro)	Signals	MoCo Countywide Mandatory Criteria		Not in TSP or no Data
MNCPPC Funtional Master Plan Planning Board Draft						Y	N	
1	Georgia Avenue North	Montgomery General Hospital	Wheaton Metrorail station	13	30	15	9	6
2	Georgia Avenue South	Wheaton Metrorail Station	District of Columbia line	8	24	13	2	9
3	MD 355 North	Corridor Cities Transitway	Rockville Metrorail station	20	44	26	15	3
4	MD 355 South	Rockville Metrorail Station	District of Columbia line	14	47	15	20	12
5	New Hampshire Avenue	Colesville Park & Ride	District of Columbia line	12	34	15	10	9
6	North Bethesda Transitway	White Flint Metrorail Station	Montgomery Mall Transit Center	7	14	1	0	13
7	Randolph Road	US 29	White Flint Metrorail Station	11	30	8	15	7
8	University Boulevard	Wheaton Metrorail Station	Takoma/Langley Transit Center	9	21	11	7	3
9	US 29	Burtonsville Park & Ride	District of Columbia line	11	25	19	3	3
10	Veirs Mill Road	Rockville Metrorail Station	Wheaton Metrorail Station	11	19	13	6	0
			Totals	**116**	**288**	136	87	65
						288		

II.3 Other Projects/Efforts

Several other projects are ongoing including those that will influence the long-term deployment of TSP technologies within the County

- The WMATA TSP (TIGER Grant) includes both a technology assessment of TSP components and a demonstration of queue jumps and TSP on MD 193 and MD 586. As discussed in Technical Memorandum 2, WMATA is proposing a different roadside communications technology than that recommended for the Countywide TSP system.
- The MTA's Corridor Cities Transitway (CCT) is a 15-mile BRT fixed-guideway system between COMSTAT and the Shady Grove Red Line Metro Station. MTA is currently considering incorporating TSP as part of the CCT design and operations plan. The alignment includes segments which run along MD 124 and MD 119. The decisions made as part of the CCT project development and facility planning that may impact TSP within the RTS system include: its Transit Operations Center and how it interfaces with other transit service and the Montgomery County and City of Rockville signal systems; the specific automatic vehicle location/computer aided dispatch (AVL/CAD), Automated Passenger Counter, and other Transit ITS software and systems chosen as part of the CCT; and the advanced types of TSP treatments potentially considered or desired by the CCT operations planners (phase suppression, phase swapping, etc.)

- The MTA's Purple Line Light Rail project is a 16-mile Light Rail Line that runs from Bethesda to New Carrollton in primarily dedicated transitways, and is currently considering incorporating TSP and preemption as part of its design and operations plan. The Purple Line will be designed and constructed by a yet-to-be awarded Public Private Partnership entity. The alignment includes segments that run along MD 193 and MD 320. Whether the RTS and LRT service will both be allowed to request priority when they are in the same corridor (along University Avenue) and when they cross (New Hampshire) needs to be determined.

III. ROAD MAP OF TSP POLICY AND SYSTEM DECISIONS

This section highlights key policy and system issues and decisions that will need to be resolved to finalize TSP integration within the RTS network. A few highlights include:

- The current Montgomery County Advanced Traffic Management System can only implement basic TSP strategies such as early green, extended green and exclusive bus phases (e.g. queue jump detection). Other advanced TSP (e.g. phase rotation, phase suppression, predictive priority and adaptive controls) will be costly and require changes to the overall system (beyond Econolite firmware v 2.50).
- Integration of WMATA's TSP system in Montgomery County remains unresolved. WMATA's recommended system uses different communications both on-board and wayside that need to be fully tested for operational compatibility. In addition, different Automatic Vehicle Location / Computer Aided Dispatch technologies (e.g. Ride On OrbCad and Metro Clever Devices) will have significant impacts on capabilities for TSP Conditional priority.
- Integration of two separate premium transit systems (e.g. CCT and Purple Line) will require careful coordination of TSP operations, communications and components
- Installing TSP hardware and software in select City of Rockville signals
- Integrating and coordinating MTA commuter services that run along the RTS network.

While it is not possible at this point to determine TSP configurations at specific intersections, the following table (Table 2) provides a road map for key issues and elements to develop a TSP deployment plan that fully supports the RTS vision.

Table 2 Road Map Decision Matrix

Issue	Element	Decision Maker	Stakeholders	Time frame	Discussion
Policy					
Owner/ Operator	Project Delivery	County	SHA, MTA, WMATA	Short-Term	Dependent on funding and project delivery
Performance measures	Operations policy/ modal priority	SHA / County	RideOn, WMATA, MTA, SHA, County	Short-Term	Person-throughput is a goal of the Plan
Services within RTS Priority ROW	Travel Time Reliability	County	RideOn, WMATA, MTA	Long-term	Accommodation of multiple service types would impact TSP strategies, service plans and guideway design
Services that can request priority	TSP strategies	County	RideOn, WMATA, MTA	Long-term	Determines need for bus-to-bus communications
Architecture/Technology					
Integrated or Separate Transit Operations Center	Real-time transit and traffic management	County	Ride On, WMATA, MTA	Short-term	Capabilities to log, monitor, and analyze TSP requests
Central/Distributed System	System architecture	County	SHA, RideOn, WMATA, MTA	Short-term	Communications components
Technology Selection	Equipment specs and cost	County	SHA, RideOn, WMATA, MTA	Long-Term	Compatibility with current technology and vendor
TSP Priority Strategies					
Use of advanced strategies	Hardware and software upgrades	County	SHA, RideOn, WMATA, MTA	Short-term	These include phase swapping, skipping, and suppression, and adaptive signal control Pilot testing proof of concept and technology
Conditional Parameters	Request granting protocol	County / SHA	RideOn, WMATA, MTA	Mid-Term	Maximizing TSP benefits and minimizing TSP impacts to other modes of travel
Corridor Infrastructure and Intersection Operations					
Guideway design	Right-of-Way and priority treatments	County / SHA	RideOn, WMATA, MTA	Short-Term	Determines intersection-level applicable TSP strategies
Future transit and traffic volumes	Congestion standards	County / SHA	RideOn, WMATA, MTA	Short-Term	Tolerance for variability in transit schedules and traffic LOS
CCT and Purple Line Integration	System Management	MTA / County	SHA, RideOn, WMATA	Mid-Term	Premium transit should be a seamless system

IV. CONCEPT OF OPERATIONS

Technologies and system capabilities for traffic signal operations, transit ITS and operations, and TSP will continue to evolve as RTS corridors are planned and implemented within the overall RTS system. Consequently, as an initial starting point in preparing a full concept of operations, some basic assumptions and operational scenarios were developed for the first/early RTS corridors to be implemented within the overall RTS system. These initial assumptions and operational scenarios are presented below. They are followed by a visionary set of assumptions and example operational scenarios based upon what may be feasible as additional RTS corridors are implemented in the future (and the initial system evolves).

In both cases, two types of conditional priority are envisioned: Schedule Control and Headway Control.

- **Schedule Control:** For schedule control, the schedule and associated time point locations are downloaded each day and stored on the vehicle. The vehicle AVL/CAD system uses GPS to monitor where the vehicle is and where it is supposed to be as the vehicle makes each trip throughout the day. If the vehicle is late by 5 minutes or more, then the priority request generator starts transmitting a priority request as the vehicle travels along its route. As the vehicle approaches each intersection, it will be considered for TSP by the intersection priority request server.
- **Headway Control:** For headway control, each vehicle needs to know how long it's been since the vehicle in front of it has gone by any particular point on its route (i.e. the gap). This information is best maintained at the operations center. Each vehicle's AVL/CAD system transmits its location to the operations center and then receives information on the preceding vehicle periodically (every 1 to 2 minutes). If a gap between the two vehicles is greater than a specified threshold (e.g. 1.5 times the desired headway), then the trailing vehicle's priority request generator starts transmitting a priority request as the vehicle travels along its route. As the vehicle approaches each intersection, it will be considered for TSP by the intersection priority request server. The vehicle will continue to transmit its priority request until the gap matches the desired headway or reaches some acceptable lower threshold.

IV.1 Early RTS Corridor Implementation Assumptions.

The assumptions for a TSP system and capabilities that can be implemented in the near term are:

- TSP will be installed at all signalized intersections within the RTS network. Activation within each time period (AM Peak, PM Peak, Midday, Other) will be dependent on the specific conditions at each intersection for the period (e.g. available slack time, typical volume-to-capacity ratio).
- Decentralized TSP architecture
- The Operations Center will be integrated/connected with real-time interfaces between ATMS, Ride On, and RTS (but not necessary physically integrated).
- Vehicle to transit operations center real time communications of vehicle location and status.
- Transit operations center to vehicle real time communications of headway (gap) status for headway control.
- Initial Technology and Equipment

  - Econolite ASC/3 controller
  - Current Montgomery County ATMS system (without significant software upgrades)
  - GTT Opticom TSP system (GPS with spread spectrum radio, and possibly WMATA modems)
  - AVL/CAD with APC on all RTS vehicles
- TSP signal strategies supported by the initial technologies (without significant upgrades to software or hardware): Early Green, Extended Green, Leading Green/Transit Only Phase Insertion
- Conditional TSP to support "Headway" adherence of RTS service within the RTS corridors
- Conditional TSP to support "Schedule" adherence of RTS service within the RTS corridors
- Conditional TSP to support prioritization by:
  - Service Type (RTS, Express, Local)
  - Direction by Time of Day (peak, off peak)
  - Historic passenger loading

Operational scenarios that illustrate how the envisioned TSP will operate based upon the above assumptions are briefly presented below:

0) Initiation (start of service)/termination (end of service)

At login each morning, each vehicle will download and store in the Opticom GPS Control unit and Priority Request Generator (PRG): Updated schedule information for the routes and trips assigned to the vehicle for the day; A priority order factor table by route/trip that accounts for type of service, direction, time of day, and historic passenger loading. Higher order factors will be granted TSP first when simultaneous priority requests are received at an intersection.

At the end of each day (or run), the vehicle will upload service performance data including the automatic passenger information, the schedule adherence of each trip, and the requests for Transit Signal Priority. The traffic operations center will also produce a report /database of signal operations, TSP requests, etc.. These will be archived for post processing and evaluation of the TSP on transit and traffic performance.

1) RTS vehicles in exclusive guideway

RTS vehicles within the exclusive guideway can issue TSP priority requests when they are more than 5 minutes behind schedule, or when operating under headway control the gap between vehicles is greater than 1.5 times the desired headway. TSP requests from other transit service not within the exclusive guideway will not be granted if they are received. Higher priority order is given to vehicles moving in the peak direction with historic high passenger loads.

The first set of examples assume that an exclusive two way RTS guideway exists at Route 355 at East Deer Park Lane. RTS service operates in both directions within the guideway with a peak headway of 6 minutes. Local Ride On service operates in the mixed flow traffic lanes beside the guideway at 15 to 30 minute headways. For this illustration, the headway control threshold is assumed to be 1.5 the desired headway. The actual value will likely be set as part of the facility planning and initial operations testing.

Single vehicle on time and/or within headway bounds: At 6:00 am, an RTS vehicle is running southbound (peak direction) and is 2 minutes behind schedule, the previous bus is running on schedule. No request for TSP will be transmitted and priority will not be granted for this vehicle.

Under schedule control, the vehicle is not more than 5 minutes late (schedule control) and the request transmitter will be turned off. Under headway control, the gap between the vehicle and the previous vehicle is less than 1.5 times the desired headway (8 minutes < 6 times 1.5 or 9 minutes) and the request transmitter will be turned off.

Single vehicle behind schedule and outside headway bounds: At 8:30 am, an RTS vehicle is running southbound (peak direction) and due to an accident is 5 minutes behind schedule, the previous bus is running on schedule. A request for TSP will be transmitted and priority may be granted. Under schedule control the vehicle is 5 minutes late (schedule control) and the request transmitter will be turned on. Under headway control the gap between the vehicle and the previous vehicle is greater than 1.5 times the desired headway (11 minutes > 6 times 1.5 or 9 minutes) and the request transmitter will be turned on.

The priority request generator transmits a message to the priority request server at the intersection to request priority on the southbound approach. The message contains the vehicle ID, the priority order factor (accounting for type of service, direction, time of day, and historic ridership), the passenger count, and the number of minutes behind schedule.

The priority request server at the intersection receives the request from the approaching vehicle and compares the current position of the bus to its list of detection zones, determines that it has just entered the southbound detection zone for the intersection and estimates when it will reach the intersection. It then logs the vehicle ID, the date and time, the passenger, the priority order factor, passenger loading, the number of minutes behind schedule, and the approach. The server activates the input in the detector rack that corresponds to the southbound through phase and checks the vehicle in. The arrival time for the vehicle is calculated to be 30 seconds from check in.

The traffic signal controller senses that this input is active. At the time, the through phases for MD 355 are green, with 24 seconds remaining until their force-off point. An extended green TSP is provided for 6 seconds to allow the southbound bus to pass through the intersection (saving approximately 75 seconds of additional delay would the bus have arrived during the beginning of the mainline red interval). The vehicle proceeds, leaving the detection zone and clearing the intersection, and is checked out. The extended green is terminated and the signal reverts to its normal cycle.

Multiple Vehicles with Conflicting TSP Requests: At 8:30 am, two RTS vehicles (one southbound and one northbound) and a northbound local Ride On Route 59 bus approach the signal at Route 355 and East Deer Park Lane. Due to heavy congestion and an accident earlier in the morning, the southbound RTS vehicle is 6 minutes behind schedule. The northbound RTS vehicle is 5 minutes behind schedule and the route 59 bus is 6 minutes behind schedule. A second southbound RTS vehicle follows the first at 8:35 am. It is also behind schedule.

Schedule control: The northbound RTS vehicle approaches the intersection and enters the detection zone first. The AVL/CAD system has signaled the priority request generator to turn on the request transmitter because the vehicle is more than 5 minutes behind schedule. The priority request generator transmits a message to the priority request server at the intersection to request priority on the northbound approach. The message contains the vehicle ID, the priority order factor (accounting for type of service, direction, time of day, and historic ridership), the passenger count, and the number of minutes behind schedule. The priority request server at the intersection compares the current position of the bus to its list of detection zones, determines that it has just entered the southbound detection zone for the intersection and estimates when it will reach the intersection.

The Route 59 RTS vehicle approaches the intersection next. It transmits a priority request to request priority on the northbound approach message because it is more than 5 minutes behind schedule (the countywide TSP criteria for local service). The message contains the vehicle ID, the priority order factor, the passenger count (if available), and the number of minutes behind schedule. The priority request generator on the vehicle compares the current position of the bus to its list of detection zones and senses that it is in the northbound detection zone for the intersection, and estimates when it will reach the intersection.

The southbound RTS vehicle approaches the intersection last. It also sends a priority request for priority on the southbound approach because it is more than 5 minutes behind schedule. The message contains the vehicle ID, the priority order factor, the passenger count, and the number of minutes behind schedule. The priority request generator on the vehicle compares the current position of the bus to its list of detection zones and senses that it is in the northbound detection zone for the intersection, and estimates when it will reach the intersection.

The priority request server at the intersection receives the requests from all three approaching vehicles. The priority request server logs the vehicle ID, the date and time, the passenger, the priority order factor, passenger loading, the number of minutes behind schedule, and the approach for each vehicle. The priority request server does not consider the request from the Route 59 northbound bus because it is local service not in the exclusive guideway. Based upon the priority order factor, the server chooses the southbound RTS vehicle because it is in the peak period peak direction and has historic higher ridership than the northbound RTS vehicle. The server activates the input in the detector rack that corresponds to the southbound through phase and checks the vehicle in. The arrival time for the vehicle is calculated to be 30 seconds from check in.

The traffic signal controller senses that this input is active. At the time, the through phases for MD 355 are green, with 24 seconds remaining until their force-off point. An extended green TSP is provided for 6 seconds to allow the southbound bus to pass through the intersection. The vehicle proceeds, leaving the detection zone and clearing the intersection, and is checked out. The extended green is terminated and the signal reverts to its normal cycle.

Headway control: Under headway control with a desired headway of 6 minutes the sequence will be slightly different. Each vehicle will be periodically sending its status and location to the operations center and the operations center in turn will be sending the location and time of the previous vehicle back. The approaching southbound RTS vehicle will receive a message that it has been 11 minutes since the vehicle in front of it has passed by. The operations center would also send a message to the northbound RTS vehicle that it has been 10 minutes since the previous vehicle has passed by. Both of these vehicles would then transmit requests for TSP since both of them have gaps larger than 1.5 times the desired headway (both 10 and 11 are greater than 9 minutes). The Route 59 Ride On bus will still be operating under schedule control and will also issue a request, but will not be considered since it is not in the guideway.

At the intersection, the same process will be followed as described following schedule based control. The Priority request server will compare requests and based upon the direction, historic passenger loads, and type of service, grant priority to the southbound RTS vehicle. The controller will then provide an extended green of 6 seconds to allow the vehicle to pass through. The vehicle is checked out, the extended green is terminated and the signal reverts to its normal cycle.

Lockout: At 8:35 am the next southbound RTS vehicle approaches the intersection also transmitting a priority request message. The priority request server determines the approach, calculates the arrival time and checks the vehicle in. The traffic signal controller senses that the input is active. It checks to see when the last priority was granted and determines that it was 5 minutes ago. The overall cycle for this signal is set at 180 seconds (3 minutes) and the lockout period is set at 3 cycles. Therefore the request for TSP is NOT granted (5 minutes is less than 9 minutes).

2) RTS vehicles in dedicated curb lanes or mixed flow with queue jump

In dedicated curb lanes or mixed flow with queue jumps it is recommended that all transit service can issue conditional TSP requests.

An example of schedule based controls is provided for an RTS vehicle on westbound Randolph Road approaching Parklawn Drive. It is 6 minutes behind schedule. The signal indication for westbound vehicles is red and the back of the queue is 300 feet from the stop line.

The AVL/CAD system has signaled the priority request generator to turn on the request transmitter because the vehicle is more than 5 minutes behind schedule. The priority request generator transmits a message to the priority request server at the intersection to request priority on the eastbound approach. The message contains the vehicle ID, the priority order factor, the passenger count, and the number of minutes behind schedule.

The priority request server at the intersection receives the request from the westbound bus. The priority request server logs the vehicle ID, the date and time, the priority order factor, the passenger loading, the number of minutes behind schedule, and the fact that the bus is on the westbound approach. The server activates the input in the detector rack that corresponds to the westbound exclusive bus phase.

The traffic signal controller senses that this input is active. At the time, the through phases for Parklawn Drive are green, with 24 seconds remaining until their force-off point. The eastbound and westbound left turn phases are supposed to be serviced next. There is demand for this phase, whose normal split is 28 seconds, but is delayed and reduced by 8 seconds during an intervening priority request. The bus-only phase is called and the westbound bus proceeds, leaving the detection zone and clearing the intersection, and the call drops.

IV.2 FUTURE LONG TERM RTS CORRIDOR DEPLOYMENT

As time passes and both the traffic signal system and transit operations and TSP technologies/ capabilities evolve, the TSP within RTS should be able to address more advanced TSP strategies and conditional parameters. Potential enhancements include:

- Econolite ASC/3 controller firmware updates to current versions (beyond 2.49) to incorporate new TSP signal strategies
- Upgrades to the ATMS central signal control system to make compatible with ASC/3 controller enhancements
- Ability to include advance TSP signal strategies including phase skipping, phase rotation, and phase swapping
- Ability to account for downstream system conditions and real time detection of intersection level of service and passenger loading
- Automatic passenger counters on all vehicles in service along RTS corridors (Ride On, MTA, RTS, WMATA)
- Real time communications between all vehicles within the roadside

An advanced operational scenario provides an example of capabilities envisioned by these assumptions.

3) RTS bus in exclusive guideway with competing local and cross route transit

In this scenario, three buses approach the intersection.

Bus 1: A Ride On bus is westbound on Tuckerman Lane. It has just started its run at Grosvenor Metro Station and is full, but is 6 minutes behind schedule. The AVL/CAD system has signaled the priority request generator to turn on the request transmitter because the vehicle is more than 5 minutes behind schedule. The priority request generator transmits a message to the priority request server at the intersection to request priority on the westbound approach. The message contains the vehicle ID, the priority order factor, the passenger count, and the number of minutes behind schedule. The priority request server at the intersection compares the current position of the bus to its list of detection zones, determines that it has just entered the westbound detection zone for the intersection and estimates when it will reach the intersection.

Bus 2: Another Ride On bus is eastbound on Tuckerman Lane. It is near the end of its run, which terminates at Grosvenor Metro Station. It has only a few passengers and is 8 minutes behind schedule —3 minutes more than the threshold for lateness that was agreed upon by transit and traffic. The AVL/CAD system has signaled the priority request generator to turn on the request transmitter because the vehicle is more than 5 minutes behind schedule. Also, the doors are closed, so the priority disable input has not been activated by the door open sensor. The priority request generator transmits a message to the priority request server at the intersection to request priority on the eastbound approach. The message contains the vehicle ID, the priority order factor, the passenger count, and the number of minutes behind schedule. The priority request server at the intersection compares the current position of the bus to its list of detection zones, determines that it has just entered the eastbound detection zone for the intersection and estimates when it will reach the intersection.

Bus 3: Meanwhile, an RTS bus travelling northbound on MD 355/Rockville Pike has just left Grosvenor Metro Station with a half-full load. It is 5 minutes behind schedule. The AVL/CAD system has signaled the priority request generator to turn on the request transmitter because the vehicle is 5 minutes or more behind schedule. The priority request generator transmits a message to the priority request server at the intersection to request priority on the northbound approach. The message contains the vehicle ID, the priority order factor, the passenger count, and the number of minutes behind schedule. The priority request server at the intersection compares the current position of the bus to its list of detection zones, determines that it has just entered the northbound detection zone for the intersection and estimates when it will reach the intersection.

The priority request server at the intersection receives the request from all three buses at the same time. The priority request server logs each vehicle ID, the date and time, the passenger loading, the number of minutes behind schedule, and the direction of approach. Because the RTS bus is a higher priority of service, the priority request server activates the input in the detector rack that corresponds to the northbound through phase.

The traffic signal controller senses that this input is active. At the time, the through phases for Tuckerman Lane have just been forced-off. The northbound and southbound left turn phases are supposed to be serviced next. There is demand for this phase, whose normal split is 28 seconds, but due to an intervening priority request, the phase is rotated to lag after the Rockville Pike through movement. The northbound and southbound green phase begins 28 seconds earlier and the RTS bus proceeds, leaving the detection zone and clearing the intersection, and the call drops. The full mainline green split is completed and the mainline left-turn phase is then serviced at its full 28 second split.

At this point, the priority request for the eastbound and westbound Ride On buses are still active. However, since one cycle has not elapsed since TSP was granted priority to the eastbound Ride On bus, it does not adjust the splits. Eventually, the Ride On buses clear the intersection (despite the fact that they were not granted priority) and drop the priority request.

While these are hypothetical operational scenarios, it is recommended that conditional TSP parameters be defined within each ROW Priority Treatment for the following elements:

- Type of service
- Time of day and direction
- Load factors (either real time or historical)
- Lateness/headway
- Downstream/Upstream conditions

A comprehensive operations plan must also include protocols for incidents, weather and special events, construction, firehouse pre-emptions, and system breakdowns.

V. COST ASSESSMENT (PRELIMINARY)

This section summarizes the initial cost estimates for implementing TSP within the RTS system. It only addresses the incremental costs for enabling TSP on vehicles, at intersections, and within the operations centers. A full RTS system may also include new signal design, installation or upgrades including new features, communications networks, and/or detection and monitoring sensors. These overall system modifications will be important but are not addressed here. The preliminary cost estimates are summarized in Table 3 and further explained below.

Table 3 Preliminary Cost Estimates for the TSP components of the RTS system

	Countywide TSP Existing Service	RTS system Without Countywide	RTS System Countywide First
Element Summary	200 signals 342 buses	273 signals 262 RTS veh.	147 additional signals 262 RTS veh.
Transit Vehicle and System Equipment, Software, Installation and Training	$1.8 million	$1.4 million	$1.4 million
Roadside & Traffic Control System Equipment, Software, Installation and Training	$3.4 million	$4.7 million	$2.5 million
Contingency Costs	$0.5 million	$0.6 million	$0.38 million
County Planning, Design, & Supervision	$0.3 million	$0.3 million	$0.3 million
Total	**$6.0 million**	**$7.0 million**	**$4.6 million**
All costs in current dollars			

The costs are based on the same unit cost and system assumptions used to prepare budget estimates for the recommended Countywide TSP system described in Section II.2. These are:

- $3,375/transit vehicle for TSP equipment (Opticom GTT GPS radio, GPS control unit, antenna and cable/hardware kit.
- $1,500/transit vehicle for equipment installation and testing
- $10,500/signalized intersection for Opticom GTT equipment (phase selector, cards, racks, GPS radio, control unit, antenna, and miscellaneous cables/hardware)
- $5,000/signalized intersection for equipment installation
- $400/Econolite ASC/3 controller for the TSP module key
- $50,000 one time charge for additional monitoring software for the 200 intersections. This runs at $25,000 for 1-75 intersections and increases to a maximum of $75,000 for more than 200.
- Replacement of 10% of the roadside and vehicle equipment over their economic life
- $15,000 for additional training and firmware support.
- $300,000 internal County planning, design, and supervision costs
- Approximately 1% contingency costs.

The initial cost estimate for the recommended Countywide TSP implementation (200 signalized intersections and Ride On fleet of 342 buses) is approximately **$6.0 million** in current dollars. This breaks down to:

- $1.8 million for transit vehicle and system equipment, software, installation and training,
- $3.4 million in roadside and traffic control system equipment, software, installation and training
- $0.3 million in County planning design and supervision costs
- $0.5 million in contingency costs.

Two cost estimates were developed for the RTS system. The first provides a high cost upper bound by assuming that the recommended Countywide TSP deployment has not taken place and that all signalized intersection within the RTS corridors will be made TSP capable. There are roughly **273 unique signalized intersections** in the RTS system (288 by corridor – 15 duplicates in more than one corridor). The initial fleet requirement for RTS vehicles from the RTS Service Planning and Integration Operational Cost estimate is **262 vehicles**. This results in an upper bound estimate of **$7.0 million** which breaks down to:

- $1.4 million for transit vehicle and system equipment, software, installation and training,
- $4.7 million in roadside and traffic control system equipment, software, installation and training
- $0.3 million in County planning design and supervision costs
- $0.6 million in contingency costs.

The second is a lower bound that assumes that the full recommended Countywide TSP deployment takes place prior to implementing TSP within the RTS system. Using this assumption 126 of the 273 unique signalized intersections with RTS corridors will already have TSP equipment installed and therefore only 147 additional signalized intersections require TSP. However, the 262 BRT vehicles for the RTS system would still need to be outfitted for TSP. Some savings also occur in training and software. For example, the incremental cost for the centralized monitoring software is $25,000. This results in a lower bound estimate of **$4.6 million** which breaks down to:

- $1.4 million for transit vehicle and system equipment, software, installation and training,
- $2.5 million in roadside and traffic control system equipment, software, installation and training
- $0.3 million in County planning design and supervision costs
- $0.38 million in contingency costs.

Note, that these cost estimates do not include the costs for the CCT BRT system. These are being developed separately as part of the CCT facility and system planning. Nor do they include the costs of signal modifications or full reconstructions which are assumed to be a part of the guideway costs.

VI. SUMMARY (NEXT STEPS)

In conclusion, this effort:

- Summarized the current status of TSP and RTS within Montgomery County
- Developed a Road Map of key TSP Policy and System decisions
- Developed a preliminary concept of operations for key RTS operational scenarios
- Estimated costs for TSP components

Although a logical planning-level decision may be to equip all RTS vehicles and intersections with TSP, it is recommended to establish an advanced TSP screening process in the future as the RTS system proceeds through detailed planning and design and to determine optimal locations for TSP deployment. The advanced TSP strategies will result in more costly deployments than current TSP components, and complexities regarding service hierarchy and complimentary strategies should be carefully weighed. Building on the foundational process for TSP screening developed in the Countywide study , an initial review of the 288 signals[4] along the RTS corridors revealed that 136 signals would meet the current mandatory criteria (slack time and volume-to-capacity ratio) required for TSP deployment. Eighty-seven locations would not meet those criteria. The remaining sixty-five locations were not evaluated under the Countywide TSP assessment as they did not fall under one of the eighteen identified primary corridors.

Moving forward, to advance TSP deployment as part of RTS corridor improvements, more detailed TSP analysis should be performed as information such as future traffic volumes, future transit service plans, and future guideway configurations are developed during the facility planning, preliminary engineering and final design for the following on-going studies:

- CCT Systems Engineering
- MD 97 Georgia Avenue North
- Viers Mill MD 586
- MD 97 Montgomery Hills Phase II Planning Study
- Purple Line Light Rail
- WMATA TIGER Grant TSP Demonstration and Technology Assessment

While no final decisions can be made regarding TSP deployment or operations at this early stage, the following next steps would be recommended to advance TSP applications in an RTS network as funding allows or is provided:

- Explore hardware and software upgrades and perform tests within the County for advanced TSP strategies (phase rotation, phase omission, phase insertion, predictive priority, adaptive signals with TSP, etc.) including detection systems. This will allow for finalization of the TSP strategy operational policy.
- Conduct additional research on how to implement headway control, what is required (is it feasible with the County's current systems) and how/when to use schedule based versus headway based control on different routes or time periods throughout the day.
- Develop a policy for including synergistic priority strategies such as queue jumps and non-transit vehicle turn prohibitions as a priority treatment in an RTS mixed flow right-of-way configuration.
- Perform route-level and corridor level analyses through traffic simulation including predicted transit travel times with TSP and without TSP (e.g. passive priority).
- Conduct pilot testing to see how the recommended Montgomery County TSP and WMATA TSP systems and technologies will operate in the same corridor.
- Develop a final competing services hierarchy based on guideway treatments (local bus, commuter bus, BRT, LRT, WMATA PCN service, etc.) for both parallel and crossing services.
- Finalize conditional priority factors and thresholds including bus occupancy, service type, direction, schedule adherence, door status, and time out of coordination.

[4] 273 unique signals with 15 in more than one corridor.

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