National Capital Region Transportation Planning Board
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TO: Transportation Planning Board

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and Chair, Traffic Signals Subcommittee

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SUBJECT: Status Report on Traffic Signal Timing/Optimization in the Washington Region

Executive Summary

At the February 20, 2013 meeting, the Transportation Planning Board requested a status report on traffic signal timing/optimization in the region, as well as a review of the TPB's discussions of the topic in conjunction with a 2002-2005 Transportation Emissions Reduction Measure (TERM). This memorandum contains the results of an April/May 2013 TPB staff survey on the topic of signal timing, as well as associated information on background and on related traffic signals management activities by the region's transportation agencies. Key points are as follows:

- Survey results showed a rate of retimed/optimized signals in the region (within defined criteria) of 76%; 22% not retimed/optimized; and no report received for 2%. This is a similar but slightly reduced level of optimization compared to the last such survey in 2009.

- In 2002, credit was taken as a TERM in the regional air quality conformity determination process for an increased level of signal optimization. Such credits are now part of the "base" conditions for conformity determinations and cannot be counted anew in future emissions reduction measures/TERMs. Note that the region today still meets (in fact exceeds) the target set in the 2002 TERM for retiming signals.

- The world of traffic signal operations has evolved significantly since the 2002 TERM, including advancing technologies and increased real-time active management of signals, going above and beyond what is achievable in pre-set optimization. This memorandum describes a number of those activities.

- A total of 21 different agencies have ownership and/or maintenance responsibilities for the approximately 5,500 traffic signals on public roads in the National Capital Region.

- The costs of equipment installation and ongoing maintenance remain a constraint for signals agencies around the region.

- A presentation on one or more of these topics can be made at a future TPB meeting at the convenience of the Board.

What Are Signal Timing and Signal Optimization?

Signal timing (definition adapted from Wikipedia) is the traffic engineering technique to allot right-of-way at an intersection, involving the determination of how much green time the traffic lights shall provide at an intersection approach, how long the pedestrian "walk" signal should be, and numerous other factors. Signal timing strives for the dual goals of safety and efficiency. Signal timing may be achieved in advance studies and the uploading of "pre-planned" timings, and/or in "real-time" adjustments of signals (if so equipped – see below for more information on adaptive and active management of signals).

The concept of signal optimization generally falls into the "pre-planned" category. Signal optimization is a traffic engineering concept whereby traffic signals (often groups of signals in corridors and/or isolated systems) are (re-)timed to reduce delay for vehicles on the roadway system while ensuring safety. In optimization studies, engineers use a combination of traffic volume counts, in-car and in-field travel time observations, control center observations, and computer analysis to determine signal timings given the complex interactions of traffic flows. The results for any one driver on any one trip may not appear to be “optimal”, due to high traffic loads, cross-traffic, pedestrian movements, and other factors, but overall system delay should be minimized. An engineering “rule-of-thumb” recommends checking signal timing at least every three years because traffic patterns evolve.

Traffic signals allot time at intersections for safety, traffic flow, pedestrians, and other factors; an individual signal’s timing needs to be balanced for these factors. Multiple nearby signals can be analyzed as a system to coordinate timings. Under certain conditions, a corridor with a predominating flow and direction can be timed for “progression”, reducing delays for traffic in that flow. Signals generally have three or more timing plans, usually including morning peak period, midday, and evening peak period, and frequently additional plans such as weekend or overnight plans.

“Optimized”, however, does not mean “without delay”. The motorist may still experience delays even after signal or corridor optimization, if, for example:

- There are high traffic volumes / left and right turns / high cross-traffic volumes
- The motorist is traveling in the opposite direction of predominant flow
- The safety of and sufficient crossing time for pedestrians necessitate extra time
- Signals are optimized for multi-modal travel

It is overall system delay, not necessarily the delay experienced by a given individual motorist, which is minimized in optimization.

Changes since 2002 in the Air Quality Analysis Context of the Signal Optimization TERM

In 2002, the region committed to an increased level of signal optimization at a level of 2,946 signals over a three year period for air quality credits as a "TERM". At that time, this commitment helped

the region achieve a finding of conformity with air quality standards. However, a number of changes have occurred in the years since that alter the air quality context of such a program. The former TERM level of optimization achieved is now assumed in the "base case" for regional air quality, and cannot be repeated. Also, the new Environmental Protection Agency-sanctioned "MOVES" model, in contrast to the old "Mobile" model, no longer readily accommodates analysis of TERMs of this type. Today's cleaner vehicle fleets also mean less impact for any optimization effort compared to 2002. Nevertheless, though the air quality conformity motivation for optimization may have been reduced, there are still congestion management and other reasons to continue optimization efforts.

Results of the Latest Signal Timing/Optimization Survey

According to regional records, a total of 21 different agencies have ownership and/or maintenance responsibility for traffic signals in the Washington region (this number excludes military bases/facilities which may have signals on their non-public roads). Thirteen of those agencies, covering an estimated 98% of the signals in the region, completed the recent TPB staff survey. The overall results of the survey show a slight decline in the percentage of traffic signals regionally which had been retimed within the 3-year "rule of thumb" window for the period ending December 31, 2012. An estimated 76% of the region's eligible traffic signals had been retimed or checked within the three-year window, in contrast to an estimated 80% as of the last report in 2009. This result, however, should be interpreted within the context of the comments below.

Summary Table of Regional Signal Timing/Optimization Results of 2009 and 2013 Surveys (Original TERM commitment = 2946 signals)

Survey Year	Total Signalized Intersections	Total Retimed		Retiming Method			Not Checked		No Report	
				Computer Optimized	Engineering Judgment	Active Management				
2013	**5500**	**4200**	**76%**	**47%**	**7%**	**22%**	**1200**	**22%**	**100**	**2%**
2009	5400	4300	80%	56%	24%	*	1000	18%	100	2%

* Combined with engineering judgement in the 2009 survey

Additional information/comments provided by respondents of the survey:

- Regional results overall held to a similar albeit lower level to that of three years ago, in the context of widespread budgetary belt-tightening by involved transportation agencies; it is hoped that some upcoming anticipated investments will improve the regional picture.
- DDOT currently has a five-year signal re-timing project. This includes a phased approach, with the intent to touch all signals based on areas of concern. DDOT has also identified three corridors for possible deployment of an adaptive system.
- Signal optimization can help get an arterial closer to its design capacity but cannot increase capacity.
- Techniques are often combined; signals can be optimized using computer software followed by active field management for validation purposes.
- Active management is particularly useful to address non-recurring congestion caused by incidents and special events.
- Signal equipment must be properly maintained for signal timing to be effective.

Beyond Optimization: Other Traffic Signals Management Activities

Computer-based, pre-timed traffic signal optimization is just one of numerous activities undertaken by traffic signals agencies to ensure proper or improved operations of traffic signals. The systems described help signals (and support staff) do their jobs better, and have been the focus of a number of resource investments in the region in recent years. The following sections describe some of these activities (descriptions adapted from the Maryland State Highway administration and other sources).

Traffic Signals in Real Time

Since the adoption of the TERM in 2002, there have been technology changes (improved signals timing analysis programs, traffic detection equipment, video surveillance, traffic management centers) which make it easier for traffic engineering staff to monitor traffic flow and provide adjustments to signal timings from remote locations to address congestion caused by incidents, special events, and diverted traffic from other roads. Real-time traffic management, which is adjusting signal timing based on current demand, provides congestion relief above and beyond those obtained from the timing plans created by computer programs such as Synchro™. As can be seen from the results of the survey a number of jurisdictions have adopted such a practice either on a daily basis or during special events. Agencies such as the Virginia Department of Transportation and Montgomery County Department of Transportation actively manage their signals using the traffic operations center in real time.

Adaptive Signal Control Technology (ASCT)

There are a number of situations when a computer-generated traffic signal timing plan may not produce the desired result as discussed above. To handle such a situation, implementation of ASCT which is performed by a computer program may offer an improvement over the existing operation. ASCT employs specialized detection equipment to adjust traffic signal timing based on real-time transportation demands – within an established set of parameters. The implementation of these systems requires the installation of specialized field equipment at the selected locations – representing additional costs to the implementing agency. The traffic signals subcommittee has discussed this subject and a number of jurisdictions in the region are considering the use of ASCT for selected corridors.

Management through Engineering Judgment/Troubleshooting

The third technique used by a number of jurisdictions is managing good efficient operation of signals through engineering judgment and troubleshooting. Whenever complaints are received traffic engineers visit the signalized intersection and using their experience and judgment adjust the signal timing to reduce delay and improve operations.

The techniques continue to provide improvements over a stand-alone optimized timing plan operation which otherwise may deteriorate over time.

Sustainment of Benefits

Benefits from retiming/optimization are, of course, limited if the corridor in question was already reasonably well-timed. Once a corridor is well-timed, benefits can only be maintained, not improved upon.

Multi-Modal Considerations Including Transit Signal Priority

Urban streets and roadways are multi-modal in nature (e.g., including buses, pedestrians, bicycles, trucks, others). Best practices in traffic engineering recognize this in the operation of traffic signals, including the levels of bus, bicycle, and pedestrian activities, and ensuring that they are accommodated in traffic signal timing.

Transit Signal Priority (TSP) Systems

Transit Signal Priority is the modification of traffic signal timing to benefit transit vehicles operating along a roadway. TSP gives additional time to the green phase for buses or streetcars, by extending the green light, providing an early or advanced green light, or adding an extra green

phase just for transit. The $58.8 million Transportation Investments Generating Economic Recovery (TIGER) grant awarded to the TPB in February 2010 for Priority Bus Transit in the National Capital Region includes a project to install TSP at up to 77 intersections along seven major bus corridors across the region and at another 82 signals in downtown DC. The TIGER funded TSP system will initially be installed and tested on VA-7 (Leesburg Pike) in 2014, by WMATA in close coordination with Virginia DOT and the partner jurisdictions. The system will subsequently be tested in the District and in Maryland, for their respective, different wayside traffic signal technologies, with completion planned for 2016.

Pedestrians

Traffic signal timing is an essential factor in accommodating pedestrians at intersections, and safety is paramount. Agencies must consider pedestrian crossing time and wait time within their overall timing/optimization processes. Pedestrian countdown signals have come into widespread use in the region, also aiding safety.

Equipment Upgrades

Detection Systems

Until recently, the most commonly used vehicle detectors were inductive loops, typically installed in saw cuts in the pavement, with detected vehicles passing over them. Inductive loops are now being supplanted by other technologies that provide engineering advantages. Wireless detectors that are smaller, nicknamed "hockey pucks", are easier to install than the old, large inductive loops, and provide maintenance advantages as well. Video detectors are another predominant form of vehicle detection for traffic signals. A video-based detector consists of a video image acquisition system (e.g., visual spectrum or infrared camera), digitizer, appropriate cabling, and a video image processing unit, with appropriate vision processing software. Signal detection cameras generally are separate from traffic management or law enforcement cameras because of the need for signals cameras to remain fixed on their assigned detection points, and cannot be panned or zoomed.

Signals Operations Centers

Some agencies have installed sophisticated communications networks that link traffic signals, traffic cameras, and detectors into a central traffic operations center. These centers have two-way communications with field equipment that allows traffic technicians to monitor traffic signal data and video, and make changes to signals right from the office. The ability to monitor traffic signals from a central location also may enable instant notification of equipment malfunction (loss of power, detector malfunction, etc.), allowing staff to respond quickly to malfunctions and mitigate problems in real time.

LED Signal Heads

Light-Emitting Diodes (LEDs) are now the predominant form of illumination for signal heads, having largely superseded incandescent signal lamps. The higher efficiency of LEDs means that their electrical power consumption is vastly reduced, so running costs for power supply are correspondingly low. LED signal heads with their low energy consumption thus represent a valuable contribution to environmental protection: saving up to 90% of the energy consumed by signal lamps and lasting up to 15 years. Typical power consumption for a LED head is 30 watts compared to 160 watts for a regular signal head. It is also more feasible to provide battery-based power back-up systems for LED signals.

Power Back-Up Systems for Signals

Traffic signal power back-up systems provide emergency power to traffic signals when the input power source, typically public utility electric power, fails. Power back-up systems have become more practical and common in recent years as traffic signal lights have been converted from incandescent to efficient LED lights. Regional events such as the disruptive January 26, 2011 snow and ice storm and the June 29, 2012 derecho illustrate the need for such systems. There are two types of power back-up system widely used in the National Capital Region: battery-based and generator-based.

Battery-based power back-up systems provide instantaneous or near-instantaneous protection from input power interruptions by means of one or more attached batteries and associated electronic circuitry. As with any battery-powered systems, batteries will run down with use, or even at rest, and have to be maintained and replaced. The main advantage of battery-based systems is that they can start working immediately and seamlessly if main power fails, without the need for a technician to be deployed to the site. The main disadvantage is that the operational time enabled under battery power is limited, usually between two and eight hours depending on the size of the signal and its operational mode (full color versus flashing yellow/red). For battery back-ups, the signal must be composed of LED lights, and the traffic signal cabinet(s) at the intersection must be properly equipped to accommodate the battery arrays.

Generator-based power back-up systems require diesel generators to be deployed to traffic signals when power outages occur. Signal cabinets must be outfitted to handle the deployment of the generator, and, of course, generators must be obtained by the agency or jurisdiction, and be available for deployment. The main advantage of a generator system is that once equipment is deployed, the system can operate for essentially an unlimited amount of time if the generator is refueled periodically. The main disadvantage is that if back-up is needed, personnel must travel to the site of the intersection and deploy the equipment, which has inherent delay and may be difficult or impossible in given emergencies or situations.

TPB staff has surveyed the region's traffic signals agencies regarding the numbers and types of traffic signal power back-up systems in the region, most recently as of December 31, 2012; a survey as of June 30, 2013 will be completed soon. As of the end of 2012, about 50% of the region's signals benefited from either a battery-based or generator-based back-up system, up from about 26% in 2011.

Ongoing Maintenance

Given the reliance of modern signal timing technology on functioning detection devices, ongoing maintenance of loops, cameras, and other signal equipment is essential. The implementation of real-time traffic management requires adequate detection of traffic patterns, and the performance of these systems will deteriorate if equipment begins to fail. This task can be challenging given that funding is required not only to install equipment for advanced signal systems, but to also ensure that it is properly maintained.

Emergency Preparedness

Major traffic signals agencies have developed and coordinated plans for signals operations in the event of a major emergency, in coordination with state and D.C. emergency management agencies. Also, the locations of power back-up systems for traffic signals have been coordinated with emergency transportation plans. The real-time management capabilities of signals systems in the region also aid preparedness.

Outlook

There is ongoing awareness and commitment to safe and effective signals operations among the transportation agencies of the region. There is continuing interagency coordination through the Traffic Signals Subcommittee and other forums. There are benefits of providing sufficient resources to ensure good signals operations, and it is hoped that these resources can continue to be devoted. As of now, the majority (76%) of the region's traffic signals are being re-timed/optimized or checked on a frequent basis.

A presentation on one or more of these topics can be made at a future TPB meeting at the convenience of the Board.