City of Winchester, VA Traffic Signal Upgrade Project

Keith Riniker, PE, PTOE, Perry Eisenach, PE, Thomas Hannan, PE, PTOE

I. Abstract

This paper discusses the methodologies and challenges for the City of Winchester, Virginia's traffic signal upgrade project. The project included equipment upgrades and signal retiming for the City's 65 traffic signals, and signal retiming for 33 signals adjacent to the City maintained by the Virginia DOT. The scope of work included equipment selection, traffic signal design, signal system design, development and implementation of optimized signal timing plans, creative contracting, equipment procurement, and cross-jurisdictional signal timing. The project is unique because agencies rarely implement a single task that consists of these elements in combination.

Although the signal system is relatively small, the challenges presented are typical of those encountered by many small cities throughout the USA. The project encompasses many unique scenarios and solutions that are applicable to owners and operators of a significant amount of traffic signals in the USA.

The paper documents factors used to compare between different signal controller and video detection equipment, the training of City staff, challenges and solutions in the setup of a closed-loop system, traffic signal clearance interval and pedestrian timing challenges, determination of the number of signal timing plans, network partitioning, cross-jurisdictional signal timing, and a unique solution for traffic signal design and construction in a short time frame. This paper discusses the details of these challenges, identifies the solutions implemented and reports on lessons learned.

II. Summary

Figure 1 illustrates a map of the traffic signals in the Winchester, Virginia area at the start of the project. The project included signal reconstruction of 48 traffic signals in the City, removal of 8 unwarranted City traffic signals, Citywide signal timing optimization, and cross-jurisdictional signal timing optimization of all 33 VDOT signals on all major corridors surrounding the City. The project is currently on-going and is approximately 50% completed. It is a challenging project due to the large scope, short duration and political investment in the improvements. The signal upgrades and re-timing have been hugely successful due the following key factors: 1) a committed, hands-on, empowered project champion in the City's Public Services Director, 2) an experienced, hard-working contractor with adequate resources and staff, 3) two experienced traffic engineering consultants that successfully divided the work between the right people for each job, 3) regular coordination meetings that included everyone from the contractor's foreman to the consultants, 4) establishing difficult expectations, goals and deadlines early-on in the process, and 5) City Council (political) support and funding.

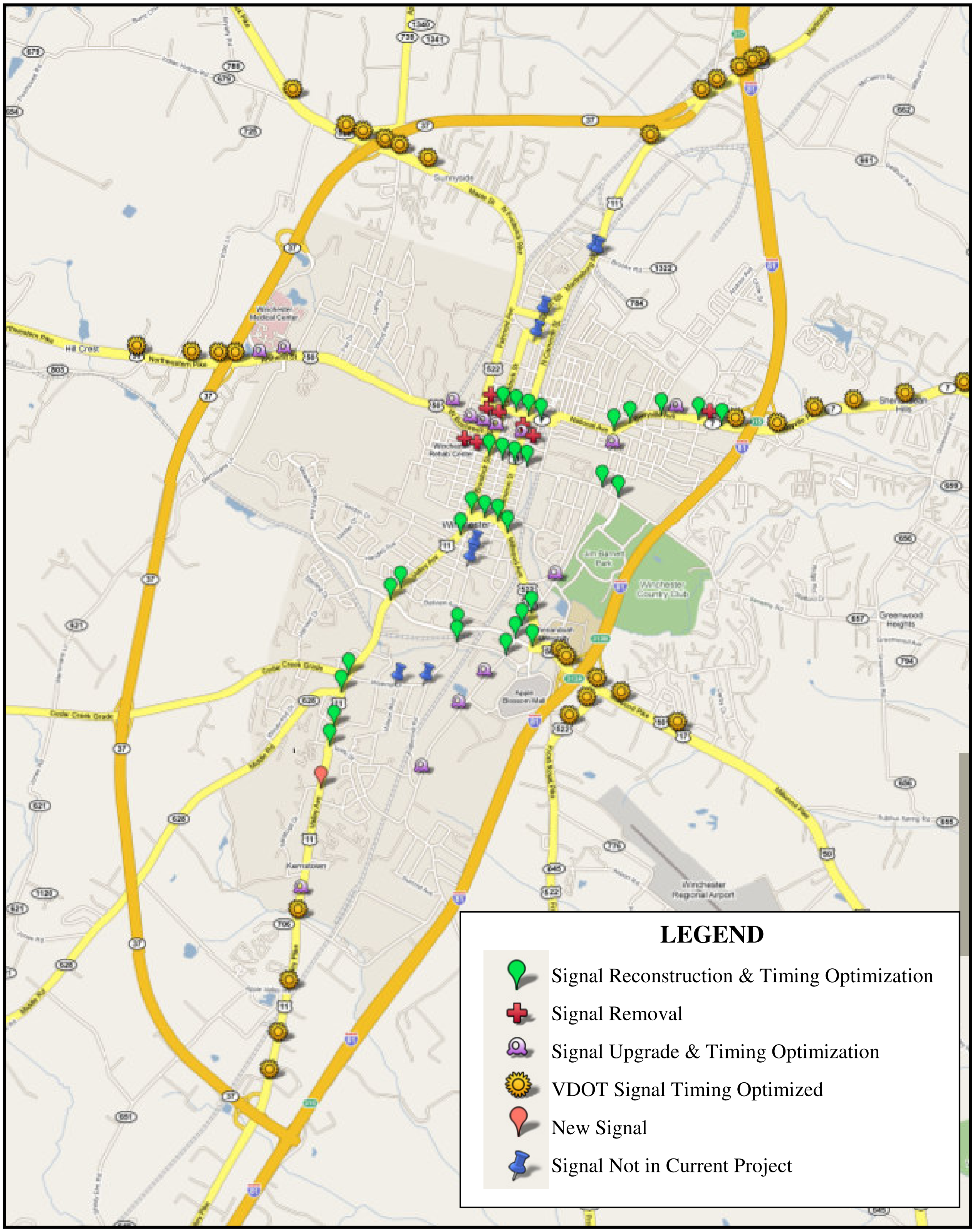

Figure 1. Map of Traffic Signals in Winchester, Virginia

III. Project Overview

The City of Winchester, Virginia is located in the northern part of the Commonwealth, 72 miles northwest of Washington D.C – close enough for some residents to commute to work in the Washington D.C. area, but far enough away that the areas outside of town are still considered rural. The City is located along the I-81 corridor between I-70 to the north and I-66 to the south. The City is less than 10 square miles, and is regional hub of industrial, commercial, and retail activity in the area. The City is located in the Shenandoah Valley west of the Blue Ridge Mountains, with rolling hills and an underlying layer of rock beneath the surface, which contributed to the challenges of rebuilding traffic signals in the City.

IV. Existing Conditions

At the start of the City's Signal Upgrade Project, the City operated 65 traffic signals. Approximately ½ of the signals are location within the downtown area, and the other half along the urban arterials in the City's "suburbs." Many of the traffic signals were 30-years old or older, with others being constructed as recently as 2006. The City experienced growth outward from the downtown area to the suburbs from the late 1980s through the early 2000s. As with many cities, the development shifted traffic loads from the downtown area to suburban arterials, and brought with it new traffic signals.

Old Controller and Cabinet

Generally, the downtown signals were the oldest and were operating in a pretimed mode using Traffic Control Technologies LC 2000 controllers installed in the mid 1980s. The signals along the arterials were operating in a fully-actuated, uncoordinated mode with a mix of late-model (80s and 90s) NEMA controllers (various Peek, TCT, and Eagle models). Vehicular detection was mostly via inductive loops with a mix of different video detection products (Iteris and Peek). Traffic signals were a mix of span-wire and mast-arm designs. Signal cabinets were TS-1 and pre TS-1 standards. The span wire designs were mostly on wood poles shared by the utility companies. Some signals were operating in a time-based coordination (TBC). However, for the signals operating under TBC, none of the internal controller clocks were in synch and as a result, the coordinated plans were not operating as designed. Some hardwire interconnect was installed, but was not operating due to either a crushed conduit or other underground wiring problem. The City owned two Closed-Loop software products (PEEKs CL-MATS and Eagle's MARC NX), but were not able to successfully use them. There was no communication between any of the City offices and the local controllers in the field. The only method of interfacing with the controllers was via the screen on the unit (the City did not provide laptops for the signal technicians). The City traffic signal staff consisted (and still does) of 2 traffic signal technicians. At that time, there was neither a traffic signal maintenance contractor nor a traffic engineering consultant under contract. The traffic signal technicians were able to perform the electronic maintenance work to maintain the signals, but did not have any background or training in signal timings or traffic engineering. The staff relied on vendors to help them with signal timing issues. The City did not own any controller or cabinet test equipment, and therefore was no performing routine functions such as conflict monitor testing. The Signal Technician staff was (and still is) responsible for signal operations and maintenance, signal timing, signal engineering studies and installation of roadway pavement markings for resurfacing projects and routine maintenance. In other words, their responsibilities included other work outside the scope of traffic signals.

V. Reasons for Signal Upgrade

The majority of the signal equipment was old and needed to be replaced. Most of the signals were 15 to 25 years old with some older than 30 years. Due to the age of the equipment, there were frequent maintenance problems, development and maintenance of coordinated signal timing plans was difficult, and replacement parts were no longer available. Signal equipment was not standardized and as such the signal technicians were not able to become familiar with any one type of device and the result was that none was used effectively. Furthermore, traffic volumes had increased significantly during the past several years and most of the signals were not on a coordinated system. As a result, traffic congestion and driver frustration were prevalent during peak travel times. In order to improve the quality of life for its citizens, the Winchester City Council established that "making significant improvements to traffic flow throughout the City" would be a high priority. The Signal Upgrade Project had two major stages of work. The first stage was to upgrade the Pleasant Valley Road and Jubal Early Drive corridors – 9 signals total. The second stage consisted of the remaining traffic signals in the City – 47 signals total. Due to lack of funding 9 signals are currently excluded from the Citywide project. The project is currently on-going, and if funds remain at the conclusion of the second stage, these signals will be upgraded.

VI. Pleasant Valley Road & Jubal Early Drive Signal Upgrades – Stage 1

The City of Winchester's highest priority was to improve traffic flow along the Pleasant Valley Road and Jubal Early Drive corridors. These corridors serve as access between the Interstate and the regional shopping mall, and numerous other retail and commercial developments. The City's goal was to improve traffic flow in time for "Black Friday" shopping traffic (November 23, 2007). Black Friday is the day after Thanksgiving, which is traditionally the heaviest shopping day of the year and the day that retailers move from the red (negative balance) into the black (making a profit). The previous Black Friday's had created long traffic jams on Pleasant Valley Road and Jubal Early Drive.

The project essentially started on March 2, 2007 with a presentation by the Public Services Director to the City Council regarding proposed transportation improvements. The City approved the request for $1.2 Million to fund the improvements. The City hired the traffic engineering consulting firms of Whitman, Requardt & Associates (WRA) and Sabra, Wang & Associates (SWA) to assist with the signal upgrade project. The first kick-off meeting between the City staff and the consulting team and was held on April 6, 2007. At that time, the City did not have a contractor on-board, did not have contracting mechanisms in place to procure equipment, nor had available internal resources to reconstruct/upgrade 9 signals within 7 months. The following steps describe the process the design team followed to meet the challenging schedule for this project.

1) Identification of Contracting Mechanisms

The first step was to identify mechanisms to get a contractor on-board. Due to the long time required to advertise and award a new project, the City elected to develop Rider contracts based off of already established contracts between equipment suppliers and contractors. The City was able to write a rider contract off of a recently awarded Virginia Department of Transportation's traffic signal construction contract to bring a contractor on-board. For the equipment selection, rider contracts from nearby Virginia municipalities were used to order the signal cabinets, controllers, wireless interconnect equipment, street name signs, traffic signal poles, video detection, preemption equipment and battery-back up systems.

2) Technology Assessment

Concurrently with the identification of contracting mechanisms, a technology assessment was performed. The technology assessment was to serve as a basis for deciding not only what equipment to procure for this project, but citywide. Prior to ordering the equipment, the City and design team visited a nearby jurisdiction that was using the same equipment and also visited the signal cabinet manufacturer to select the different features within the cabinet (police panel functions, number of load switches, fans, etc). The following describes the equipment selection process.

Visit to the Signal Cabinet Manufacturer

Signal Controller Selection

The following criteria were used as a basis for evaluating the various signal controllers. The City was familiar with NEMA controllers and therefore only NEMA models were evaluated. The signal controller vendor selection hinges on the availability of local technical support, ease of use, proven track record, good closed loop system software, support of spread spectrum radio interconnect for closed loop system, compatibility with existing City controllers, software support of GPS time reference, compatibility with neighboring VDOT equipment, responsiveness to the timeline of this project and competitive pricing. Based on the evaluation shown in Table 1 below, the city selected ***the Eagle EPAC3608M52 Controller***.

Eagle M52 Controller

TABLE 1: Signal Controller Selection Criteria

Controller Criteria/Vendor	PEEK	EAGLE	Econolite	NAZTEC
Local Technical Support		√	√	√
Equipment used by neighboring VDOT		√		

Controller Criteria/Vendor	PEEK	EAGLE	Econolite	NAZTEC
Supports Closed Loop System Used by VDOT		√		
Can be Purchased with Rider Contracts		√		
Can be Provided within 4-8 weeks		√		
Supports Radio Closed Loop	√	√	√	√
Supports GPS TRR		√		√
Currently Used by the City	√	√	√	

Interconnect Medium Selection

The City had two choices of interconnect systems to pursue: a hardwire interconnect and/or a wireless/spread spectrum radio system interconnect. The hardwire interconnect would be relatively expensive (approximately $45 per foot, or $400,000 for the Phase 1 project) and disruptive. A radio path survey was performed to test the feasibility of a wireless/ radio interconnect system. The radio path survey was conducted by setting up the omni antenna at the master location and yagi antennas at the furthest points of the interconnected signal system. The radio signals were measured and found and were found to have good signal strength. The City selected the wireless/spread spectrum radio system interconnect system. The total cost of the wireless interconnect system was $35,000, which was a significant cost savings compared to the underground hardwire system. Furthermore, the system was procured and installed in the required timeframe, whereas the underground system would have taken much longer to construct. An additional advantage is that the Eagle controllers come "radio-ready" in that the radio receivers are connected to the RS 232 connecter, thus leaving the D-connector open for the preemption equipment.


Radio Path Survey

Video Detection Selection

Prior to this project, the City of Winchester was using either Iteris or PEEK video detection at several intersections. The city selected the Traficon video detection system based on ease of use, cost effectiveness, and that the Traficon supplier was on the rider contract the City used to procure the equipment (other manufacturers were not) on the rider contracts). The City is very pleased with the Traficon equipment and has found it very easy to use. For example, midway through the signal upgrade project, the City signal technicians were already setting up the equipment and programming the detection zones in lieu of requiring the vendor to come on-site.

3) Identify and Refine the Scope of Work

The general scope of work was to reconstruct/upgrade 9 traffic signals. However, the City's $1.2 Million budget could not be exceeded, and was not adequate for the full scope of work. Therefore, the scope of work was refined to match the available budget. Although this is listed as the second step, refining the scope of work started immediately after the kick-off meeting. Refining the scope was an iterative process as different rider contracts were authorized and prices established. In order to stay within budget, the newer traffic signals were upgraded rather than replaced. The upgrades consisted of new signal heads, preemption equipment, signal controllers, radio interconnect equipment and illuminated street name signs. In some cases, signal cabinets were replaced for some upgraded intersections. Full reconstructions included all of the upgrades above, new traffic signal cabinets, new traffic signal structures with powder coated black poles and battery-back up systems. The final project consisted of 5 signal reconstructs and 4 signal upgrades.

4) Traffic Signal Design

During the time between the kick-off meeting and the start of work, the signal designers performed field surveys and began designing the signal layouts. Utilities were identified by calling MISS UTILITY for the field markings, and then surveying the marked intersection. By May (one-month after the kick-off meeting), the locations and lengths of mast arm poles were identified, and the traffic signal poles were ordered directly from the vendor, with a delivery date of mid-October. Since the traffic signal plans were not finalized by the time the contractor started work, the designers and contractor staked-out the locations in the field. In Virginia, each mast arm pole and foundation is designed specifically for the installation based on signal and sign loading and a test bore taken at the location of the proposed foundation. Due to the time required to obtain test bores, then design and approve foundation drawings, two standard signal foundations was designed using test bores from elsewhere in the City.


Setting a Traffic Signal Pole

5) Progress Meetings

The design team regularly met throughout the process and included the design consultants, City staff, inspectors, contractor's vice president in charge of signal operations, and the contractor's foremen. Formal meetings were held 1 to 2 times per month. This proved invaluable in resolving issues quickly, anticipating problems, and meeting the schedule

6) Traffic Signal Construction

The signal contractor started work on August 15, 2007, 4 ½ months after the initial kick-off meeting. Although the contractor to perform the work was identified early in the process, developing and executing the rider contract took 3 months. The contractor was able to put multiple crews on the project in order to fast-


Conduit Trench Excavation

track the project. Work started on the signal upgrades and foundation work first since the poles and cabinets would not arrive for 2 months. By the end of September 2007, all underground work (foundations, conduits) for the reconstruction intersections and most of the upgrade intersection work was completed. The signal poles and traffic signal cabinets arrived in mid-October. Work was substantially complete by mid-November. The average cost for a full reconstruction was $150,000, and for a signal upgrade was $80,000.

One of the challenges for the signal construction was the amount and size of rock formations under the ground surface. This caused problems in that 1) it is very difficult to excavate through the rock when blasting is prohibited (because the project is located in an urban area) and the contractor destroyed more than one piece of equipment trying, 2) it required additional time unforeseen at the start of the project, 3) there was engineering judgment problems for the structural engineer's re-designing foundations during construction since they did not know how large the rock formation was (no test bores were performed as noted previously), and 4) problems in determining how to fairly compensate the contractor. Regarding the issue of fair compensation for the contractor for foundations in rock, unit prices were established for rock excavation, and cubic yards concrete (which included excavation of soils). The issue is pertinent when the contractor excavated more than necessary for the foundation, which occurred frequently when rock was encountered. Rock excavation is difficult in that an exact cylinder (the shape of the signal foundation) can not be maintained, and large pieces of rock break away making the excavated hole large than anticipated. The problem is should the contractor be paid for cubic yards of concrete based on the designed size of the foundation, or for cubic yards of concrete to fill the complete excavated hole (which was much larger than the designed hole size). For this the Stage 1 project, the contractor was paid to fill the entire hole. The City thought this was fair since the issue was not established prior to the start of work and the contractor had no way of incorporating costs into his bid prices. However, during Stage 2, the contractor was made aware, prior to starting work, that no payment for concrete excavation, in excess of the designed foundation size would be allowed.

Wiring of Signal Heads

7) Traffic Signal Timing

Traffic signal timing included traffic data collection, coding and calibration of a Synchro model, evaluation and selection of pattern times and days, change interval calculations, cycle/split/offset design, setup of the coordination patterns, field implementation and fine tuning.

Programming Signal Controllers

For this project, the new signal controllers arrived at the end of August 2007. Some initial coordinated signal timings were implemented using the new Eagle controllers under Time Based Coordination. The closed-loop system could not be set up since the master controller did not arrive until after Black Friday. The initial coordinated plans were implemented with relatively low cycle lengths (70 seconds to 110 seconds). Although these plans did reduce delays, they did not reduce the number of stops as much as the City wanted. The City's goal was to be able to travel the 1-mile long corridor with a maximum of 1 stop per direction. The signal timings were fine-tuned and final optimized timings were completed on November 15, 2007, 1 week prior to Black Friday. A 180-second cycle length was used for the peak-period and a 150-second for the shoulder periods. The traffic signals at the limits of the corridor run at half of the 180-second cycle length. The distances to these signals running half-cycles are greater than the 500 foot average spacing of the signals in the core of the arterial. The half-cycles worker very well and were able to maintain progressing while not subjecting side street traffic to the long delays associated with the 3-minute cycle.


Optimized Signal Timings on Pleasant Valley Road

8) Traffic Signal Timing Methodology

The number of signal timing patterns was selected using 7-day portable machine count data. A sample snapshot of the data analysis is shown in **Figure 2**. The traffic volumes plotted on the Figure are the sum of both directions. Volumes were collected at a cordon line around the study area. As noted earlier, traffic on the corridor is retail; there is only a minor volume of commuter traffic. The traffic peaks are associated with the lunch rush and dinner rush. As such, traffic volumes steadily increase throughout the day, until they reach a point to where they are consistent for several hours, and then steadily decline. One of the challenges was to determine the number of timing plans. The start and end times were based the collected traffic volumes, directional distribution and field observations. In this corridor, the directional distribution was nearly 50/50 throughout the day. The timing plans start prior to the initial "spike" at 7 AM and change to a new timing plan prior to the "spike" at 11 AM (see the figure for the "spikes"). During the night, the signals run in Free-operations with a 20-second minimum green on the mainline.

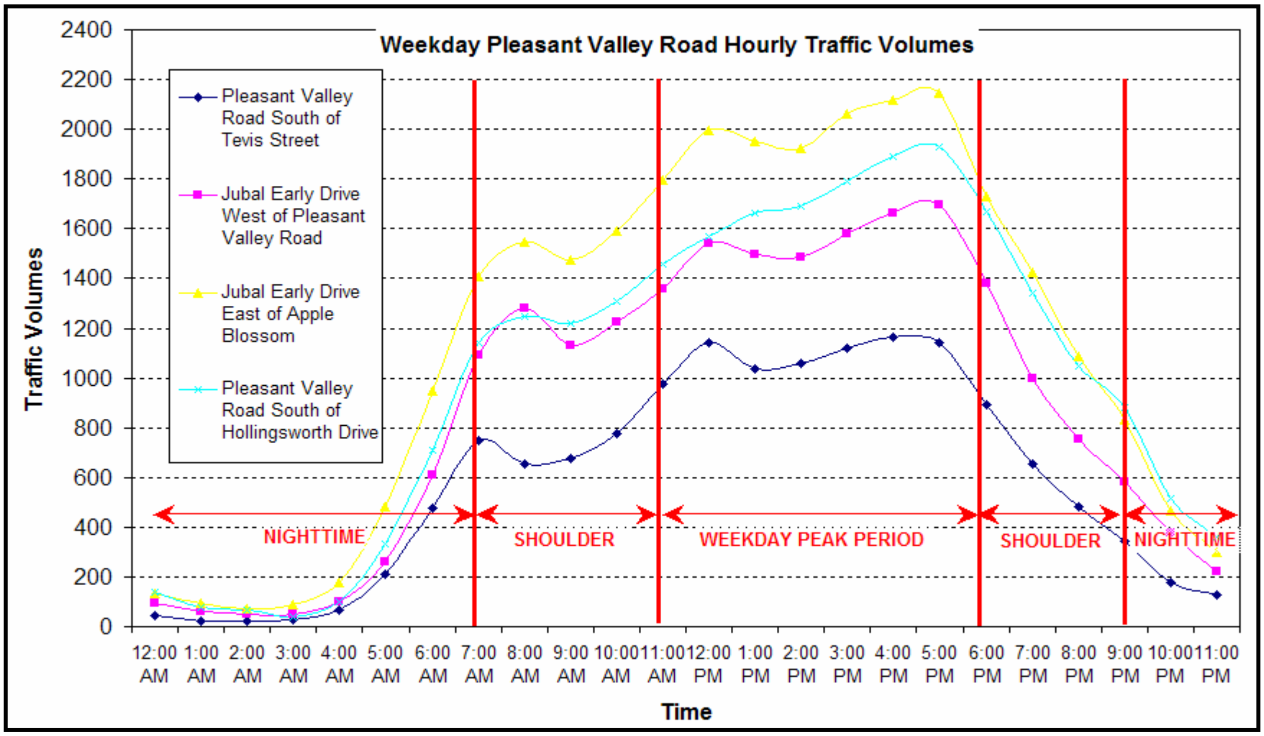

Figure 2. Traffic Volume Analysis to Identify Signal Pattern Start and End Times

9) Travel Time Improvements

The results of the signal timing optimization met the City's goal of a maximum of 1 stop per direction. The Black Friday 2007 event was a success – traffic was never gridlocked and motorists were able to move freely throughout the corridor. Data was not available for comparison with the 2006 Black Friday, but was compared between the average weekdays. Travel time and delays studies were conducted to compare the "Before" optimization with the "After" optimization. The most significant improvement was southbound, where the average travel time was reduced by 50%, and the average number of stops by 63%. The signal timing optimization showed a benefit-cost ratio of 72:1, with a weekly savings of 1,900 gallons of fuel and a reduction of 2,700 vehicle-hours of delay.

10) Roadway and Sidewalk Improvements

Under a separate contract, following the signal upgrades, the City resurfaced Pleasant Valley Road and Jubal Early Drive and constructed sidewalks and curb ramps along the corridor.

VII. Citywide Signal Upgrade Project – Stage 2

Stage 2 consisted of upgrading, reconstructing, or removing the remaining 56 traffic signals in the City. The City obtained state and federal funds for this portion of the project for a total budget of $7.5 Million. The timeframe was not as aggressive for Stage 2 and allowed time for the development of an Invitation to Bid (ITB) book, advertisement and award of an "areawide" type contract. Stage 2 consisted of the remaining intersections in the City divided into 4 assignments with an option to include more or less as the City deemed necessary. Signal plans were prepared and completed prior to the contractor starting work on each assignment for Stage

2. The following discussion includes items that are noteworthy for this project. The intent is not to describe the entire process, but to document the challenges, solutions and lessons learned.

1) Schedule

The original schedule called for 4 assignments of 8 to 10 signals each, with a 4 to 5-month construction schedule for each assignment. Each assignment would be immediately followed by the next assignment for a total project duration of 17 months. The schedule was aggressive as indicated by the fact that several contractors said they did not submit bids because they did not think they could meet the schedule.

All of the items on the Stage 2 project were furnished and installed by the contractor; expect the mast arm traffic signal poles in Assignment No. 1. The design team realized that the contractor would not be able to meet the Assignment No. 1 schedule due to the long lead time required for poles. Therefore, the City advertised a separate mast arm traffic signal poles contract for the 10 intersections in Assignment No. 1.

2) Two-Step Bid Process

The ITB included a two-step bid process wherein each responding contractor submitted a technical proposal and a bid. The first step in the bid was a technical proposal, which was qualification based. The technical proposal was designed to be relatively simple with specific questions, a 30-page limit, and included items such as resumes, past experience, etc. The two-step process was introduced in an attempt disqualify some contractors that the City had did not like based on past experiences. The second step was the submission of bid prices. If a firm did not meet a minimum score on the first step, they would be disqualified. Only two firms submitted bids – one of which was a contractor the City did not like working with and hoped to disqualify. The review team, consisting of representatives from the City and consultant engineer's, were not able to disqualify either of the bidders. The review team thought the contractors did not fully understand the intent of the technical proposal process as they do not regularly have to prepare these and as such do not have the appropriate marketing staff.

3) Bids

The wining bid came in from the City's preferred contractor at $4.8 Million, 3% under the engineer's estimate, and 3% under the second contractor's bid. Bids were due on August 25, 2008. The Notice to Proceed date was Work started on October 28, 2008 with a finish date of February 11, 2010.

4) Signal Removal Studies

The City had identified 16 signals that were to be studied for removal. Removal studies were performed using the MUTCD signal warrant criteria. Understanding that signal removals are political issues, the Public Services Director solicited permission from the City Council. Typically, signal warrant (and removal) studies are based on data from one day. For these studies, a one-day turning movement count was performed, and supplemented with 7-day volume counts on the side streets. The supplemental counts were performed to anticipate complaints from residents that the engineering study missed the some weekly traffic event. In fact, when the analysis was conducted, there was one location where the turning movement count showed the signal was not warranted, but the data from the other 6 days in the week showed the signal was in fact warranted. Of the 6 intersections studied to date, 4 did not meet the MUTCD criteria and were brought to the City council for a decision. Of these 4 signals, 3 were removed. The only signal not removed was a political issue. To date (June 2009), the City has removed, or is scheduled to remove 8 signals total. **Figure 3** illustrates how the volume data was used to evaluate the MUTCD traffic signal warrants.

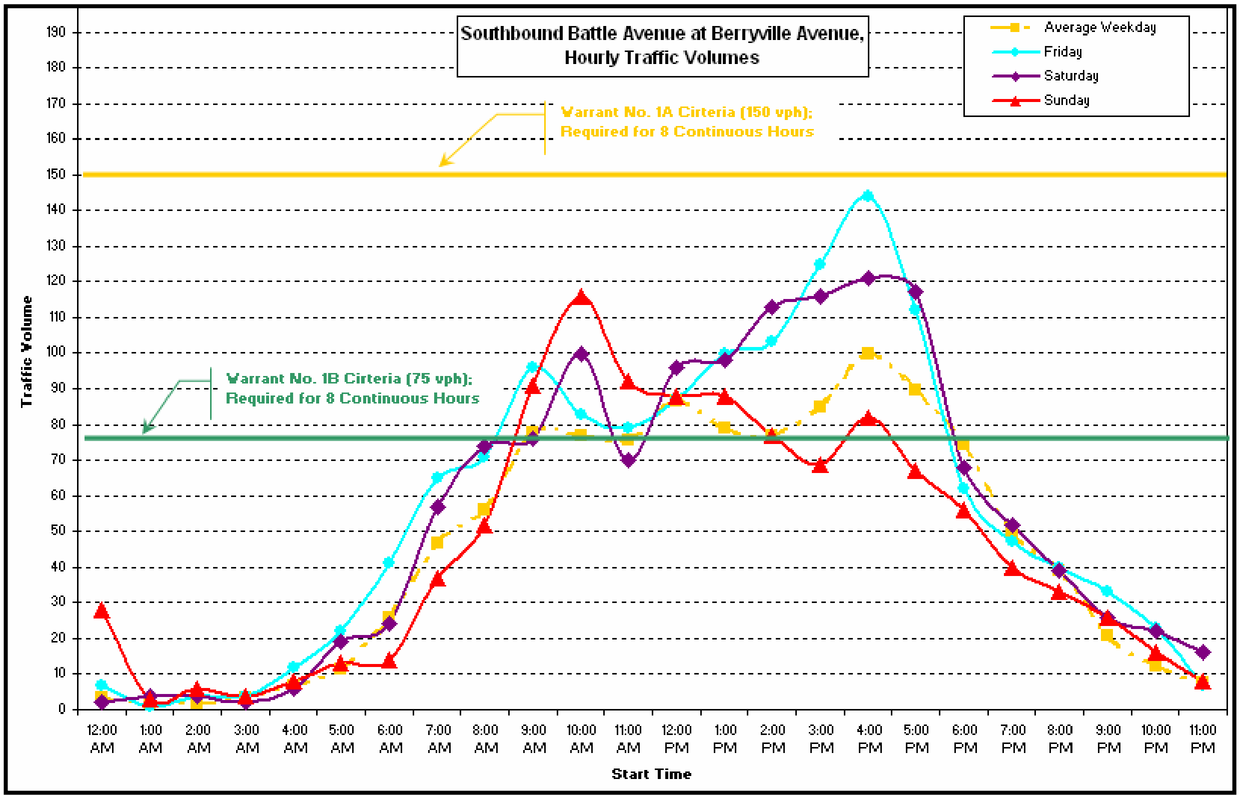

Figure 3. Signal Removal Analysis of Side Street Traffic Volumes

5) Signal Design

The signal design was prepared in the same manner as Stage 1, expect with a few changes based on lessons learned. As noted earlier, utilities were identified by MISS UTILITY locating and marking them in the field. During Stage 1, several signal poles locations had to be moved to avoid utility conflicts because not all utilities were identified by MISS UTILITY. To avoid potential problems with having to move a mast arm pole further away from the intersection and then not being long enough, mast arm poles were designed to be 3 to 5 feet longer than needed to account for potential relocations during construction.

6) One-Way to Two-Way Street Conversions

The City had been discussing changing two of the streets downtown from one-way to two-way. The issue centered on difficulties in navigating through the City and access to businesses. Once the City approved the Signal Upgrade Project, the Public Services Director pushed the issue to the City Council to make a final decision. The Council recognized that the best time to do the conversion would be when the signals are upgraded. The City Council voted to change to two-way streets on December 9, 2008. The conversion has not occurred yet, but is scheduled for November 2009.

7) Powder Coating Traffic Signal Poles


Unloading New Signal Poles

As mentioned above, the signal poles for the 10 intersections in Assignment No. 1 were procured through a separate contract with a pole manufacturer prior to establishing the contract with the signal contractor. The signal contractor received an NTP on October 28, 2008 with a finish date of February 16, 2009. The signal poles were delivered to the site by early December 2008, approximately 6 weeks after the signal contractor started construction. If the signal poles were to be furnished by the signal contractor, rather than by the City, the signal poles would not have arrived to the site until after the February deadline. Providing the poles through a separate contract would have allowed the project to meet the original schedule if there were not problems in the manufacturing process with power coating the signal poles.


Peeling Paint on New Poles

The poles were delivered to the site, wrapped to avoid damage, and carefully unloaded. The signal contractor subsequently installed the poles. After installation at a few intersections, the City noticed air bubbles and paint peeling off of the poles. The following week, the manufacturer's representative visited the site and agreed there was a problem with the coating process. The poles were taken down and shipped to Unique Coatings in High Point, NC for repair.


Unique Coatings Spray Booth

The problem was that the pole manufacturer did not follow the powder coating system manufacturer's specific instructions, and the preparation of the galvanized poles were not to be compatible with the application of the powder coating system.

The following describes the process that Unique Coatings following to repair the poles. All poles were "sand" blasted ("profiled") with engineered plastic shot. The profiling and preparation process took about 8 to 12 hours for each upright mast arm pole, and about 5 to 9 hours for each mast arm, depending on the length. The poles were then cleaned and heated to 400-degrees F, then cooled slightly in a spray booth and shot with the primer coat using an electrostatic, powder spray gun. Primed poles were baked in the oven a second time to set the primer coat, and afterwards again returned to the spray booth for the application of the finish coat. Finally, the finish coated pole is returned to the oven a third time to set the two coatings and the pole surface together.

8) Traffic Signal Timing

Traffic signal timing optimization was performed in the same general manner as previously described. For the Stage 2 assignments, the optimized signal timings were implemented in conjunction with the end of the signal upgrades. This was a public relations imitative to match public expectations of improvements in traffic flow with new signals. This was also a practical approach since maintaining coordination would have been more difficult during construction due to the fact that there were a variety of different controllers in use. Two additional features that were utilize in Stage 2 were the Force Mode and Dynamic Split functions in the Eagle controllers.

Force Mode

The Eagle controllers define two types of force modes: Plan, which returns unused split time to the coordinated phases, and Cycle, which provides unused split time to the next phase. The Plan force mode was used at intersections that were critical in terms of maintain the through bandwidth along the corridor. The Cycle force mode was generally used at all other locations. **Figure 4** shows the time-space diagram on an arterial where the middle intersection is critical in terms of the bandwidth. The Plan force mode was used at this intersection to reallocate any unused time to the coordinated (mainline) phases.

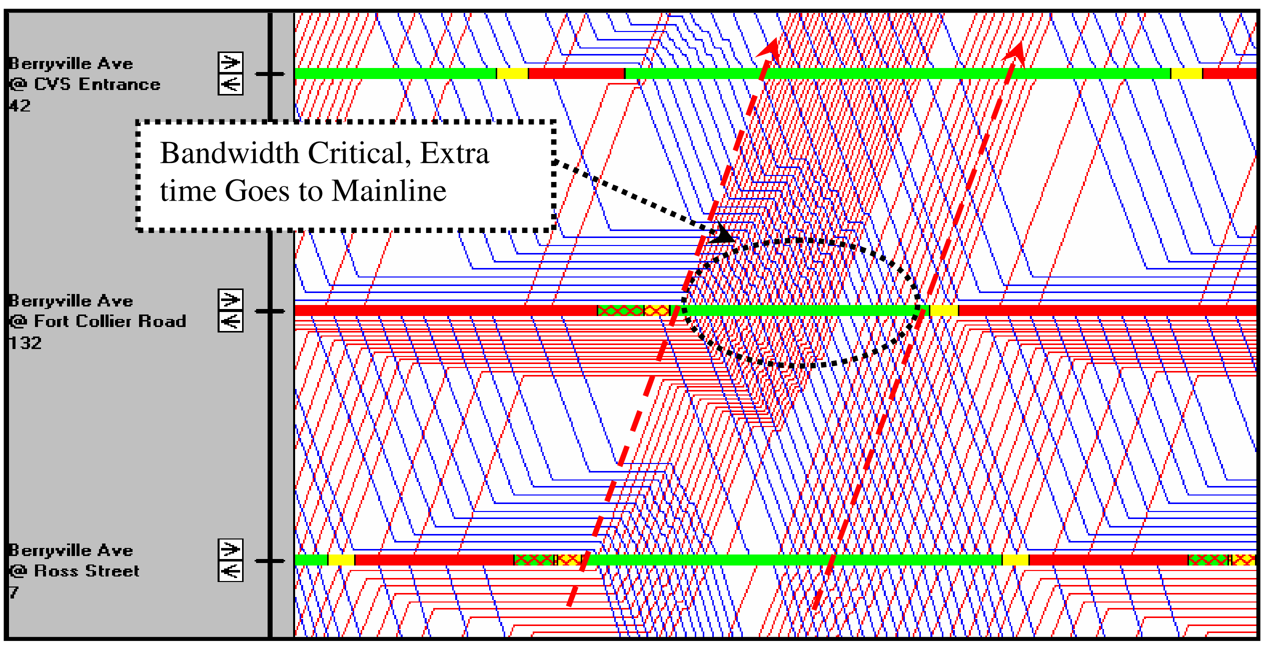

Figure 4. Time-Space Diagram Illustrating where the Plan Force Mode was Used

Dynamic Split

These two intersections (Berryville Avenue and Pleasant Valley Road, and Cork Street and Pleasant Valley Road) are the junction of two major roadways which are prone to hours, which led to.

During the fine turning process, there were several intersections where the programmed split times did not accommodate the heavy surges of traffic. These intersections were subject to abrupt variation in traffic volumes during the peak hours which led to long queues and increases in delays. Due to surges on alternate approaches of the same intersection during other periods, the splits could not be modified. In order to help alleviate the congestion associated with these surges, a special function in the Eagle controllers was enabled to respond to observations of heavy surges - *Coordination Adaptive Split* (CAS) – which essentially "steals" time from phases that don't need it and "gives" times to phases that do need it.

The CAS function allows the controller to adjust the splits for all non-coordinated phases based on whether or not a phase was forced-off or gapped-out. The controller monitors the time usage of each phase under coordination, and designates a phase as a *Wanting Phase* (requesting additional increments of split time) if the phase is forced by coordination for two consecutive cycles. Conversely, a phase is designated as a *Giving Phase* (capable of contributing an increment of split time) if the phase gaps out with over one second left in the coordination force timer, in two consecutive cycles. This adjustment to splits based on examination of the supply/demand situation allows the controller to respond to sudden surges/variation in traffic demand.

Enabling the CAS did not completely solve the side-street congestion, but did maximize the efficiency of the cycle lengths and provided extra green time to accommodate surges of traffic.

9) Construction Costs

Work on Assignment No. 1 is 100% complete. The average cost for a signal rebuild was $127,000.

Optimized Signal Timings on Berryville Avenue

10) Travel Time Improvements

The following is based on data from Assignment No. 1, which is the only assignment 100% completed to date. The goals for this corridor were established early-on in the project, and were to 1) limit the number of stops along the arterial to a maximum of one per direction, and 2) alleviate PM peak hour congestion heading out of the downtown area accessing the arterial from a major side street. The signal timing optimization met both of these goals. Travel times decreased by an average of 25%, and the number of stops decreased by an average of 50%. The signal timing optimization showed a benefit-cost ratio of 25:1, with a weekly savings of 500 gallons of fuel and a reduction of 350 vehicle-hours of delay.

VIII. City Staff Training

As part of the Citywide Signal Upgrade Project, the Public Services Director wanted to train his staff to perform the work that the consulting engineers performed, and to provide them with the resources to do it. One of the recommendations in the Technology Assessment was to purchase bench test equipment. Prior to this project, the City of Winchester did not own any controller or cabinet test equipment. As part of this project, the City purchased a complete TS 2 controller test kit which included: Controller Tester, Conflict Monitor/MMU Tester**,** Surge Suppressor Tester, Loop Detector Analyzer, and a Ground Test Kit. The City also purchased durable laptops for their signal technicians and a signal shop computer. The signal shop computer runs the closed-loop software. Spare parts were ordered for all of the equipment that was purchased in Stage 1 and 2 so that the technicians would have spare parts in case of equipment malfunctions.

The signal technicians in Winchester are responsible for signal timing, signal design, and signal studies. The City purchased Synchro software and the traffic engineering consultants trained the City staff in Synchro. The City also purchased traffic data collection equipment to support traffic signal studies. City staff has also attended ITE webinars and attended short courses on traffic engineering.

IX. VDOT Signal Timing Optimization

The Virginia Department of Transportation Staunton District was able to participate in the Winchester area project through signal timing optimization. The District had allocated some funds for signal retiming and was able to utilize the City's consultants to perform the work. The distances between City-owned and VDOT-owned signals are sometimes within 400 feet. As such, the project was a joint effort to improve mobility, which made the project successful. Both the City and Commonwealth recognized that motorists don't know, or even care which signals is VDOT's and which are the City's – it's all the same road as far as they are concerned. The project consisted of signal optimization of 33 VDOT signals on 7 corridors.

Optimized Signal Timings on US 50 / US 17

One of the challenges was the different philosophies in signal timing. Most of the VDOT signals are along an arterial with signals at expressway / interstate access ramps. As such, VDOT preferred low cycle length to minimize queues. Their chief concern was to avoid queues spilling onto the mainline travel lanes of an expressway / interstate. This contrasted with the City's goals of preferring longer cycle lengths with an emphasis on the number of stops. These different philosophies were resolved through simulation to evaluate various cycle lengths and the resulting queues and stop, and by including both the VDOT and City signals as part of the network. At most locations, the same cycle lengths were selected that would be acceptable in both the City and the Commonwealth. In the one location where this was not possible, a harmonic cycle length was chosen to provide coordination every third cycle.

The other challenge was to maintaining the same background clock time. Although both the City and the Commonwealth used the same closed-loop software, both wanted to retain control of their signals. In order to maintain the same time, both agencies set-up their closed-loop software to reference the atomic clock time, and to update the master clock time at the same time every night.

VDOT created press releases before the start of each corridor optimization project and after each was completed. The "Before" press releases established the goals and served to inform the public of the project. The "After" press releases provided the final costs and the resulting travel time, delay and environmental improvements.

During the project, VDOT identified commuters who had complained about the signal timing along the corridor and asked if they would partner with them during the optimization process. The designed team recognized that regular commuters often notice signal timing issues that the design team may not notice over a short period. This approach was only as useful as the interest from the commuter. The commuters that were interested provided valuable feedback; the uninterested did not provide any useful feedback.

The project benefits included decreases in travel times by an average of 20%, and decreases in the number of stops by an average of 40%. The signal timing optimization showed an average benefit-cost ratio of 40:1, with a total weekly savings of 4,000 gallons of fuel and a reduction of nearly 2,000 pounds of emissions.

X. Lessons Learned

The signal upgrades and re-timing have been hugely successful due the following key factors: 1) a committed, hands-on, empowered project champion, 2) an experienced, hard-working contractor with adequate resources and staff, 3) two experienced traffic engineering consultants that successfully divided the work between the right people for each job, 3) regular coordination meetings that included everyone from the contractor's foreman to the consultants, 4) establishing difficult expectations, goals and deadlines early-on in the process, and 5) City Council (political) support and funding.

XI. Authors Contact Information

Mr. Keith A. Riniker, PE, PTOE, Senior Traffic Engineer
Sabra, Wang & Associates, Inc.
1506 Joh Avenue, Suite 160
Baltimore, MD 21227
kriniker@sabra-wang.com
Phone: 410-737-6564

Mr. Perry Eisenach, P.E.,
Public Services Director
City of Winchester
15 North Cameron Street
Winchester, VA 22601
peisenach@ci.winchester.va.us
Phone: 540-667-1815

Mr. Thomas Hannan, P.E.,
Senior Vice President
Whitman, Requardt and Associates, LLP
801 South Caroline Street
Baltimore, MD 21231
thannan@wrallp.com
Phone: 443-224-1523