Metroplan CARTS Adaptive Signal Control Technology (ASCT) System Engineering Analysis

By

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and

October 14, 2015

Metroplan CARTS Adaptive Signal Control Study

Concept of Operations

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Solutions you can build upon

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1 SCOPE

1.1 Document Purpose and Scope

The scope of this document covers the consideration of adaptive signal control technology (ASCT) use within the City of Maumelle, the City of North Little Rock, and Pulaski County AR as part of the Central Arkansas Regional Transportation Study area, as shown in Figure 1. This document describes and provides a rationale for the expected operations, maintenance and stakeholder management of the proposed adaptive system. It also documents the outcome of stakeholder discussions and consensus building that has been undertaken to ensure that the system that is implemented is operationally feasible and has the support of the stakeholders identified in the ITS Regional Architecture, and through identification of other stakeholders from the cities of Maumelle and North Little Rock, and Pulaski County.

Following completion of the concept of operation, with agreement among stakeholders about the needs, the operating concepts, the operational environment and support environment, the detailed system requirements will be prepared and documented separately as part of the full System Engineering Analysis (SEA).

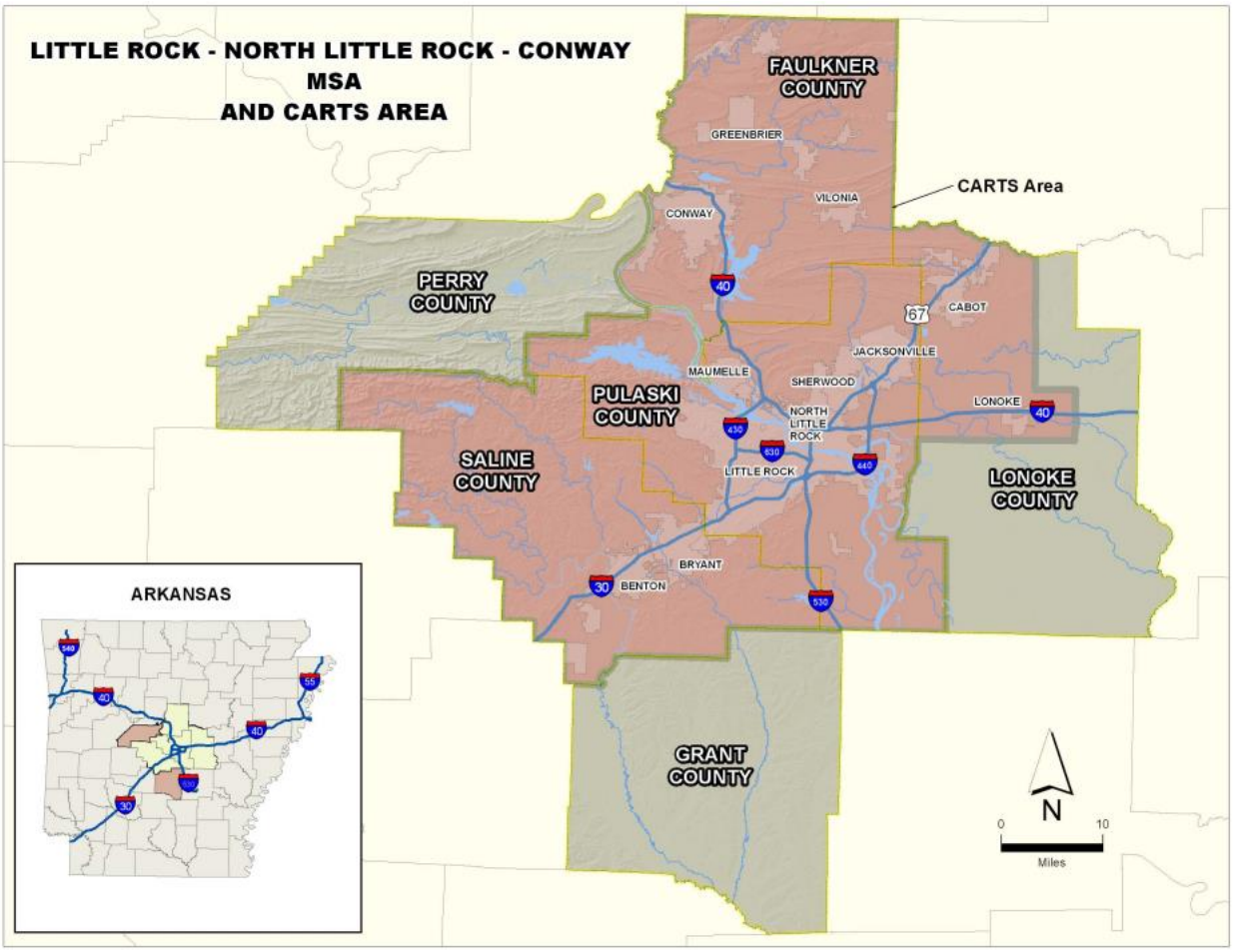


Figure 1 CARTS area

1.2 Project Purpose and Scope

The main purpose of this project is to define all of the stakeholder's needs and objectives to qualify the use of adaptive traffic signal control, and to select a system that can best accommodate these needs and objectives. There are many operational stakeholders within the proposed initial project area of Maumelle Boulevard. This makes this particular adaptive signal study unique in that the initial corridor has many maintenance entities, or responsible parties, for the signals on the study corridor. The later design portion of this project will define the adaptive traffic signal system that satisfies the documented system requirements and the stakeholder's needs and constraints through technical special provisions and all necessary design plans and documents as required by the City of Maumelle, City of North Little Rock (also herein referred to as the 'City'), Pulaski County, the Arkansas Highway and Transportation Department (AHTD), and the Federal Highway Administration (FHWA).

This project involves consideration of the application of ASCT initially to Maumelle Boulevard and Highway 365 (MacArthur Drive) between Northshore Drive, by the interchange of Interstate I-430, north to I-40 at the north terminus of the initial study corridor. However, to the extent that it appears feasible, consideration will also be given to application of ASCT to other future corridors within the operating and maintaining jurisdictions, as residential and commercial developments grow within the project area. The project initial corridor location is shown in Figure 2.

The primary objectives of the adaptive traffic signal system are to accommodate the irregular traffic patterns within the project area created by existing commuter and commercial traffic, provide smoother traffic flow along Maumelle Blvd for that traffic, and to accommodate the need for constantly changing signal timing for new developments in the area. The Cities of Maumelle and North Little Rock (NLR) continue rapid growth both in residential and commercial developments. The Maumelle Blvd corridor is the main arterial for these developments to access the interstate system and the subject of many traffic complaints by Maumelle and NLR citizens. An adaptive signal system is one tool that may help alleviate these complaints.

An adaptive traffic signal system is one in which some or all the signal timing parameters are modified in response to changes in the traffic conditions, in real time. The purpose of providing adaptive control in the project area is to overcome the limitations of the existing system to handle the irregular traffic pattern introduced by the interstates and variations in adjacent land uses. This project will review the needs for adding adaptive capabilities to the functionality of the existing coordinated signal system. All the capabilities of the existing coordinated system will be required to be maintained. The adaptive system may function independently or work with the existing traffic signal system and time-of-day (TOD) plans that may be in place. Additionally, the adaptive system may be manually turned off to allow the existing traffic signal system to have control. The adaptive system will be integrated with the existing traffic signal system, and fallback and failure modes will be defined in Section 5.3.

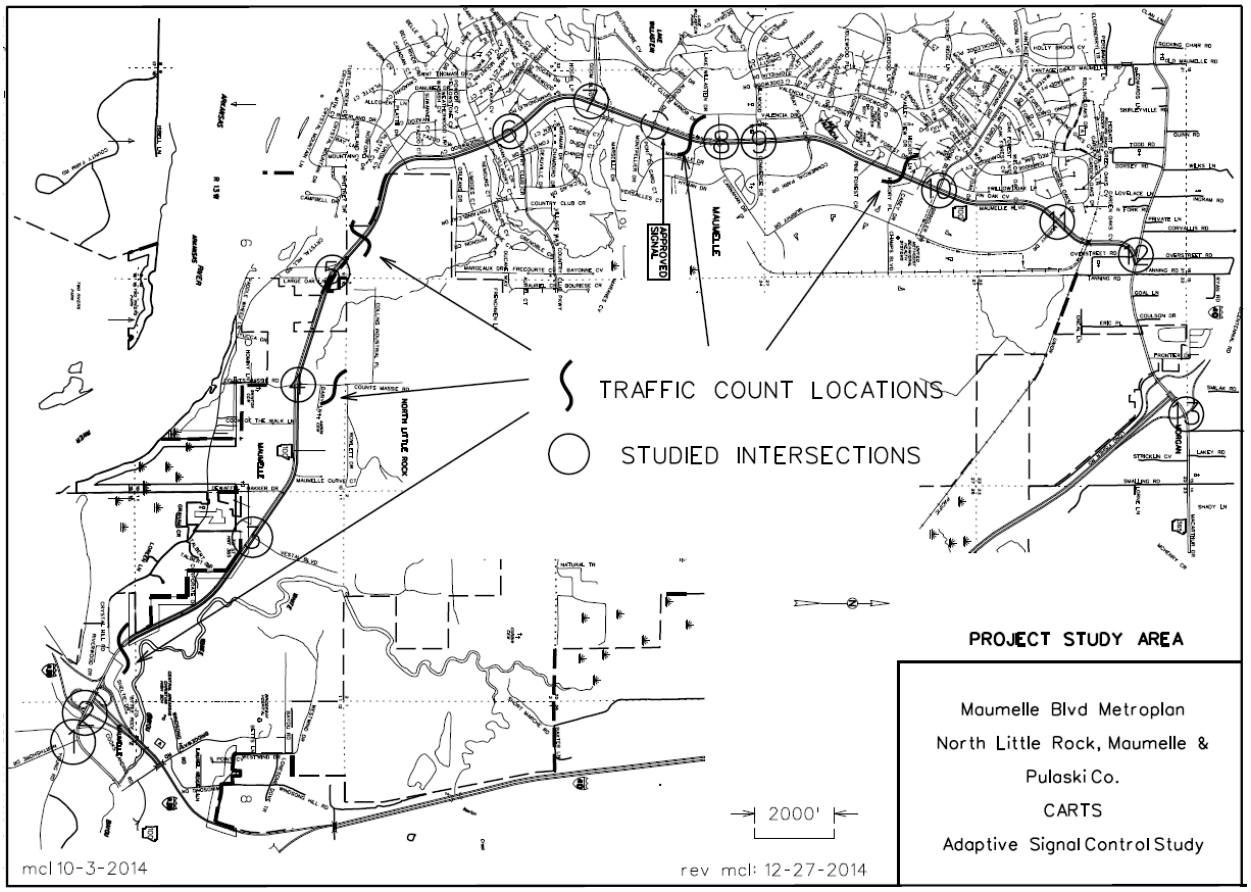


Figure 2 Maumelle Blvd adaptive signal system study corridor location

1.3 Procurement

The proposed ASCT will be procured through a Best Value Request for Proposal procurement process, in keeping with the procedures adopted by AHTD and FHWA. This will allow the selection of the system that best satisfies the system requirements, subject to satisfactory price negotiations. Should there be a significant amount of field construction required, it may be appropriate to separate the system procurement from the field construction, and enter into a low-bid construction contract for the field installation work. Procurement options for detection and communications modifications are being discussed with AHTD and FHWA.

2 REFERENCED DOCUMENTS

The following documents have been referenced or used to guide the preparation of this concept of operation.

2.1 Planning Documents

- Regional Strategic Transportation Network: http://www.metroplan.org/files/53/2011-01Regional_Strategic_Network.pdf
- Transportation Planning Structure: http://www.metroplan.org/files/53/TransPlanStructure001.pdf
- CARTS Transportation Improvement Plan: http://www.metroplan.org/files/53/TIP-2013-16_02.pdf
- FY 2015 Unified Planning Work Program: http://www.metroplan.temp1000.com/files/53/2015UPWP.pdf
- CARTS Public Participation Plan: http://www.metroplan.org/files/53/2011CARTS_PPP.pdf
- The Long-Range Transportation Plan for Central Arkansas: http://draftplan.imaginecentralarkansas.org/draft-plan-chapter-7-long-range-metropolitan-transportation-plan

2.2 Adaptive Signals

- NCHRP Synthesis 403: "Adaptive Traffic Control Systems: Domestic and Foreign State of Practice", http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_403.pdf

2.3 ITS, Operations, Architecture, Others

- FHWA Rule 940, Federal Register / Vol. 66, No. 5 / Monday, January 8, 2001 / Rules and Regulations, DEPARTMENT OF TRANSPORTATION, Federal Highway Administration 23 CFR Parts 655 and 940, (FHWA Docket No. FHWA-99-5899) RIN 2125-AE65 Intelligent Transportation System Architecture and Standards
- Regional ITS Architecture Guidance Document, "Developing, Using, and Maintaining an ITS Architecture for your Region; National ITS Architecture Team; October, 2001
- CARTS Intelligent Transportation System Plan and Regional ITS Architecture http://www.metroplan.org/files/53/2010CARTS_ITS.pdf
- NTCIP 1211 version v02. "Signal Control and Prioritization (SCP)."
- NEMA TS1
- NEMA TS2

2.4 System Engineering

- FHWA. (2012, August). Model Systems Engineering Documents for Adaptive Signal Control Technology (ASCT) Systems - Final Guidance Document. U.S. Department of Transportation. http://ops.fhwa.dot.gov/publications/fhwahop11027/mse_asct.pdf
- FHWA. (2007, January). Systems Engineering for Intelligent Transportation Systems - An Introduction for Transportation Professionals. U.S. Department of Transportation. http://www.ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf
- FHWA Systems Engineering Guidebook Version 3.0, http://www.fhwa.dot.gov/cadiv/segb/
- FHWA. (2013, July). Measures of Effectiveness and Validation Guidance for Adaptive Signal Control Technologies http://www.ops.fhwa.dot.gov/publications/fhwahop13031/index.htm

2.5 Procurement

- NCHRP 560 Guide to Contracting ITS Projects, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_560.pdf
- The Road to Successful ITS Software Acquisition, http://www.fhwa.dot.gov/publications/research/operations/its/98036/rdsuccessvol2.pdf

3 USER-ORIENTED OPERATIONAL DESCRIPTION

3.1 How Does the Existing System Work?

The existing traffic signal system within the suburban project area is operated and maintained separately by the City of North Little Rock (signal #'s 1 – 5 on Figure 2), and by contract to an independent signal maintenance technician for the City of Maumelle (signal #'s 6 – 11 on Figure 2), and Pulaski County (signal #'s 12 – 13 on Figure 2). The City of Maumelle and the County can do light traffic signal maintenance, such as replacing bulbs or resetting conflict monitors, but contract out complex signal maintenance to an outside company. The City of North Little Rock (NLR) does all of their signal operation and maintenance with their own City personnel. Both NLR staff and the signal maintenance contractor have Siemens TACTICS-Marc software to maintain the signal databases along this corridor.

The traffic signals along the North Little Rock portion of the corridor are currently operating under time-of-day (TOD) control which implements the appropriate traffic signal timing parameters based on time of the day and day of the week. The intersection at Vestal in NLR operates free during the AM peak. This operation has been found to be beneficial to the flow of traffic in the NLR owned section. Recently, coordination has been done for the signals from Northshore Dr. through Crystal Hill Rd. The traffic signals in the City of Maumelle and Pulaski County sections currently operate under 'Free' control, not under any specific timing plan, though timing plans at one time were developed by AHTD. The traffic signals in the project area operated by NLR are connected to the City Traffic Engineering Division through a broadband modem at a master controller at the intersection of Counts Massie and Highway 100 (Maumelle Blvd). The intersections in the City of Maumelle and Pulaski County are connected through a repeater radio on the Maumelle water tower. Master communications to the local intersections are accomplished through 900 MHz spread spectrum radios operating at 19.2 k baud with a repeater at the Maumelle water tower. These units have been subject to lightning damage and inconsistent communications to the Maumelle and Pulaski County intersections.

Local detection has been upgraded to video at some of the intersections. The City of North Little Rock can currently dial in and see video from their equipped intersections on the initial study corridor. Intersections maintained by the City of Maumelle utilize loop detection. In the absence of vehicles detected on the left turn lanes or the side streets, or pedestrian push button actuation across the main road, the signals typically rest in green for the coordinated or main street movement. The green time for the left turns and cross streets extend up to the pre-set maximum phase time, or split times if running TOD operation, but may terminate early if all waiting vehicles are served. The main road always receives at least the pre-set phase time (and any unused time from the minor phases), regardless of number of vehicles present. If a pedestrian phase is operating, the associated vehicle phase will not terminate unless the pedestrian safety timing has been satisfied.

Along the corridor, there is marginal pedestrian activity. There is a limited service transit express route (Central Arkansas Transit) along the corridor, however it does not currently implement Transit Signal Priority. There are Emergency Management/Fire facilities along the corridor as well, however they do not currently operate any remote controlled signal preemption devices, with the exception of a push button signal service/preemption at the fire station on Maumelle Blvd.

Monitoring of the system for local failures is primarily on an "as called" basis. Failures often go unreported until a motorist reports an issue to the local agency. It was noted that detection failures can exist for some time before being reported, since there is currently not active traffic operations personnel monitoring the signal system on a consistent day to day basis.

3.2 What are the Limitations of the Existing System?

The existing traffic signal system manages a limited number of different traffic signal timing plans based on the time of the day in the North Little Rock section (Figure 3 provides example). The NLR section is one of the busiest and most congested sections due to trickle-down commuter traffic to the interstate and the various commercial and retail businesses in the south portion of the corridor. In the middle and north sections, mostly within the City of Maumelle, the timing plans implemented by AHTD some time ago are not currently running, mostly due to communication loss from the master controller to the controllers on these middle/north sections. These signals are currently operating in 'free' operation. Appendix A provides additional volume data plots.

Although it is possible to store a large number of timing plans in the controllers to possibly help alleviate the congestion by time of day, the communications issues and variations of traffic patterns due to development over the past few years have made it difficult to keep up with any sort of signal timing in this area. Another issue of this corridor is construction closures and accidents on the interstate (I-40 or I-430) cause this corridor to become a bypass to the interstate, sometimes doubling the volume it usually carries (see Figure 4).

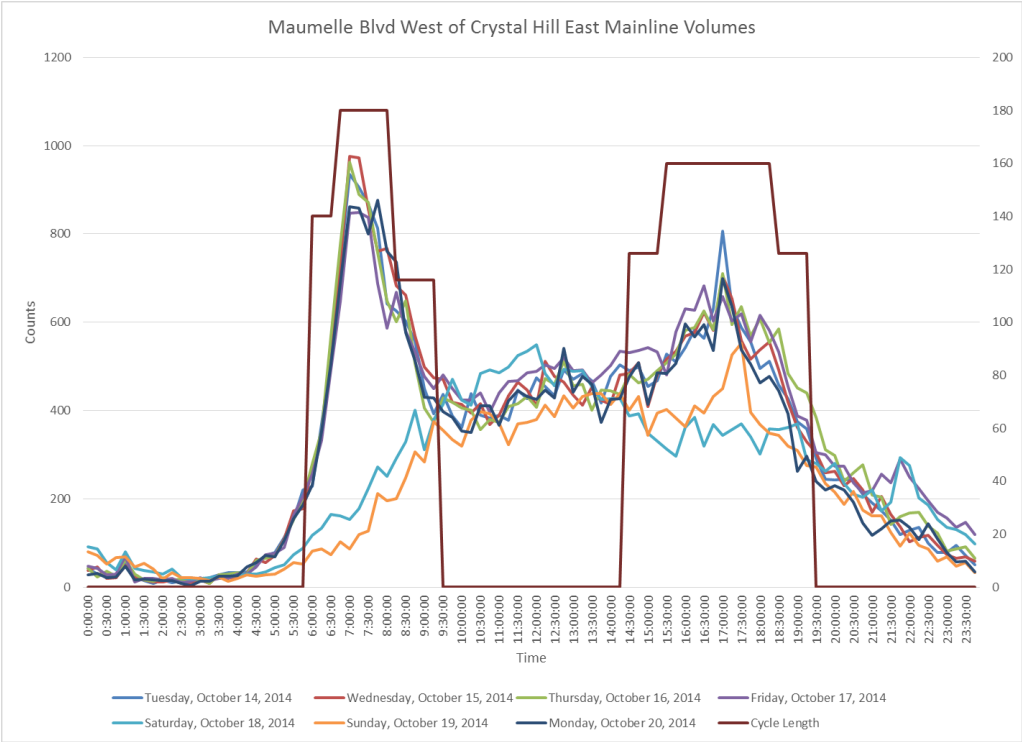


Figure 3 Example volume data plot vs. cycle length – typical week

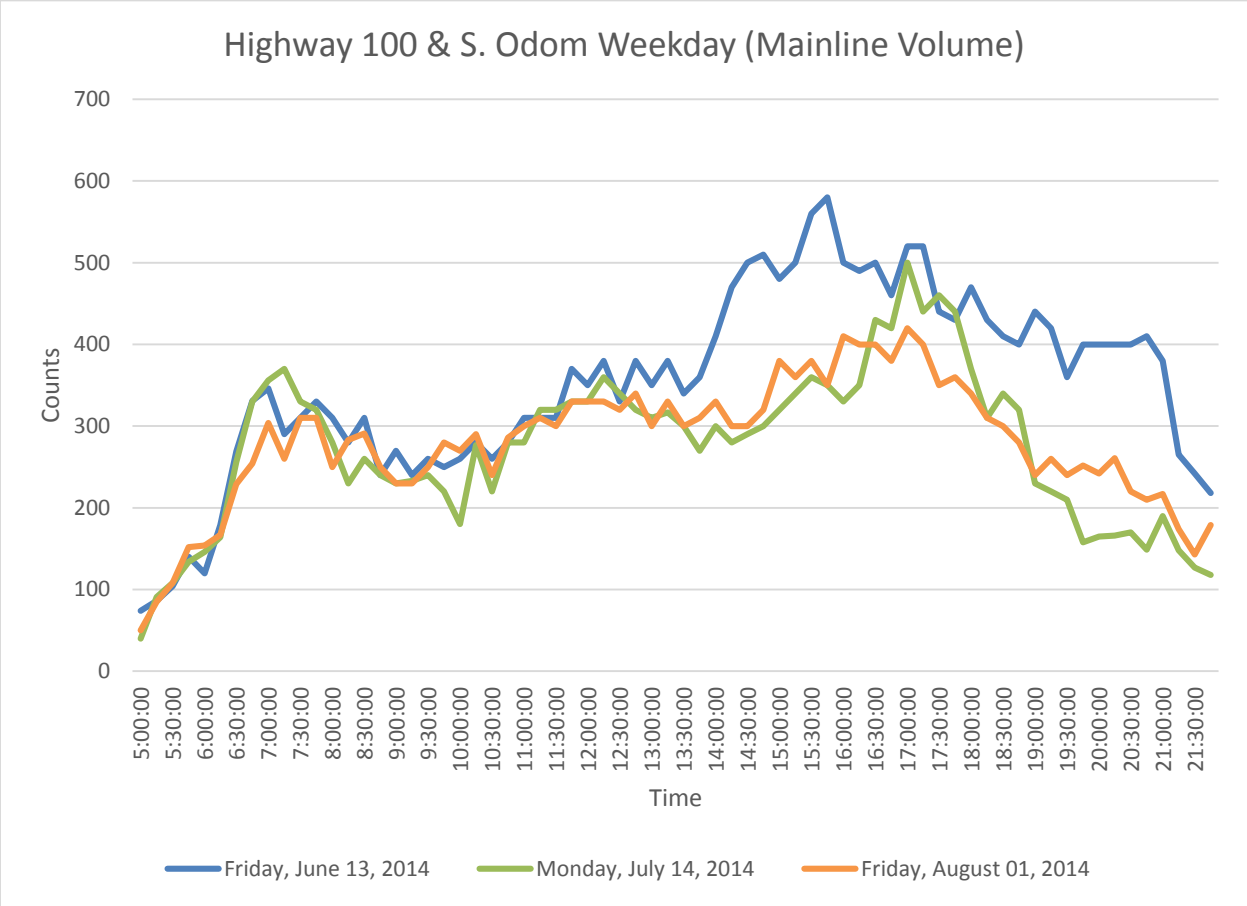


Figure 4: Example volume increase on corridor from an interstate incident (13:30 Through PM Peak Friday, June 13, 2014)

While the existing system could be configured to dynamically choose different timing plans based on measured traffic volume and occupancy, using traffic responsive pattern selection (TRPS), this approach has not been employed to date. Because of the variable and complex nature of the traffic patterns and the quick peaks at which they arrive, the existing system cannot successfully, dynamically choose the most appropriate timing plan from among a large number of candidates over the time required for TRPS to work. As a result, the current traffic signal system and operations staff cannot provide sufficient variation to handle the irregular traffic patterns to and from the nearby commercial and residential facilities, as well as to and from the freeway, in an efficient manner.

The following statements summarize the traffic situations that are affected by the limitations of the existing system described above:

- The existing arterial system cannot detect unexpected changes in traffic demand and adjust signal timing as a result of incidents on the arterial or from the nearby freeways.
- Large industrial and distribution companies have varying work and delivery schedules throughout the work week, and throughout the year which add to unstable traffic demands at the signalized intersections

- There are not any alternative arterials that can access the freeways as bypass routes for this traffic. Maumelle Blvd is the only arterial in this area that can access the freeway system. This creates instability on the corridor, and is a source of variability in traffic volumes and traffic patterns.

3.3 How Should the System be Improved?

There is a strong need to improve the system so it can better accommodate changes in traffic patterns and volumes, both expected and unexpected. It needs to be able to monitor the traffic conditions in real time and modify the signal operation to efficiently accommodate the measured conditions to provide directional as well as optimal two-way smooth flow. These improvements would allow the system to accommodate the normal large fluctuations in traffic patterns associated with the various seasons of the year, and also accommodate diverted and congested traffic during incidents on the freeway and on the arterial roads.

While it is believed that a short term solution would be to implement new TOD plans along the entire corridor, the area has developed so much in the past 10 – 15 years that those TOD plans would likely not be a viable solution over a longer sustained period. The need to update these plans annually would place a burden on the maintaining agencies since it is likely it would require an outside consultant contract to complete that signal timing work. It has been demonstrated that TOD plan upkeep is not a reliable source for continued traffic signal operations along this corridor. In addition, this solution would not solve variability in traffic demand due to incidents on the freeway, or from variability of work and delivery schedules from the nearby industry and commercial facilities.

3.4 Statement of Objectives for the Improved System

The objectives of the improved system are:

- More rapidly adjust operations to changing traffic conditions
- Reduce delays at traffic signals
- Reduce travel times through the traffic signal system
- Smooth the flow of traffic along coordinated routes
- Maximize the throughput of traffic along coordinated routes
- Equitably serve adjacent land uses
- Manage queues, to prevent excessive queuing from reducing efficiency
- Allow remote monitoring and control of traffic signals
- Adhere to applicable traffic signal and ITS design standards and the Regional ITS Architecture
- Reduce vehicle emissions through improvements in appropriate determinants such as vehicle stops and delays
- Control arterial queue buildup and freeway off-ramps in order to prevent queue backup onto the freeway
- Provide ease of maintenance and day-to-day operation of the traffic signals. Make more efficient use of the staff time available.

3.5 Description of Strategies to be Applied by the Improved System

The adaptive coordination and control strategies that may be employed (concurrently or under different conditions) to achieve the operational objectives are:

- Provide a green band along a coordinated route to maximize the throughput during periods of high demand.
- Provide a green band along a coordinated route to smooth the flow of traffic in one or both directions.
- Distribute phase times in a way that equitably shares the green time between various movements and minimizes the risk of phase failures (phase terminates with a residual queue).
- Manage queues so that they do not exceed the available storage capacity and are located so they do not affect the capacity of other movements.
- Manage the distribution of green times for vehicles and pedestrians in an equitable manner.
- Employ a combination of these strategies when they are compatible.

It is understood that some of these strategies may conflict with one another, and the selection will best optimize the operation.

3.6 Alternative Non-Adaptive Strategies Considered

The alternative non-adaptive strategies that have been considered for this project are:

- Do nothing – The do nothing alternative is not an acceptable option in this project because the limitations mentioned above will continue. Due to ongoing and future roadway and development construction projects around the area, the traffic variability will only continue to get worse.

- Additional/New TOD patterns – (See Section 3.3 above) More TOD patterns could be used to accommodate a greater variety of traffic conditions. Traffic studies would need to be conducted at many controlling intersections along the route. This would require greater staff and/or consultant input to create and maintain the extra patterns and the plan introduction schedule. However, this would only give better coverage of normal traffic fluctuations, and would not accommodate unexpected conditions and conditions that occur at variable or unpredictable times. An improvement in the communications system would also be required.

- Hire traffic engineering/maintenance staff – with additional traffic engineering and maintenance staff, the traffic conditions could be visually monitored in real time and when unexpected or unpredictable conditions are observed, the most appropriate pre-stored timing pattern could be selected and adjusted. However, this would require using the various cities operational budget and require full visual coverage of all locations at which an adaptive system would otherwise be suitable. It would also potentially require a very large number of pre-stored plans, many of which would not be able to be tested and fine-tuned in advance because they would be prepared for hypothetical situations. Currently, there is not enough

operational budget to fund such a position or positions to do this work, nor is it feasible for the size of the corridor and surrounding City population.

- Traffic responsive pattern selection (TRPS) – TRPS has been applied successfully on arterial roads with predictable traffic conditions that are significantly different at different times of the day, are easily measurable, and on which the majority of the traffic on the coordinated route is through traffic. However, in the area under consideration, the variations in traffic conditions are more complex, and there are many trip origins and destinations within each coordinated group as well as many sections that may become one or act separately. It is therefore considered very unlikely that TRPS could be successfully used to accommodate the range of traffic conditions due to these groupings and quick increases in volume, as well as continued development of this area.

4 OPERATIONAL NEEDS

This section describes the operational needs of the users that should be satisfied by the proposed ASCT system. Each of these statements describes an operational need that the system operators have. Each of these needs will be satisfied by compliance with one or more system requirements. In the list of system requirements, each requirement is linked to one or more of these needs statements.

4.1 Adaptive Strategies

1. The system operator needs the ability to implement different strategies individually or in combination to suit different prevailing traffic conditions. These strategies include:
    a. Maximize the throughput on coordinated routes
    b. Provide smooth flow along coordinated routes
    c. Distribute phase times in an equitable fashion
    d. Manage the lengths of queues
    e. Manage the locations of queues within the network
    f. At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2. The system operator needs to manage the coordination in small groups of signals to link phase service at some intersections with phase service at adjacent intersections.
3. The system operator needs to change the operational strategy (for example, from smooth flow to maximizing throughput or managing queues) based on changing traffic conditions.
4. The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue resulting from the trailing end of the through green from blocking the storage needed by an entering side-street left turn in the subsequent phase.
5. The system operator needs to minimize the chance that a queue forms at a specified location.
6. The system operator needs to modify the sequence of phases to support the various operational strategies.
7. The system operator needs to fix the sequence of phases at any specified location. For example, the operator may need to fix the phase order at a diamond interchange.
8. The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.
9. The system operator needs to set signal timing parameters (such as minimum green, maximum green and extension time) to comply with City's policies.

4.2 Network Characteristics

1. The system operator needs to eventually adaptively control up to 200 signals.

2. The system operator needs to be able to adaptively control at least ten independent groups of signals per corridor.
3. The system operator needs to vary the number of signals in an adaptively controlled group to accommodate the prevailing traffic conditions.

4.3 Institutional and System Boundaries

1. The system operator needs to adaptively control signals operated by Pulaski County, City of Maumelle, and City of North Little Rock, and under agreement, all of the corridor signals will be maintained by the City of North Little Rock.
2. The system operator needs to adaptively coordinate signals on two crossing routes simultaneously. (All signals within the group are under the control of City Maumelle, City of North Little Rock, or Pulaski County.)
3. The system operator needs to constrain the adaptive system to operate a cycle length compatible with the crossing arterial.
4. The system operator needs to detect traffic approaching from a neighboring system and coordinate the ASCT operation with the adjacent system.

4.4 Security

1. The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator, and conform to the City's access and network infrastructure security policies.

4.5 Queuing Interactions

1. The system operator needs to detect queues from outside the system and modify the ASCT operation to accommodate the queuing.
2. The system operator needs to detect queues within the system's boundaries and modify the ASCT operation to accommodate the queuing.
3. The system operator needs to detect queues propagating outside its boundaries from within the ASCT boundaries, and modify its operation to accommodate the queuing.
4. The system operator needs to store queues in locations where they can be accommodated without adversely affecting adaptive operation.
5. The system operator needs to prevent queues forming at user-specified locations.

4.6 Pedestrians

1. The system operator needs to accommodate infrequent pedestrian operation while maintaining adaptive operation.
2. The system operator needs to incorporate frequent pedestrian operation into routine adaptive operation.
3. The system operator needs to accommodate early start of walk

4.7 Non-Adaptive Situations

1. The system operator needs to detect traffic conditions during which adaptive control is not the preferred operation, and implement some pre-defined operation while that condition is present.
2. The system operator needs to schedule pre-determined operation by time of day.
3. The system operator needs to over-ride adaptive operation.

4.8 System Responsiveness

1. The system operator needs to modify the ASCT operation to closely follow changes in traffic conditions. Should conditions change, such as a change in strategy from smooth flow to reducing total intersection delay at particular intersections, the system operator needs to identify the deficiency and adjust the operation accordingly.
2. The system operator needs to constrain the selection of cycle lengths to those that provide acceptable operations, such as when "resonant" progression solutions are desired to provide two-way coordination along one or more arterial routes.
3. The system operator needs to respond quickly to sudden large shifts in traffic conditions.

4.9 Complex Coordination and Controller Features

The system operator needs to implement the following advanced controller features while maintaining adaptive operation:

1. Service a phase more than once per cycle
2. Operate at least eight overlap phases
3. Operate four rings, sixteen phases and up to four phases per barrier.
4. Permit different phase sequences under different traffic conditions while avoiding the yellow trap.
5. Allow one or more phases to be omitted (disabled) under certain traffic conditions or signal states.
6. Prevent one or more phases being skipped under certain traffic conditions or signal states.
7. Allow any phase to be designated as the coordinated phase.
8. Allow the operator to specify which phase receives unused time from a preceding phase.
9. Allow the controller to respond independently to individual lanes of an approach. This may allow the adaptive operation to be based on data from a specific detector, or by excluding specific detectors.
10. Allow flexible timing of non-coordinated phases (such as late start of a phase) while maintaining coordination
11. Allow protected/permissive phasing and alternate left turn phase sequences.
12. Use flashing yellow arrow to control permissive left turns and right turns.

13. Service side streets and pedestrian phases at minor locations more often than at adjacent signals when this can be done without compromising the quality of the coordination. (E.g., double-cycle mid-block pedestrian crossing signals.)
14. Use negative pedestrian phasing to prevent an overlap conflicting with a pedestrian walk/don't walk

4.10 Monitoring and Control

The system operator needs to monitor and control all required features of adaptive operation from the City's:

- Traffic Engineering Division Building
- LAN workstations
- Local controller cabinets
- Remote locations Via VPN

The operator needs to access the database management, monitoring and reporting features and functions of the signal controllers and any related signal management system from the access points defined for those system components (e.g., individual office workstation).

4.11 Performance Reporting

1. The agency needs the TACTICS system to be able to monitor status of the signal system during ASCT operation.
2. The system operator needs to store and report data used to calculate signal timing and have the data available for subsequent analysis.
3. The system operator needs to store and report data that can be used to measure traffic performance under adaptive control.
4. The system operator needs to store all operational data and signal timing parameters calculated by the adaptive system, and export selected data to Microsoft Excel spreadsheets, text files, CSV files, or an open SQL database.
5. The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.

4.12 Failure Notification

1. The system operator needs to immediately notify maintenance and operations staff of alarms and alerts.
2. The system operator needs to immediately and automatically pass alarms and alerts to the City.
3. The system operator needs to maintain a complete log of alarms and failure events.

4.13 Preemption and Priority

1. The system operator needs to accommodate bus rapid transit.
2. The system operator needs to accommodate emergency vehicle preemption

4.14 Failure and Fallback Modes

The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.

4.15 Definition of Constraints

The system operator is constrained to use the following equipment:

1. Controller type – Siemens M34, M42, M52 series controllers
2. Detector type – Iteris Video detection, inductive loops, Sensys magnetometers, microwave radar
3. Communication system – hardwire/fiber and wireless IP/Ethernet,
4. Cabinet type – NEMA TS1, NEMA TS2, Type 2
5. Traffic signal system software – the adaptive system must not prevent the existing Siemens TACTICS central system from monitoring and recording intersection status, including the collection of all detection data and any signal failures being reported by the Controller.

The system operator needs to use equipment and software acceptable under the City's current technology policies and procedures (Windows-PC, Windows 7 operating system).

4.16 Training and Support

1. The Cities need all staff involved in operation and maintenance to receive appropriate training.
2. The Cities need the system to fulfill all requirements for the life of the system. The Cities therefore need the system to be maintained to repair faults that are not defects in materials and workmanship.
3. The Cities need the system to fulfill all requirements for the life of the system. The Cities therefore need the system to remain free of defects in materials and workmanship that result in requirements no longer being fulfilled.
4. The Cities need the system to fulfill all requirements for the life of the system. The Cities therefore need support to keep software and software environment updated as necessary to prevent requirements no longer being fulfilled.

4.17 External Interfaces

The Cities do not require any external interfaces for the proposed adaptive traffic signal system.

4.18 Maintenance

Each maintenance crew of the maintenance agency (currently the City of North Little Rock) needs all applicable equipment to be readily accessible for maintenance and support activities in the field and at other locations within the maintaining agency. Special access equipment not normally available to them for maintenance will not be allowed.

5 ENVISIONED ADAPTIVE SYSTEM OVERVIEW

5.1 Size and Grouping

There are several areas within the Maumelle/North Little Rock region in which the envisioned adaptive traffic signal system may adaptively control traffic. While an initial deployment on Maumelle Blvd may involve up to 13 intersections, it is expected that the number of intersections to be adaptively controlled will be expanded in the future for this region. The system will control intersection groups that are defined by the operator.

A group of intersections may be comprised of simply one intersection, or up to the total number of intersections that are sufficiently close to warrant coordination under the prevailing traffic conditions. There is expected to be some variability in the composition of groups of coordinated signals, depending on the variable nature of traffic demand levels. During some traffic conditions, there may be separate groups of intersections operating with different characteristics (e.g., different cycle lengths, some are coordinated and some are not, offsets may be in different directions). During periods when traffic conditions are similar or operating characteristics (such as cycle length) are similar, or traffic volumes on the coordinated route are heavier, different groups may be formed or specified by the operator.

5.2 Operational Objectives

The operational objective set by the system operator will vary according to the prevailing traffic conditions. Each of the following objectives will be available for implementation as appropriate.

- The objective of the coordination will be to provide for smooth flow along the arterial road, minimizing the number of stops experienced by vehicles traveling along the road. Where "natural" cycle lengths exist that permit two-way progression, the system will generally operate at one of those cycle lengths unless longer phase lengths are required to accommodate the demand.
- The objective of the coordination will be to maximize the throughput along the coordinated route. This may involve a tradeoff that increases delay to cross streets and turning movements in order to maximize the green time provided to coordinated traffic flows.
- The objective of the coordination will be to control traffic in a manner that equitably serves the adjacent land uses. The delays experienced by the traffic entering and leaving the coordinated route will be balanced with the delays and stops experienced by other traffic traveling along the route.
- The objective of the coordination will be to manage the lengths of queues stored at critical locations within the coordinated group so that long queues do not block upstream intersections, back up from freeway off-ramps to the mainline and affect the freeway mainline traffic, or otherwise reduce the capacity available during the green phases. This will involve controlling phase lengths so that the size of platoons entering a downstream block does not exceed the storage length if the platoon will be stopped. It will also involve control of offsets and phase lengths so that queues may be stored in locations where they will not adversely affect capacity of the system.

The system, or the operator, will select the appropriate coordination objective, depending on the current traffic conditions. For example, during commuter peaks the primary objective may be to maximize the throughput along the road in the peak direction. Then during the business hours the objective may be to balance delays between traffic associated with the adjacent activity and traffic simply traveling through the system.

The operator will be able to define for each group of intersections the appropriate operational objective. For example, near a freeway interchange or in a location with heavy turning movements, the queue management strategy may be specified, while on an arterial with long signal spacing the smooth flow objective may be specified.

During moderate to light traffic conditions, one or more phases may be omitted (e.g., a protected phase if protected/permissive left turns are operated), in order to more efficiently serve other movements through the use of lower cycle lengths, provided it is safe to do so. This may be accomplished disabling a phase through a time of day schedule or based on measurements of traffic conditions that confirm it would be safe and efficient to disable the phase. This does not refer to phase skipping simply due to absence of demand for a phase.

Within these operational objectives, the ASCT system will change its operation to accommodate the rise and fall of volumes through the peaks and the changing patterns of flow throughout the day and week. However, there is also a stochastic element to traffic in the short term, with the number of arrivals for a phase varying from cycle to cycle, and pedestrians not being present on all phases in all cycles. It is therefore desirable for the system to have some local tactical control. While vehicle-actuated coordination typically allows phases to run longer or shorter from cycle to cycle to match the actual number of vehicles using the phase, the system will also allow the operator to decide where the unused time will be used. If a phase is to be skipped, the operator can specify that the spare time will be added to the existing phase, the following phase or the next coordinated phase.

5.3 Fallback Operation

The system will have a fallback state that allows coordination using a common cycle length for all signals within a coordinated group, based on a time of day library, or the prior operation of the signal, such as ‘free’ operation.

The system will have a fallback state that allows (at the discretion of the operator) individual intersections to operate in a vehicle-actuated, isolated mode in the event of failures of the adaptive processor software or hardware, detectors or communication.

5.4 Crossing Routes and Adjacent Systems

While not a specific need for the initial corridor, crossing routes and adjacent systems may need to supply data and input into the ASCT system in the near future.

A coordinated group will be able to include more than one coordinated route, such as two crossing arterials. The system will be able to maintain coordination along both roads.

The stakeholders will need the adaptive system to maintain coordination with another adjacent system either by sensing arriving traffic or by using constraints on cycle length.

The system will accept data from a neighboring system that allows it to stay in coordination with the adjacent system while still operating in adaptive mode.

5.5 Operator Access

Operators, traffic engineering and maintenance staff will be assigned different levels of authority, and access to equipment for which they are authorized, based on their roles and responsibilities. This will allow them to control, view, monitor, and analyze the operation of the system as appropriate to accomplish their duties.

The system will be connected to the City of North Little Rock LAN, allowing access to all authorized users that will be maintaining the system.

5.6 Complex Coordination and Controller Operation

The City will use the following complex coordination and controller features:

- The ability to repeat a phase, such as running a left turn phase before and after its opposing through movement.
- Provision for the required number of rings, phases, phases per ring, and overlap phases.
- The ability to operate different phase sequences based on different traffic conditions or by time-of-day.
- The ability to omit a phase under some traffic conditions to allow a shorter cycle length to operate, or to provide additional time to other phases.
- The ability to use flashing yellow protected/permissive and permissive only phasing
- The ability to maintain coordination with external movements (such as crossing arterials) by preventing phases from being skipped, or by omitting phases, based on time-of-day, external input or when certain phase sequences are in operation.
- The ability to omit phases or overlaps by time-of-day schedule.
- The ability to designate any compatible phases as coordinated phases.
- The ability to separately monitor each lane on an approach and take different action depending on the conditions measured in each lane.
- The ability to introduce a non-coordinated phase later than its normal starting point within a cycle, if it can be served with minimum green within the remaining time available.

6 ADAPTIVE OPERATIONAL ENVIRONMENT

This section describes the physical and operational environment of the adaptive traffic signal system such as the location of the hardware equipment, the hardware and software compatibility, accessibility of the hardware equipment, and the maintenance requirement.

The adaptive operational environment is summarized below:

- The system will be operated and monitored from the City of North Little Rock Traffic Engineering Division
- The system will not interfere with the TACTICS Marc maintenance software in which the maintaining agency uses to perform routine signal timing maintenance and status reporting.
- The system will be operated and monitored from workstations located on the City of North Little Rock LAN, or through VPN.
- If required, the central server equipment will be housed with other City traffic servers within the City of North Little Rock in a designated air conditioned facility
- If required, the central server will be via a Windows server platform (maintained by the NLR's IT staff) and able to be replaced independently from the software.
- The selection of controller will not be constrained by the adaptive software.
- The City prefers inductive loops, video detection, magnetometers, or microwave radar as the detector technology for signal control. Detection types applicable for the ASCT
- The City prefers to use the following controller type: SIEMENS M34, M42, M52 SERIES with SEPAC firmware
- The operators will require training specific to the adaptive system, sufficient to allow them to set up, adjust and fine tune aspects of the system.
- Complaints or requests for changes in operation will be handled by the ASCT trained in-house operators on an as-needed basis, or through a ASCT vendor maintenance contract.
- Maintenance of all field equipment will be performed by in-house staff
- Funding for future maintenance of the adaptive system will come from the City of North Little Rock, the City of Maumelle and Pulaski County.
- Replacement or repair of defective or failed equipment will be covered for two years after final acceptance by the manufacturers' warranties. The labor cost of replacement during this period will be included in the purchase price.
- The City expects maintenance of parts and equipment for a period of two years after final system acceptance included in the purchase price.
- The City expects maintenance of all adaptive system software for a period of two years after final system acceptance included in the purchase price.
- The City will seek technical support from the vendor for assistance in using the adaptive software for the lifetime of the adaptive system.

- Operations and maintenance staff will have the ability to log in to the system from remote locations via the internet, and have full functionality consistent with their access level.
- The ASCT's operation will be able to be customized to suit the different situations that will be experienced in the different areas where it will operate.

7 ADAPTIVE SUPPORT ENVIRONMENT

7.1 Institutions and Stakeholders

Complete Stakeholder list can be found in the Appendix. Existing stakeholders of the traffic signal system include:

- City of Maumelle
- City of North Little Rock
- Pulaski County
- Arkansas Highway Transportation Department
- Federal Highway Administration
- Emergency Services including Fire and Police departments
- Central Arkansas Transit (CAT)
- School Board/Commission
- Metroplan
- Motorists, transit passengers, pedestrians and cyclists using the road network

Arkansas Highway Transportation Department (AHTD) is involved in the project approval process and administering the Local Project funds. The activities that will be undertaken by the adaptive system stakeholders include: preparation of timing parameters, implementation and fine tuning, system monitoring and adjustment, ongoing system performance monitoring and immediate ASCT evaluation.

The organizational structures of the units responsible for installation, operation and maintenance are illustrated in the organization chart in Figure 5. The roles, responsibilities and required qualifications and experience are described in the City of North Little Rock's staff position job descriptions.

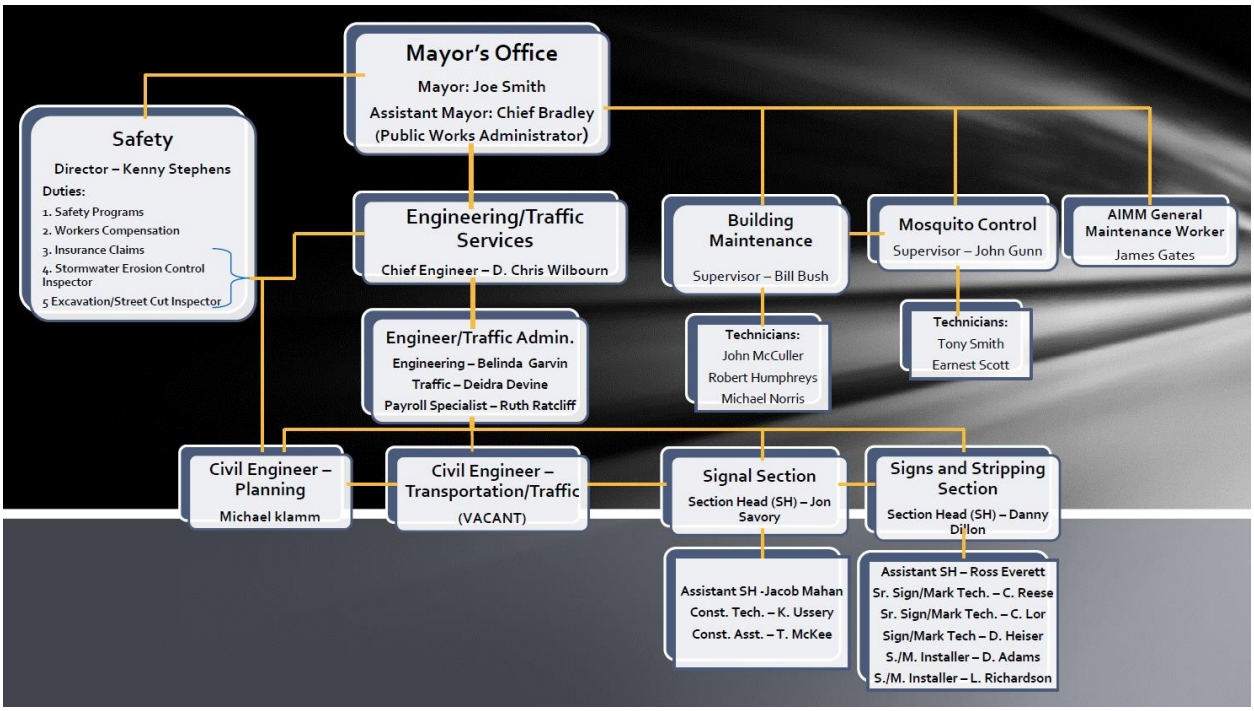


Figure 5 North Little Rock Organization Chart

7.2 Facilities

The current operations center is located at the City of North Little Rock, Traffic Engineering Division building, located at 1112 Sycamore Street, North Little Rock, AR. The building has the ability for workstations to monitor traffic conditions at various intersections via network connections to field devices.

The new servers (if required) will be installed at the Traffic Engineering Division building with other server hardware. No rack space is available, so any new servers need to include racks and cabling, as required. The City's current Engineering Division and IT staff will provide maintenance and assistance to the facilities as needed.

7.3 System Architecture Constraints

The adaptive traffic signal server and workstations will be protected within the City's firewalls, as needed. NLR will provide resources and IT assistance for Virtual Private Network (VPN) access, City equipment and system management so that the ASCT vendor may install and maintain the software as needed with NLR IT And Engineering staff assistance. The operators will have appropriate access to the system locally, from within the City's LAN and from remote locations.

The communications between the Traffic Engineering Division building and the field equipment will be via existing broadband and cellular connections.

7.4 Regional ITS Architecture

The proposed ASCT system will be within the constraints and consistent with the regional ITS architecture packages, and will interface to provide the required data flows per the needs statements. The existing ITS Regional Architecture was reviewed for the necessary service packages and flow diagrams that are required to ensure ASCT as a viable ITS traffic signal solution for the region, and for the Cities of North Little Rock and Maumelle. While the city of North Little Rock was included in the regional architecture, at the time of its development, the City of Maumelle was not a noted stakeholder. It is recommended for this ASCT that the City of Maumelle be added to North Little Rock/Sherwood as a group stakeholder in the regional architecture. This will be a change required to the next updated ITS regional architecture in order to meet federal guidelines and include Maumelle as a stakeholder to the regional ITS.

The required data flows for ASCT in the existing ATMS 03, Surface Street Control, are shown in the Regional ITS Architecture as 'planned' in Figure 6. The highlighted data flows that will be required for ASCT are also shown in Figure 6. Since the Concept of Operations needs statements for this ASCT do not require center to center or external direct interfaces for the ASCT at this time, there are no changes required to the Regional Traffic Management service package at this time, with the exception of adding the City of Maumelle to the regional architecture stakeholders, which will likely effect many service packages of the regional architecture. Architecture data flows for Regional Traffic Management are shown in Figure 6, for reference.

For the purpose of this document and the existing ITS regional architecture, when the Regional ITS Architecture is updated, we have included the Turbo 7 output for the ATMS 03 service package in Figure 7 which shows the new service package name (Traffic Signal Control) as well as the new data flows. When the conversion from Turbo 5 to Turbo 7 architecture occurred, the data flows reveal that the new data flows required for ASCT are planned as well, and as highlighted in Figure 8.

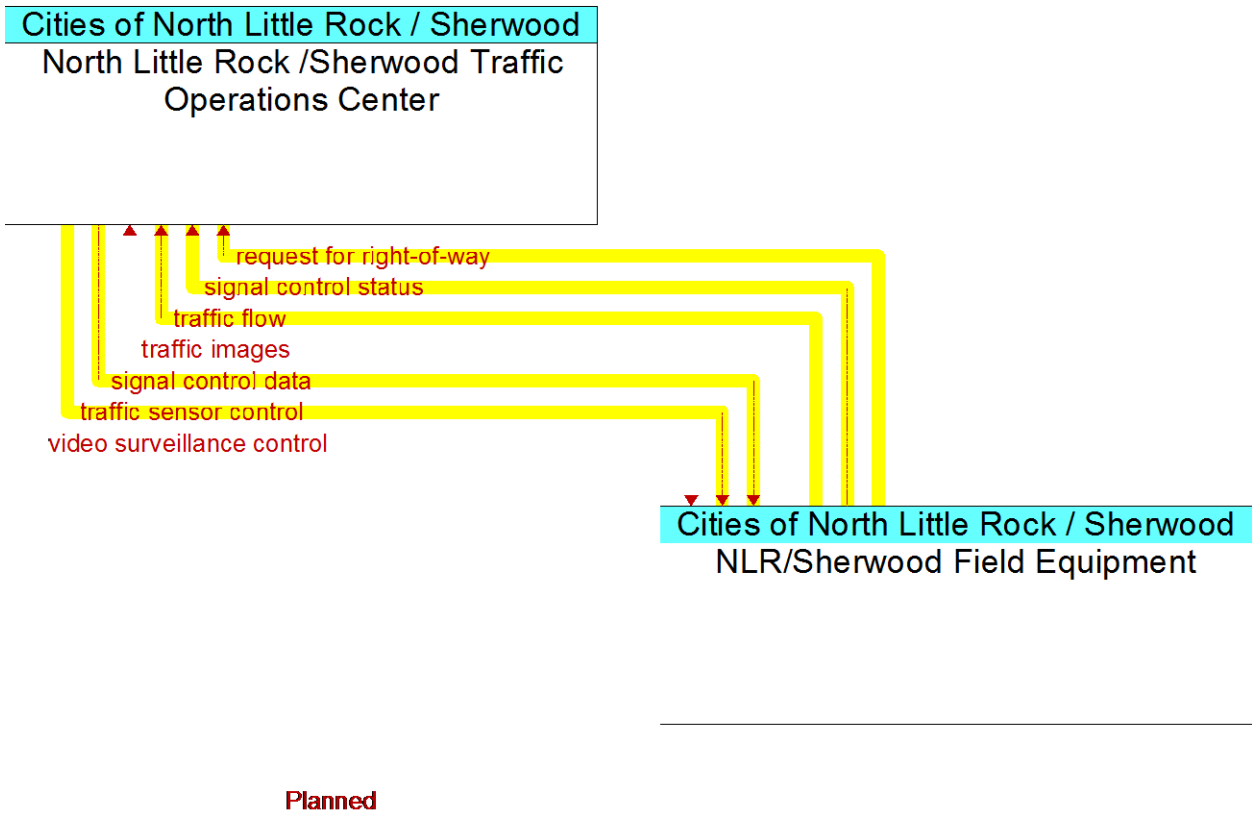


Figure 6: Current Regional ITS Architecture Turbo 5.0 – City of North Little Rock Surface Street Control ATMS03

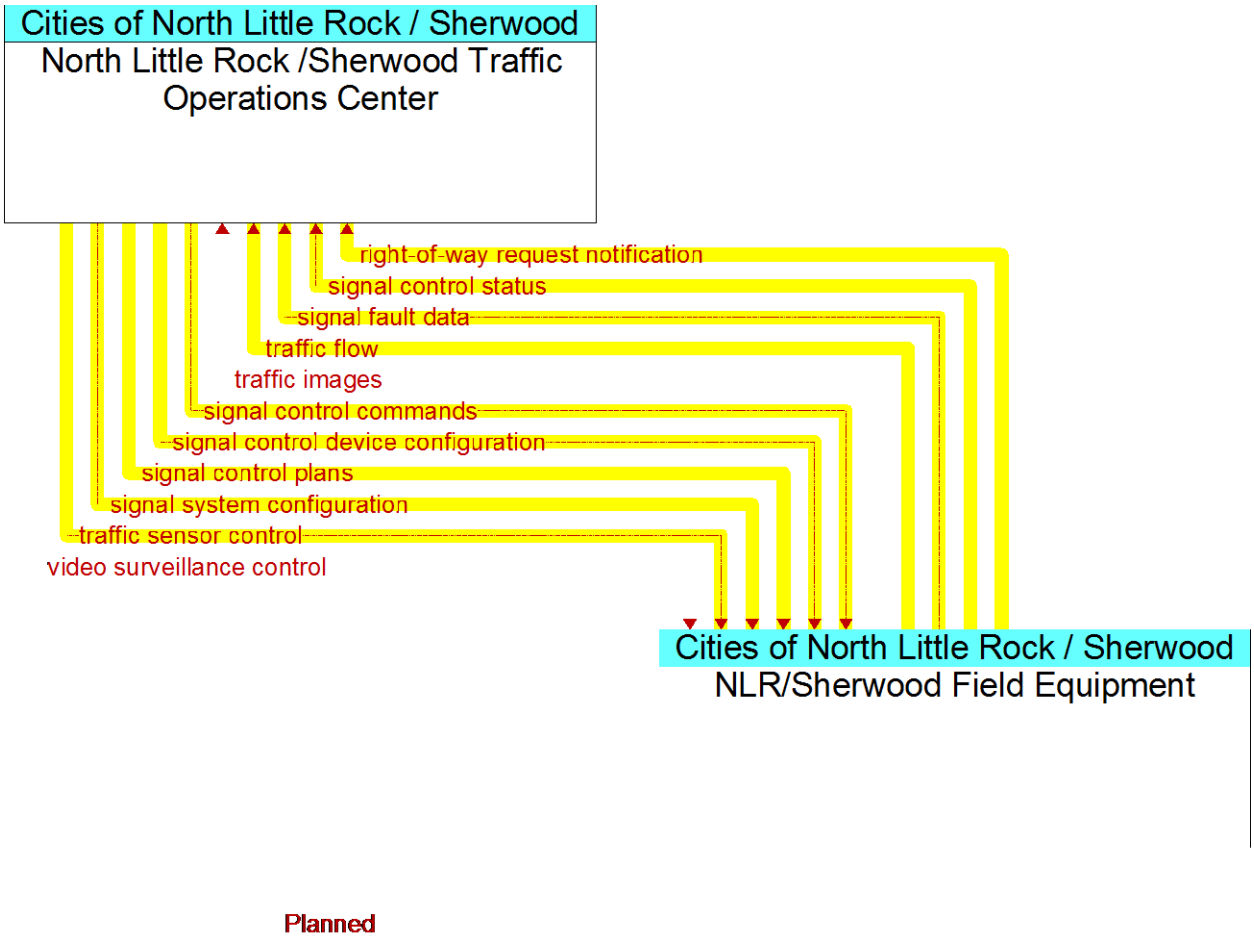


Figure 7 Regional ITS Architecture Turbo 7.0 – City of North Little Rock Surface Street Control ATMS03

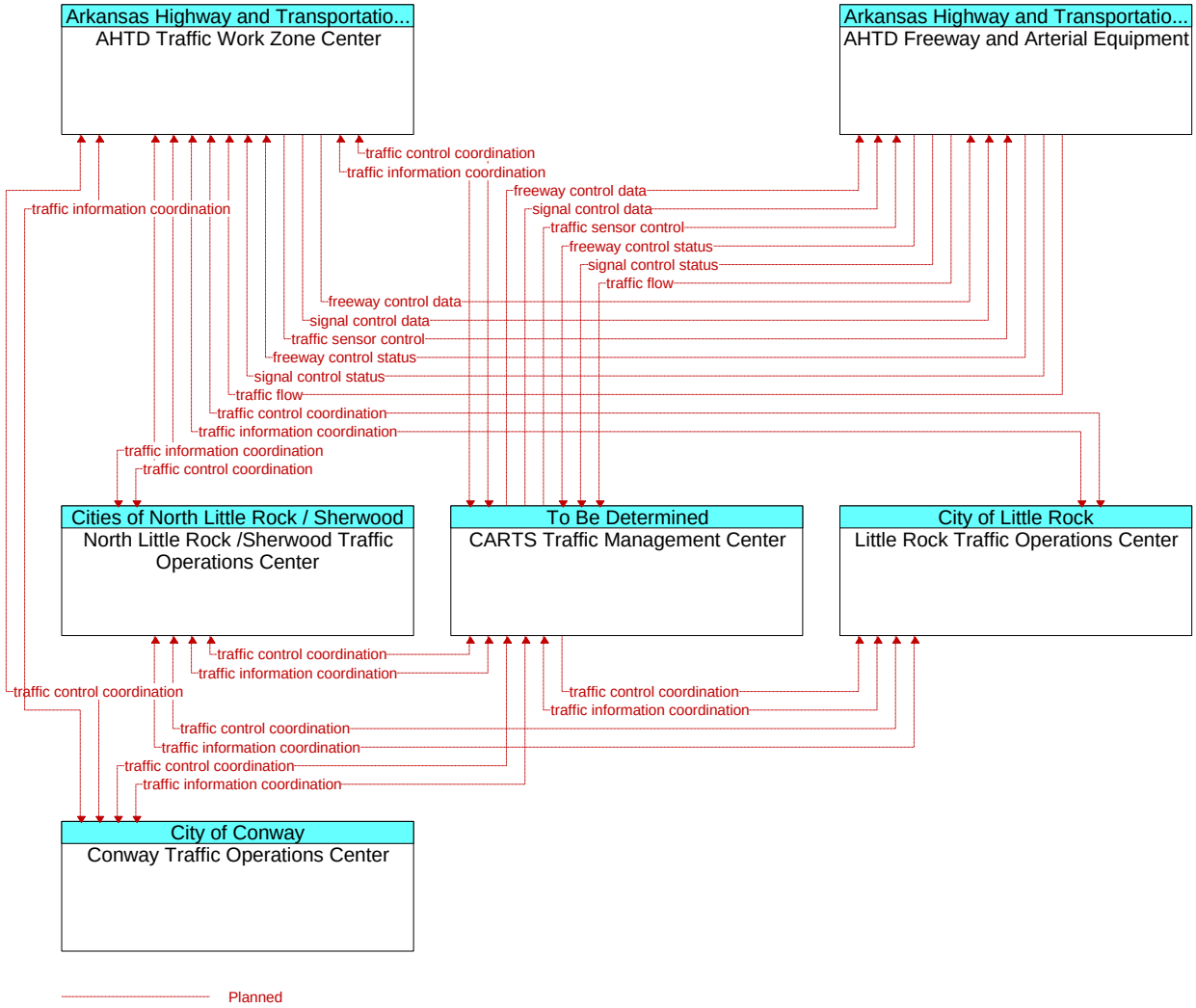


Figure 8 Regional ITS Architecture Turbo 5.0 – ATMS 07 Regional Traffic Management

7.5 Utilities

Utilities to the Traffic Engineering Division building and server room will be maintained by the City's building services.

7.6 Equipment

The communications system shall be updated to an IP/Ethernet communications system. This could be a combination of fiber and wireless Ethernet radios. The communications system and any detection devices needed for the ASCT operation will be put in by a low bid contractor, and upon direction from the Best Value winning ASCT vendor.

Vehicles for use by the Traffic Engineering Division will be the responsibility of the operating group. Additional vehicles will not be required to support this project.

7.7 Computing Hardware

Additional computing hardware beyond servers and/or field equipment needed by the ASCT is not required in this project. City IT staff are currently responsible for the maintenance and replacement of the computing hardware.

7.8 Software

Both the City Traffic Engineering Division and IT staff are currently responsible for keeping software and their corresponding licenses up to date. The City Traffic Engineering Division and IT staff also administer the usage and availability of the software on the workstations and other computers.

7.9 Personnel

The existing staff who are currently handling the same routine operations of the other traffic signal systems will be the same to operate and maintain the ASCT. Additional staff will not be required.

7.10 Operating Procedures

The City Traffic Engineering Division and IT staff are responsible for the database back up process of other software. They work together to determine backup of systems and the frequency of those backups. The database will be backed up and stored according to current procedures in place for other similar databases. ASCT Vendor assistance will be required for database backup, and all requirements and needs of the ASCT shall be discussed and approved by the City staff prior to conducting those operations.

7.11 Maintenance

Routine field maintenance on both the ASCT and the non-ASCT signal elements on the corridor will be performed by the City of North Little Rock staff on as-needed basis and per signed interlocal agreements.

7.12 Disposal

At the end of its useful life, the system will be disposed of in accordance with City of North Little Rock practices. No special conditions (such as hazardous materials) are anticipated.

7.13 ITS Standards

The NTCIP protocols for adaptive signal operation are not fully defined yet at the date of this project. The stakeholders are aware that few ASCT providers have implemented support for both existing ASCT interface protocols and NTCIP in an ASCT software package. However, any equipment and communications that are incidental to the adaptive system, and directly provided by the vendor as part of their solution, must have the ability to comply with NTCIP standards applicable to that equipment (e.g., field master, etc). The ASCT software package should also not preclude provisions for appropriate NTCIP protocol stacks to facilitate migration to a NTCIP standards-based system in the future. This will also maximize the useful service life of the new equipment and enable migration to NTCIP while minimizing hardware and software upgrades. It is highly desirable that the ASCT software vendor address their work with NTCIP interfaces, and any plans to migrate towards an NTCIP based solution in the near future.

All other incidental ITS equipment and traffic control components that are necessary for ASCT operation should conform to the ITS Standards referenced in the Regional ITS Architecture (RITSA).

8 PROPOSED OPERATIONAL SCENARIOS USING AN ADAPTIVE SYSTEM

The following operational scenarios describe how the system is expected to operate under various conditions. The proposed ASCT system is expected to be able to manage the following operational scenarios and issues envisioned for both the current and future project locations. Scenarios are described for the following operational conditions:

- Typical heavy (congested) conditions
- Typical heavy (uncongested) conditions
- Moderate balanced flow
- Light balanced flow
- Very light traffic flow
- Demand affecting event (both planned and unplanned)
- Capacity affecting event (both planned and unplanned)
- Fault conditions (communications, detection, adaptive processor)
- Priority and preemption
- Scheduled events
- Pedestrians
- Installation

8.1 Typical Heavy (Congested) Conditions

8.1.1 Road Network

Maumelle Blvd is a major arterial (4-lane divided parkway) with left turn pockets and no major arterial/cross street coordination required. The corridor can be considered as three distinct zones. The southeast portion (Zone 1) centers on a major shopping area with restaurants and strip malls. This includes the intersections from the I-430 northbound ramp on Highway 100 through the intersection of Crystal Hill/Wal-Mart drive and including Country Club during peak conditions. This area provides the entrance/exit for I-430 commuter traffic. Sidewalks are not present in Zone 1. Zone 2 is the central part of the corridor and centers on the Maumelle Central Business District. It includes the intersections of North and South Odom Blvds, Carnahan Dr, and Millwood Circle on Highway 100. It is noted that South Odom Blvd experiences a saturated left turn onto S. Odom in the PM Peak. Zone 3 consists of generally free flowing even during peak conditions throughout this mixed use corridor that includes Rolling Oaks Dr/Murphy Dr, Highway 365, and the I-40 ramps. However, the intersections at I-40 and Highway 365 and at Highway 365 and Highway 100 can become critical when an incident occurs on I-40 resulting in traffic seeking alternate routes. Generally, traffic is bidirectional in this area. Maumelle Boulevard serves as a primary route from residential and downtown to the interstate system. Some sidewalks/trails are present intermittently within the corridor, but pedestrian activity was observed to be minimal.

8.1.2 Traffic Conditions

Generally, heavy congested conditions exhibit larger queue's occurring during peak periods along this corridor. There are considerable southbound platoons in Zone 1 and 2 traveling towards I-430 in the AM peak. PM peak traffic is heavy, congested, particularly NB from I-430.

At the south portion of the corridor, Zone 1 above, the level of service breaks down during both AM and PM peak traffic conditions. During the AM Peak, traffic is very directional with platooning for South (East) bound with queues extending as far as Country Club. Considerable traffic is added to the corridor at Counts Massie and at Vestal Dr. There is considerable backup on Counts Massie waiting to turn left onto Maumelle Blvd towards the interstate. Cycle length increases from 140 seconds to 180 between 6:35 and 8:15 AM. The lack of capacity at Vestal Dr. and at the I-430 Northbound Onramp contributes to the breakdown.

During the PM Peak, cycles increase from 126 to 160 seconds between 3:40 and 6:30 PM. Platooning is very directional North (West) bound with queues sometimes blocking I-430 northbound off ramp traffic. This sometimes extends to Northshore Dr. Zone 2 exhibits a moderate level of service during peak times with heavy through traffic. Due to hardware constraints discussed earlier in this document, the intersections in Zone 2 are not coordinated, but set to free operation.

Directionality is not as significant in Zone 3 as compared to Zones 1 and 2. Zone 3 provides an alternate connection to Interstate 30 and Highway 365. The intersection of South Odom and Highway 100 experiences a period of heavy left turn traffic during the PM peak. This zone is not coordinated and is considered heavier uncongested during AM and PM peaks.

8.1.3 Operational Objectives

The operational objectives under these conditions are to:

- Maximize the throughput along Maumelle Blvd to major destination cross streets in the three zones outlined
- Accommodate the traffic at the critical intersections along Maumelle Blvd with a minimum of phase failures, particularly at the Counts Massie and Vestal intersections
- Provide smooth flow along the arterials and connecting arterials through identified main intersections; and
- Manage queues at the I-430 freeway interchange and adjacent major intersections to prevent queue overflows reducing movement capacities, or impacting traffic flow on the freeway mainline.

8.1.4 Coordination and Signal Timing Strategies

The signal timing strategies to be used by the system to accommodate this situation are:

- At the critical intersections, select phase times that eliminate phase failures
- At the critical intersections, select phase sequence that eliminates queue overflow in left turn bays
- At the non-critical intersections on all project arterials, provide sufficient time to serve all turning and side street traffic without phase failures

- At the non-critical intersections, provide sufficient time on the arterial road phases in a manner that minimizes the stops for through traffic along the arterial.

8.1.5 Summary of Operation

Under these conditions, the ASCT system will determine the critical intersection and select a phase arrangement and calculate phase times that accommodate traffic at that intersection. It will then set the timing at the other intersections to provide a green band in the direction of heaviest traffic along the arterial, to minimize the number of stops in that direction.

At closely spaced signals the offsets and phase splits will be controlled to manage the locations of queuing, to ensure traffic is not released into a short block length when it can't be serviced resulting in queuing back through the upstream intersection.

8.2 Typical Heavy (Uncongested) Conditions

8.2.1 Traffic Conditions

This condition was generally observed prior to, and after peak periods in Zone 1 and Zone 2. During AM/PM peak, this condition was noted in Zone 3. It was also observed during noon periods during all days of the week at various points along the corridor, mostly in Zone 1.

Noontime peak traffic is generally non directional and heavy (uncongested) in Zone 1. There are heavy turning movements during lunch (left turns into retail/restaurants). This would be considered a destination area with retail/big box, light shopping and restaurant traffic.

8.2.2 Operational Objectives

The operational objectives for this case are to:

- At the critical intersections, select phase times that eliminate phase failures
- Reduce delay by improving the efficiency of each phase.
- Provide smooth flow along the arterials.

8.2.3 Coordination and Timing Strategies

The signal timing strategies used by the system to accommodate this situation are:

- Select a cycle length that minimizes overall delay at the critical intersection
- Select a phase sequence that maximizes the efficiency of the movements in the peak direction
- Distribute phase times to minimize phase failures on all approaches
- Modify cycle length and phase times if necessary to accommodate occasional pedestrians
- Select offsets to provide coordination in the heaviest direction of travel
- Select phase sequence and phase times at freeway interchanges to prevent excessive queuing between the ramp intersections and on the off-ramps.

8.2.4 Summary of Operations

The adaptive system will measure the traffic flow and determine the appropriate cycle length and phase times to accommodate the current demand. When traffic volumes are sufficiently high, lead-lag operation can be selected for one or both approaches and unused time generally added to the phases serving the peak directions. Strategies for smooth flow for platoons along this corridor during heavy, uncongested times should be implemented on Zone 2 and 3, with Zone 1 being more volatile to periods of destination/turning traffic.

8.3 Moderate Balanced Flow

8.3.1 Traffic Conditions

During business hours traffic is uncongested and the flows along the corridor are similar in both directions. No major inbound or outbound peak was noted on weekends, but moderate flow was noted. Traffic follows a general shopping pattern, building through the day until noon. Traffic is centered around the shopping areas. Occasionally, there is an increase in traffic turning into and out of the several side streets that service local commercial and retail facilities. There is enough side street and turning movement traffic that most signal phases are called every cycle.

8.3.2 Operational Objectives

The operational objectives for this condition are to:

- Select a cycle length that minimizes overall delay at the critical intersection
- Provide smooth flow along major arterials; and
- Provide signal timing that prevents phase failures at all intersections.

8.3.3 Coordination and Timing Strategies

The coordination approach for these conditions is to provide progression, maximizing bandwidth while providing two-way coordination. This can be done at a resonant cycle length for the corridor, however those cycle lengths may change by zone as outlined above. The strategies applied while maintaining this cycle length are:

- At each intersection, provide sufficient time to serve all turning and side street traffic without phase failures;
- At each intersection, select phase times (or offsets) that provide smooth flow along the arterial in both directions.
- At each intersection, select phase sequence that provides smooth flow along the arterial
- At major intersections, select phase times that will accommodate occasional use of pedestrian phases.

8.3.4 Summary of Operations

The critical intersection will determine the minimum cycle length that can be used for the entire group. This cycle length will accommodate all phases. The ASCT will detect the balanced flows and select offsets that provide a reasonable compromise between the two directions of travel. At the non-critical intersections, the non-coordinated phases will be set to accommodate vehicles, and all spare

time will be allocated to the coordinated phases to maximize the bandwidth for progression bands along the road. During periods (such as lunch time) when there is more turning traffic associated with local retail activity extra time will be provided to those phases within the overall cycle length, at the expense of the coordinated phases.

8.4 Light Balanced Flow

8.4.1 Traffic Conditions

During some periods of the off-peak weekdays and some weekend periods, traffic is light but predominantly passing along the arterial, and there is still value in maintaining coordination along the route. There is little pedestrian activity and lighter side street and turning movement traffic. The left turn volumes are sufficiently light that they do not need protected turn phases to provide sufficiently capacity, and can normally be accommodated by permissive phases.

8.4.2 Operational Objectives

The operational objectives for this condition are to:

- Provide smooth flow along major arterials; and
- Select a cycle length that minimizes overall delay at the critical intersection
- Provide signal timing that prevents phase failures at all intersections.

8.4.3 Coordination and Timing Strategies

The coordination approach for this condition is to provide progression along the arterial, maximizing bandwidth while providing two-way coordination. The timing strategies applied to do this are:

- At each intersection, provide sufficient time to serve all turning and side street traffic without phase failures;
- At each intersection, select phase times (or offsets) that provide smooth flow along the arterial in both directions;
- At each intersection, omit protected turning phases to minimize the impact of occasional turning vehicles on other traffic;

8.4.4 Summary of Operations

During light traffic conditions, a cycle length of adequate length as approved by the City will be implemented. If traffic volumes decrease (such as during late nights), the cycle length and two-way coordination will be maintained unless the volumes fall below a minimum threshold, in which case the signals will be set to operate in free, vehicle-actuated mode. If traffic increases to the extent that it can no longer be accommodated within the cycle length, or left turning volumes can no longer be accommodated without the protected left turns, then a longer cycle length will be implemented and a new coordination strategy selected to match the current traffic conditions.

8.5 Very Light Traffic Flow

8.5.1 Traffic Conditions

Under very light traffic conditions, such as late at night and the early morning hours of Saturday and Sunday, there is little through traffic on the arterial roads to benefit from providing coordination. It is therefore appropriate to allow each intersection to operate free operation.

8.5.2 Operational Objectives

Under the very light traffic flow condition, the objective of the adaptive system is to equitably serve the various movements and pedestrians at each intersection.

8.5.3 Coordination and Timing Strategies

Traffic signals will revert to free operation under very light traffic flow conditions.

8.5.4 Summary of Operation

When the traffic volume falls below a threshold set by the operator, the traffic signals will operate in free mode. When volumes later rise above a threshold set by the operator, a new appropriate coordination timing strategy is implemented.

8.6 Demand Affecting Event

During periods of major activity within or close to the ASCT's area of operation (such as construction traffic, a large school, or holiday industrial distribution/shipping), the traffic characteristics are often similar to the heavy congested peak periods, either oversaturated or unsaturated. The system will behave in a similar fashion to those periods, and the detection system will determine whether unsaturated or oversaturated conditions prevail. If there is heavily directional traffic before or after the activity, the system will determine the predominant direction and coordinate accordingly, with an appropriate cycle length and offset. If the event traffic is not as heavy as peak hours, but the traffic on the corridor is still highly directional, then the system will recognize this and provide coordination predominantly in the heaviest direction, even though the cycle length may be similar to business hours (with balanced flows) cycle lengths.

The entire corridor may be set by the operator to operate as one or more coordinated groups under this condition, or the system may have the freedom to operate it as one or more groups subject to user-specified criteria, such as similar required cycle lengths in different parts of the corridor, or the volume of traffic at key locations exceeds a threshold.

When an incident occurs on the interstates, such as on I-40 or I-430, the volumes on routes parallel to and connecting to the freeways unexpectedly change, sometimes quite dramatically. At these times the system will detect the changes in traffic volumes and respond by selecting signal timing that accommodates the demand as far as practicable, and provides coordination in the direction of highest flow from these type incidents on the freeways. These maximum cycle lengths shall be determined and monitored by the City.

8.7 Capacity Affecting Event

8.7.1 Incident within the System (Construction, Maintenance, Fire)

When an incident occurs on the coordinated route and temporarily reduces the capacity of the route (such as emergency vehicles stopped, unscheduled construction/maintenance, or traffic crash), there will typically be congestion upstream of the blockage, and lighter than normal traffic downstream. This is also true for infrequent weather events such as flooding of outside lanes. In such situations, it is appropriate for the downstream signals to operate with different characteristics from the upstream signals.

If the downstream signals experience lighter traffic as a result of the blockage, those signals should be coordinated as a group, with cycle length, splits and/or offsets that react to the measured traffic. If the blockage is in the peak direction, then it may be appropriate to coordinate in the opposite direction if that traffic is similar to or greater than the normal peak direction. If the blockage is in the non-peak direction, there may be no need to depart from the normal operation.

While intersections upstream from the blockage may register increased congestion, the appropriate response would not be to increase the capacity in the congested direction. On the contrary, the approach should be to match the capacity for phases in the direction towards the bottleneck to the actual capacity of the bottleneck, and prevent this movement from adversely affecting cross street traffic and the flow in the non-affected direction.

When planned events that affect capacity occur, such as maintenance or construction activities that require closure of a lane, the system will recognize the change in available capacity in the same way that it will recognize the presence of an unplanned obstruction. The system operators will also have the ability to pre-program and schedule changes in system parameters that will accommodate expected changes in available capacity.

The system will recognize the presence of an abnormal obstruction and modify the signal operation to react to the changed traffic conditions in an efficient manner.

8.8 Fault Conditions

8.8.1 Communications Fault Condition

If a communication failure prevents the adaptive system from continuing to control one or more intersections within a defined group, all signals within the group will revert to an appropriate, user-specified fallback mode of operation, either time-of-day operation or free operation. The fallback mode will be specified by the user based on location and time of day. All communication failure alarms will be automatically transmitted to maintenance and operations staff for appropriate attention.

8.8.2 Detection Fault Condition

The system will recognize a detector failure and take appropriate action to accommodate the missing data. For a local detector failure, the local controller will place a soft recall or maximum recall (to be user-specified) on the appropriate phase, and issue an alarm. For a detector that influences the adaptive operation (e.g., a system detector), the system will use data from historic data or an alternate (user-specified) detector, such as in an adjacent lane or at an appropriate upstream or downstream location. If the number of detector failures within a specified group exceeds a user-specified

threshold, the system will cease adaptive operation and go to a fallback operation specified by the user (such as time-of-day operation or free operation). The fallback operation will be specified by the user based on location and time of day. All detector failure alarms will be automatically transmitted to maintenance and operations staff for appropriate attention.

8.9 Priority and Preemption

8.9.1 Emergency Vehicle Preemption

When an intersection responds to an emergency vehicle preemption, other signals within the coordinated group continue to operate adaptively. The preempted signal returns to adaptive control once the preemption is released.

8.10 Scheduled Events

During a scheduled event, when there is little associated traffic, the system will recognize the traffic conditions and operate normally, then recognize the changing traffic pattern as patrons begin to leave the event and adopt the appropriate mode of operation until the traffic clears. The system will then return to normal operation.

While this operation is desirable for the ASCT (automated detection and real time side-street green time assignment), the system needs to be able to be scheduled to turn off for a period of time, and operate under an event timing plan used to clear such events (school departures, football games, etc).

8.11 Pedestrians

Pedestrian crossing times must be accommodated. When pedestrian volumes are sufficiently heavy that the pedestrian phase is required most cycles, the signal cycle will be long enough that the pedestrian phases will not restrict the coordinated green bands. When pedestrian volumes are low and the pedestrian phase is only required occasionally, a lower cycle length that does not accommodate all pedestrian crossing times may be employed. However, when the pedestrian phase is called, it the system will allow the full walk and clearance times while maintaining adaptive control, and not require the controller to leave coordination and then pass through a transition period to get back in step.

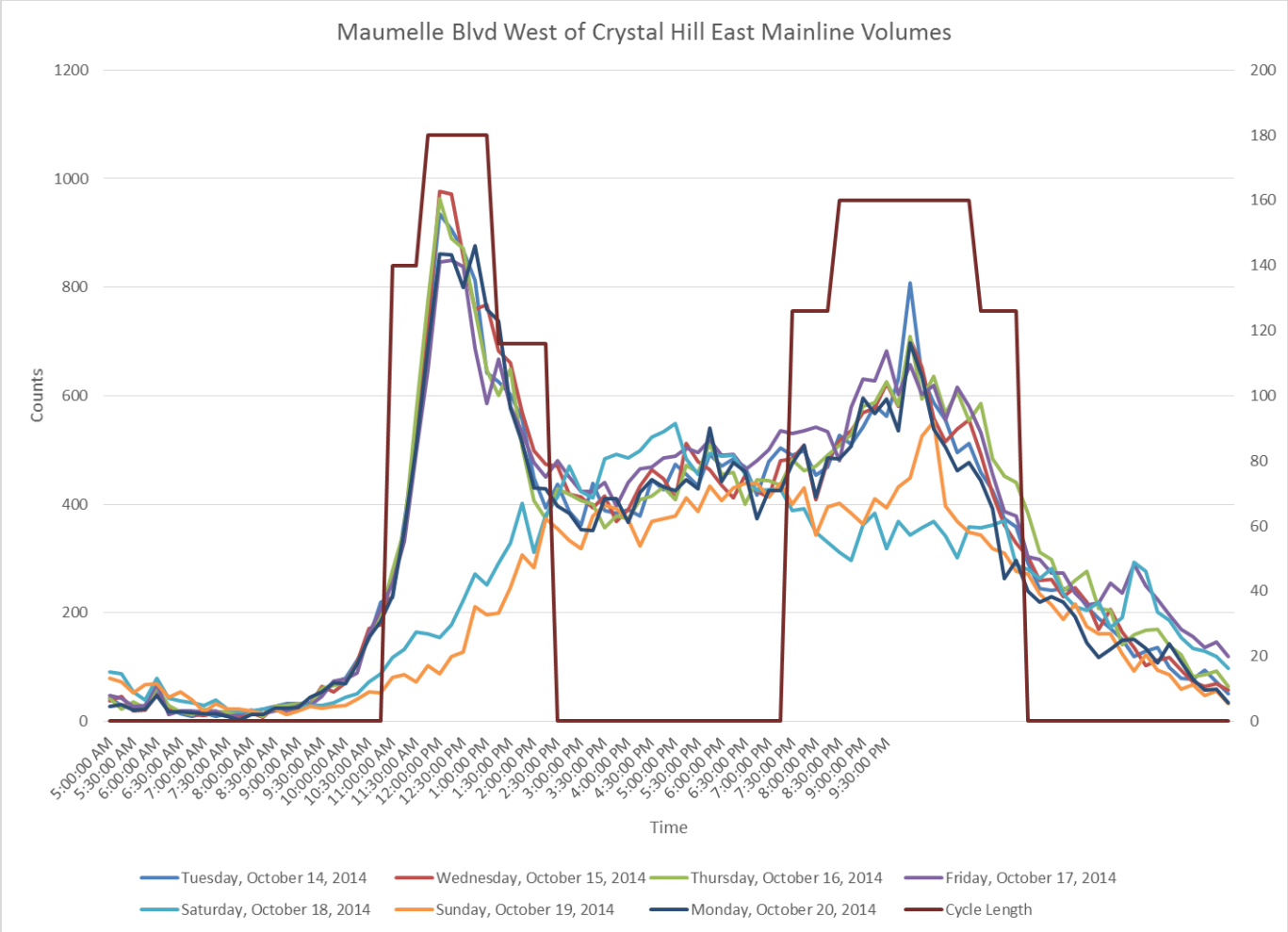
When side street traffic is light and no pedestrian is present, a vehicle may arrive on the side street shortly after the point at which its phase would normally be initiated. Typically it would then wait an entire cycle before being served. However, it is often possible to serve one or two side street vehicles within the remaining green time. So the system will be able to start a phase later than normal when there is no pedestrian call for that phase, provided it can be completed before the time the phase would normally end.

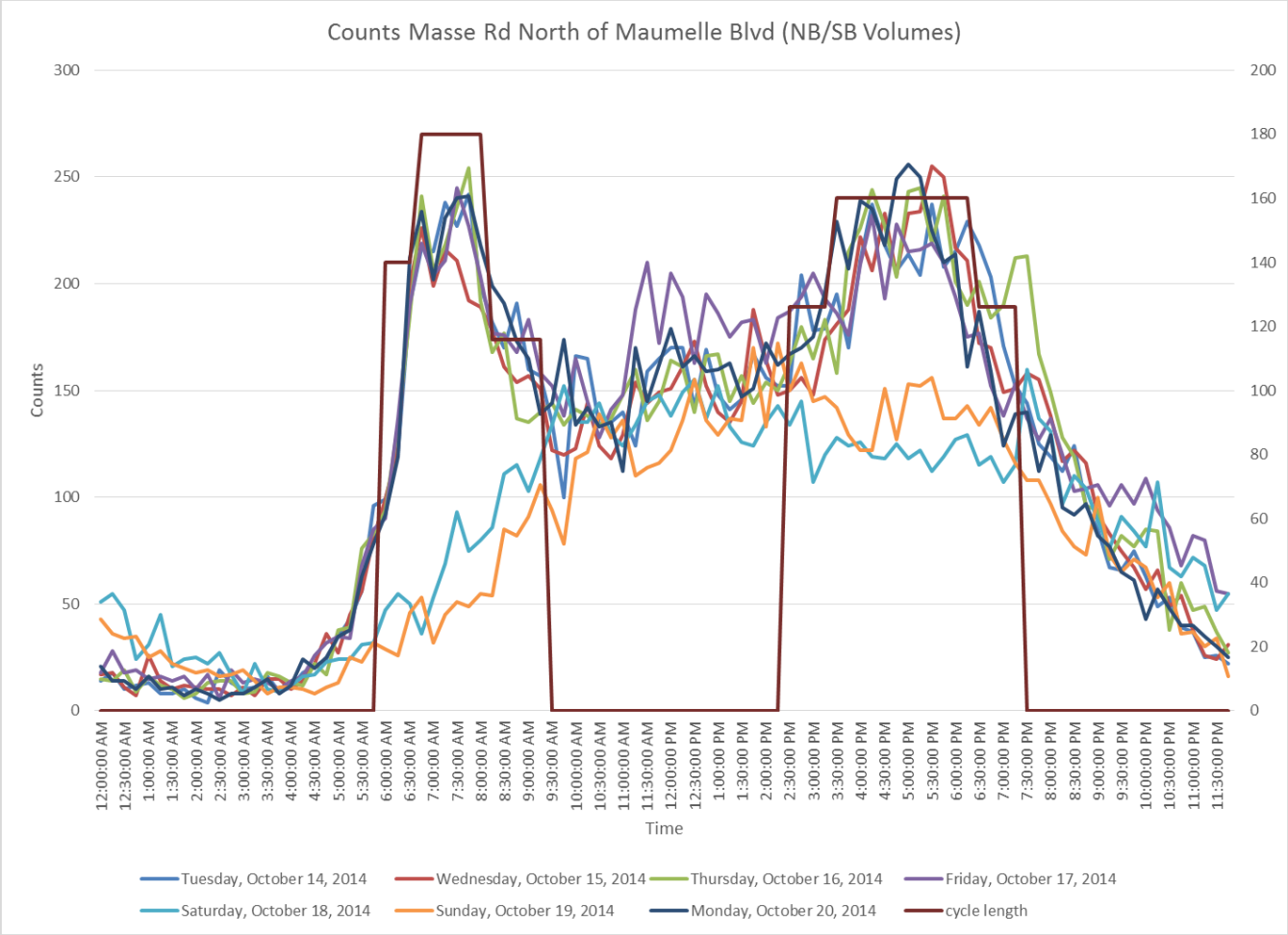
8.12 Installation

During installation and fine tuning, the operator will calibrate all the user-defined values in the system. In order to understand the response of the system to changes in traffic conditions, it is necessary to examine the results of intermediate calculations, in addition to the overall outputs and changes of state commanded by the system.

For example, if a cycle length is calculated based on a calculated parameter, such as level of saturation of detectors in critical lanes on critical movements, then the state of that calculated parameter must be available for inspection for each detector. This will allow the operator to properly calibrate each detector, and then separately calibrate the parameters in the cycle length calculation or look-up table. This would also allow an operator to identify a faulty detector that is causing an incorrect measure to be calculated, even though the detector has failed; or identify a detector on which traffic behavior is different from other detectors on that phase, such as a left turn lane that has a heavy U-turn volume.

Appendix A


Maumelle Blvd West of Crystal Hill East Mainline Volumes
Counts
Time
Tuesday, October 14, 2014
Wednesday, October 15, 2014
Thursday, October 16, 2014
Friday, October 17, 2014
Saturday, October 18, 2014
Sunday, October 19, 2014
Monday, October 20, 2014
Cycle Length


Counts Masse Rd North of Maumelle Blvd (NB/SB Volumes)
Counts
Time
Tuesday, October 14, 2014
Wednesday, October 15, 2014
Thursday, October 16, 2014
Friday, October 17, 2014
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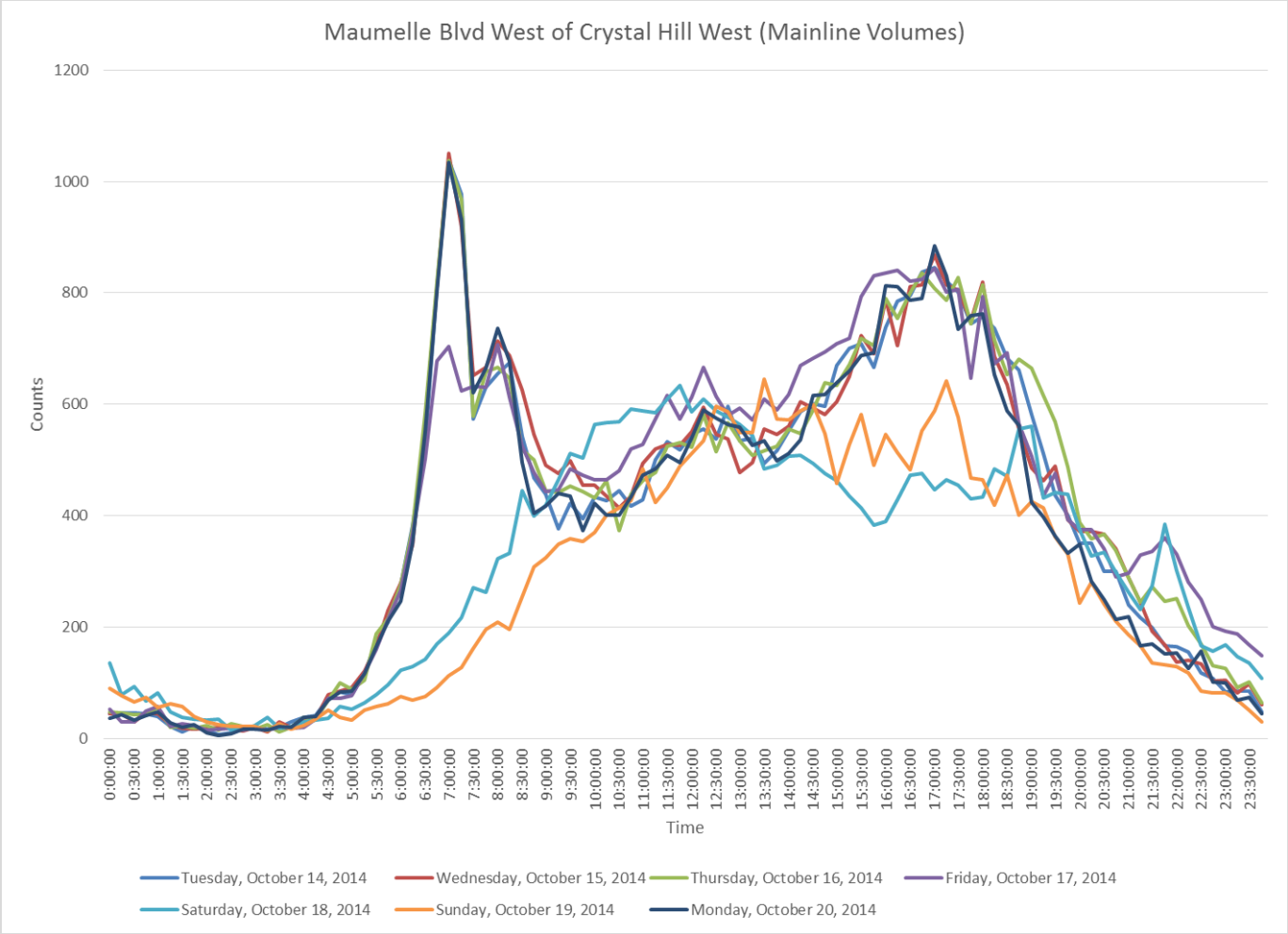
Sunday, October 19, 2014
Monday, October 20, 2014
cycle length


Maumelle Blvd West of Crystal Hill West (Mainline Volumes)
Counts
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Thursday, October 16, 2014
Friday, October 17, 2014
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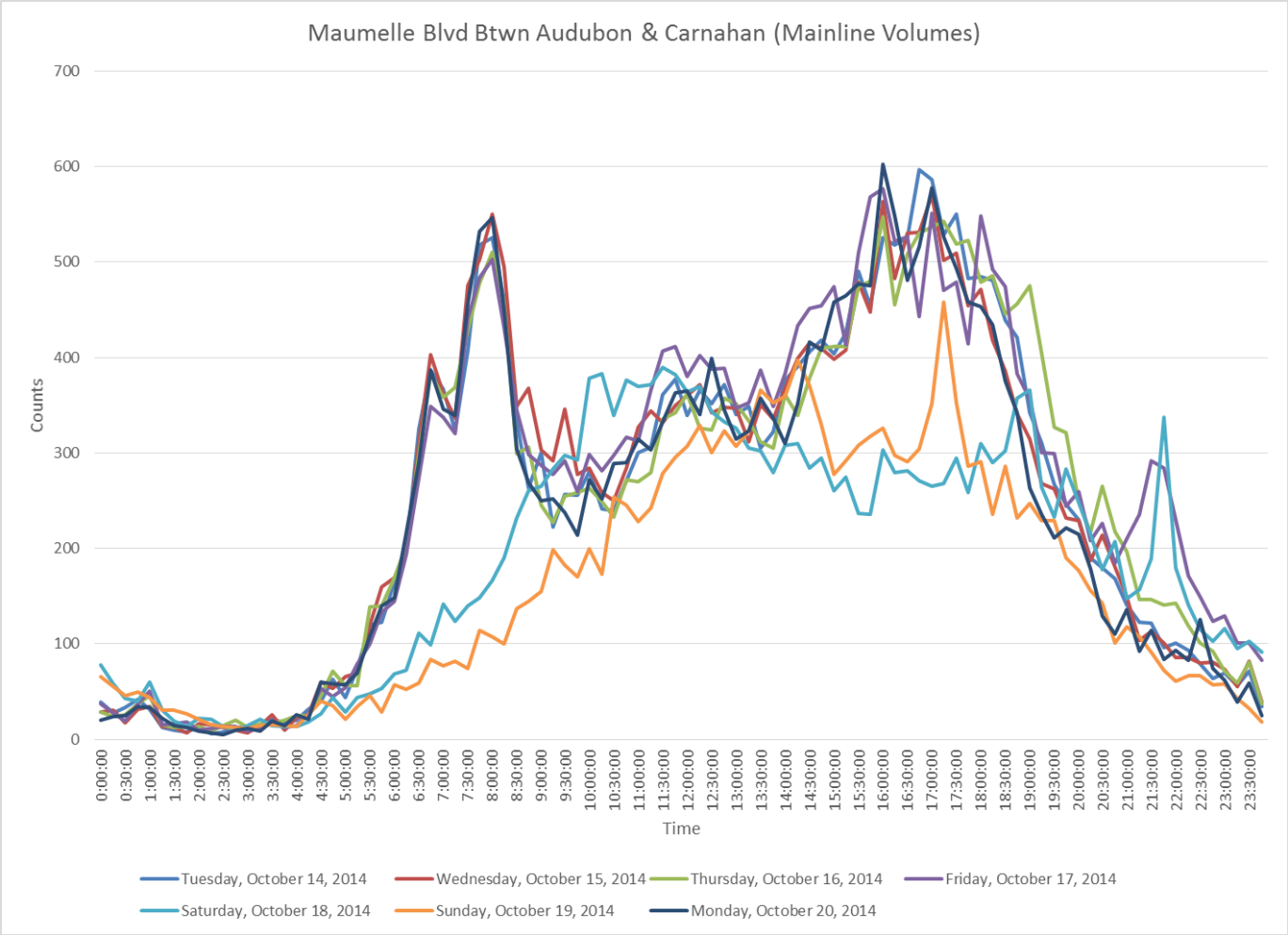
Sunday, October 19, 2014
Monday, October 20, 2014


Maumelle Blvd Btwn Audubon & Carnahan (Mainline Volumes)
Counts
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600
500
400
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200
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1:00:00
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2:30:00
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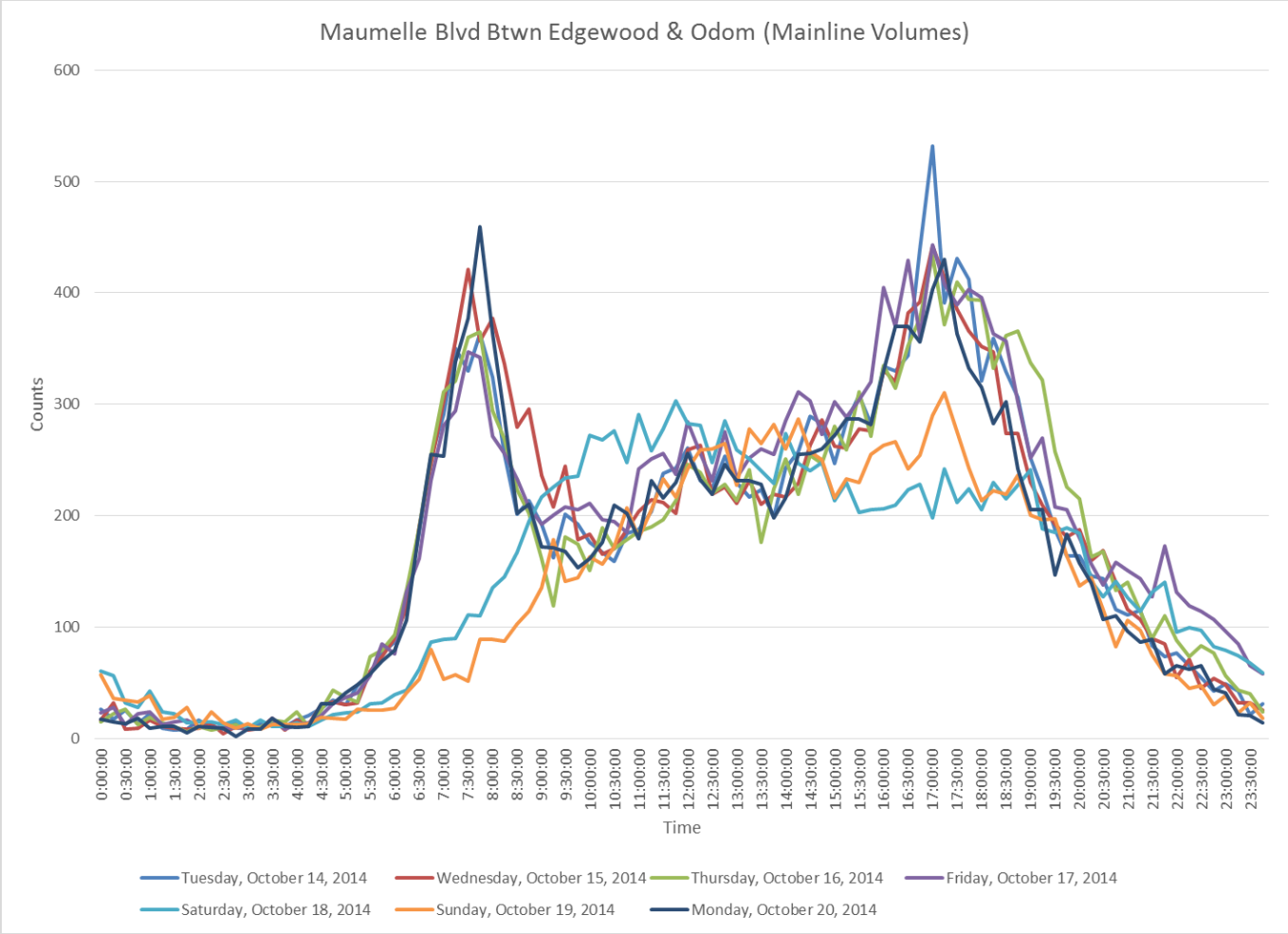
Maumelle Blvd Btwn Edgewood & Odom (Mainline Volumes)
Counts
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Time
Tuesday, October 14, 2014
Wednesday, October 15, 2014
Thursday, October 16, 2014
Friday, October 17, 2014
Saturday, October 18, 2014
Sunday, October 19, 2014
Monday, October 20, 2014

Metroplan CARTS Adaptive Signal Control Study for the City of Maumelle / North Little Rock/Pulaski County

System Requirements

By

GRESHAM SMITH AND PARTNERS

and

NEEL-SCHAFFER
Solutions you can build upon

October 14, 2015

Document Description

Client	City of Maumelle/City of North Little Rock/Pulaski County
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Version Control

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1.0 Scope

1.1 Document Purpose and Scope

The scope of this document covers the consideration of adaptive signal control technology (ASCT) use within the within the City of Maumelle, the City of North Little Rock, and Pulaski County AR. This document describes and provides a rationale for the expected operations of the proposed adaptive system. It also documents the outcome of stakeholder discussions and consensus building that has been undertaken to ensure that the system that is implemented is operationally feasible and has the support of stakeholders.

Following completion of the concept of operation, with agreement among stakeholders about the needs, the operating concepts, the operational environment and support environment, this document shall provide the detailed system requirement.

1.2 Project Purpose and Scope

The main purpose of this project is to define all of the stakeholder's needs and objectives to qualify the use of adaptive traffic signal control, and to select a system that can best accommodate these needs and objectives. There are many operational stakeholders within the proposed initial project area of Maumelle Boulevard. This makes this particular adaptive signal study unique in that the initial corridor has many maintenance entities, or responsible parties for the signals on the study corridor. The later design portion of this project will define the adaptive traffic signal system that satisfies the documented system requirements and the stakeholder's needs and constraints through technical special provisions and all necessary design plans and documents as required by the City of Maumelle, City of North Little Rock (also herein referred to as the 'City'), Pulaski County, the Arkansas Highway and Transportation Department (AHTD), and the Federal Highway Administration (FHWA).

This project involves consideration of the application of ASCT initially to Maumelle Boulevard and Highway 365 (MacArthur Drive) between Northshore Drive, by the interchange of Interstate I-430, north to I-40 at the north terminus of the initial study corridor. However, to the extent that it appears feasible, consideration will also be given to application of ASCT to other future corridors within the operating and maintaining jurisdictions, as residential and commercial developments grow within the project area. The project initial corridor location is shown in Figure 2 of the Concept of Operations.

The primary objectives of the adaptive traffic signal system are to accommodate the irregular traffic patterns within the project area created by existing commuter and commercial traffic, provide smoother traffic flow along Maumelle Blvd for that traffic, and to accommodate the need for constantly changing signal timing for new developments in the area. The Cities of Maumelle and North Little Rock continue rapid growth both in residential and commercial developments. The Maumelle Blvd corridor is the main arterial for these developments to access the interstate system and the subject of many traffic complaints by Maumelle and NLR citizens. An adaptive signal system is one tool that may help alleviate these complaints.

An adaptive traffic signal system is one in which some or all the signal timing parameters are modified in response to changes in the traffic conditions, in real time. The purpose of providing adaptive control in

the project area is to overcome the limitations of the existing system to handle the irregular traffic pattern introduced by the interstates and variations in adjacent land uses. This project will review the needs for adding adaptive capabilities to the functionality of the existing coordinated signal system. All the capabilities of the existing coordinated system will be required to be maintained. The adaptive system may function independently or work with the existing traffic signal system and TOD plans that may be in place. Additionally, the adaptive system may be manually turned off to allow the existing traffic signal system to have control. The adaptive system will be integrated with the existing traffic signal system, and fallback and failure modes will be defined in Section 5.3 of the Concept of Operations.

2.0 Referenced Documents

The following documents have been referenced or used to guide the preparation of this concept of operation.

2.1 Planning Documents

- Regional Strategic Transportation Network: http://www.metroplan.org/files/53/2011-01Regional_Strategic_Network.pdf
- Transportation Planning Structure: http://www.metroplan.org/files/53/TransPlanStructure001.pdf
- CARTS Transportation Improvement Plan: http://www.metroplan.org/files/53/TIP-2013-16_02.pdf
- FY 2015 Unified Planning Work Program: http://www.metroplan.temp1000.com/files/53/2015UPWP.pdf
- CARTS Public Participation Plan: http://www.metroplan.org/files/53/2011CARTS_PPP.pdf
- The Long-Range Transportation Plan for Central Arkansas: http://draftplan.imaginecentralarkansas.org/draft-plan-chapter-7-long-range-metropolitan-transportation-plan

2.2 Adaptive Signals

- NCHRP Synthesis 403: "Adaptive Traffic Control Systems: Domestic and Foreign State of Practice", http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_403.pdf

2.3 ITS, Operations, Architecture, Others

- FHWA Rule 940, Federal Register / Vol. 66, No. 5 / Monday, January 8, 2001 / Rules and Regulations, DEPARTMENT OF TRANSPORTATION, Federal Highway Administration 23 CFR Parts 655 and 940, (FHWA Docket No. FHWA-99-5899) RIN 2125-AE65 Intelligent Transportation System Architecture and Standards
- Regional ITS Architecture Guidance Document, "Developing, Using, and Maintaining an ITS Architecture for your Region; National ITS Architecture Team; October, 2001
- CARTS Intelligent Transportation System Plan and Regional ITS Architecture http://www.metroplan.org/files/53/2010CARTS_ITS.pdf
- NTCIP 1211 version v02. "Signal Control and Prioritization (SCP)."
- NEMA TS1
- NEMA TS2

2.4 System Engineering

- FHWA. (2012, August). Model Systems Engineering Documents for Adaptive Signal Control Technology (ASCT) Systems - Final Guidance Document. U.S. Department of Transportation. http://ops.fhwa.dot.gov/publications/fhwahop11027/mse_asct.pdf
- FHWA. (2007, January). Systems Engineering for Intelligent Transportation Systems - An Introduction for Transportation Professionals. U.S. Department of Transportation. http://www.ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf
- FHWA Systems Engineering Guidebook Version 3.0, http://www.fhwa.dot.gov/cadiv/segb/
- FHWA. (2013, July). Measures of Effectiveness and Validation Guidance for Adaptive Signal Control Technologies http://www.ops.fhwa.dot.gov/publications/fhwahop13031/index.htm

2.5 Procurement

- NCHRP 560 Guide to Contracting ITS Projects, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_560.pdf
- The Road to Successful ITS Software Acquisition, http://www.fhwa.dot.gov/publications/research/operations/its/98036/rdsuccessvol2.pdf

3.0 ASCT System Requirements

The System Requirements are derived from the objectives and needs of the Concept of Operations. These requirements describe what will be expected of the system. In order to understand the system requirements, the Needs Statements from the Concept of Operations are listed below:

3.1 Needs Statements List

User Needs Reference Number	Concept of Operations Needs Statements
1	**1 Operational Needs**
1.1	**1.1 Adaptive Strategies**
4.1.0-1	The system operator needs the ability to implement different strategies individually or in combination to suit different prevailing traffic conditions. These strategies include:
4.1.0-1.0-1	• Maximize the throughput on coordinated routes
4.10-1.0-2	• Provide smooth flow along coordinated routes
4.1.0-1.0-3	• Distribute phase times in an equitable fashion

User Needs Reference Number	Concept of Operations Needs Statements
4.1.0-1.0-4	• Manage the lengths of queues
4.1.0-1.0-5	• Manage the locations of queues within the network
4.1.0-1.0-6	• At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
4.1.0-2	The system operator needs to manage the coordination in small groups of signals to link phase service at some intersections with phase service at adjacent intersections.
4.1.0-3	The system operator needs to change the operational strategy (for example, from smooth flow to maximizing throughput or managing queues) based on changing traffic conditions.
4.1.0-4	The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue resulting from the trailing end of the through green from blocking the storage needed by an entering side-street left turn in the subsequent phase.
4.1.0-5	The system operator needs to minimize the chance that a queue forms at a specified location.
4.1.0-6	The system operator needs to modify the sequence of phases to support the various operational strategies.
4.1.0-7	The system operator needs to fix the sequence of phases at any specified location. For example, the operator may need to fix the phase order at a diamond interchange.
4.1.0-8	The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.
4.1.0-9	The system operator needs to set signal timing parameters (such as minimum green, maximum green and extension time) to comply with agency policies.
4.2	**4.2 Network characteristics**

User Needs Reference Number	Concept of Operations Needs Statements
4.2.0-1	The system operator needs to eventually adaptively control up to 200 signals.
4.2.0-2	The system operator needs to be able to adaptively control at least 10 independent groups of signals per corridor
4.2.0-3	The system operator needs to vary the number of signals in an adaptively controlled group to accommodate the prevailing traffic conditions.
4.3	**4.3 Coordination across boundaries**
4.3.0-1	The system operator needs to adaptively control signals operated by Pulaski County, City of Maumelle, and City of North Little Rock, and under agreement, all of the corridor signals will be maintained by the City of North Little Rock.
4.3.0-3	The system operator needs to adaptively coordinate signals on two crossing routes simultaneously. (All signals within the group are under the control of City Maumelle, City of North Little Rock, or Pulaski County.)
4.3.0-5	The system operator needs to constrain the adaptive system to operate a cycle length compatible with the crossing arterial.
4.3.0-6	The system operator needs to detect traffic approaching from a neighboring system and coordinate the ASCT operation with the adjacent system.
4.4	**4.4 Security**
4.4.0-1	The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator and conform to the City's access and network infrastructure security policies.
4.5	**4.5 Queuing interactions**
4.5.0-1	The system operator needs to detect queues from outside the system and modify the ASCT operation to accommodate the queuing.
4.5.0-2	The system operator needs to detect queues within the system's boundaries and modify the ASCT operation to accommodate the queuing.
4.5.0-3	The system operator needs to detect queues propagating outside its boundaries from

User Needs Reference Number	Concept of Operations Needs Statements
	within the ASCT boundaries, and modify its operation to accommodate the queuing.
4.5.0-4	The system operator needs to store queues in locations where they can be accommodated without adversely affecting adaptive operation.
4.5.0-5	The system operator needs to prevent queues forming at user-specified locations.
4.6	**4.6 Pedestrians**
4.6.0-2	The system operator needs to accommodate infrequent pedestrian operation while maintaining adaptive operation.
4.6.0-3	The system operator needs to incorporate frequent pedestrian operation into routine adaptive operation.
4.6.0-5	The system operator needs to accommodate early start of walk.
4.7	**4.7 Non-adaptive situations**
4.7.0-1	The system operator needs to detect traffic conditions during which adaptive control is not the preferred operation, and implement some pre-defined operation while that condition is present.
4.7.0-2	The system operator needs to schedule pre-determined operation by time of day.
4.7.0-3	The system operator needs to over-ride adaptive operation.
4.8	**4.8 System responsiveness**
4.8.0-1	The system operator needs to modify the ASCT operation to closely follow changes in traffic conditions. Should conditions change, such as a change in strategy from smooth flow to reducing total intersection delay at particular intersections, the system operator needs to identify the deficiency and adjust the operation accordingly.
4.8.0-2	The system operator needs to constrain the selection of cycle lengths to those that provide acceptable operations, such as when “resonant” progression solutions are desired to provide two-way coordination along one or more arterial routes.
4.8.0-3	The system operator needs to respond quickly to sudden large shifts in traffic conditions.
4.9	**4.9 Complex coordination and controller features**

User Needs Reference Number	Concept of Operations Needs Statements
4.9.0-1	The system operator needs to implement the following advanced controller features while maintaining adaptive operation:
4.9.0-1.0-1	• Service a phase more than once per cycle
4.9.0-1.0-2	• Operate at least eight overlap phases
4.9.0-1.0-3	• Operate four rings, 16 phases and up to four phases per ring
4.9.0-1.0-4	• Permit different phase sequences under different traffic conditions while avoiding the yellow trap.
4.9.0-1.0-5	• Allow one or more phases to be omitted (disabled) under certain traffic conditions or signal states.
4.9.0-1.0-6	• Prevent one or more phases being skipped under certain traffic conditions or signal states.
4.9.0-1.0-9	• Allow any phase to be designated as the coordinated phase
4.9.0-1.0-10	• Allow the operator to specify which phase receives unused time from a preceding phase
4.9.0-1.0-11	• Allow the controller to respond independently to individual lanes of an approach. This may allow the adaptive operation to be based on data from a specific detector, or by excluding specific detectors
4.9.0-1.0-13	• Allow flexible timing of non-coordinated phases (such as late start of a phase) while maintaining coordination
4.9.0-1.0-14	• Allow protected/permissive phasing and alternate left turn phase sequences.
4.9.0-1.0-15	• Use flashing yellow arrow to control permissive left turns and right turns.
4.9.0-1.0-16	• Service side streets and pedestrian phases at minor locations more often than at adjacent signals when this can be done without compromising the quality of the coordination. (E.g., double-cycle mid-block pedestrian crossing signals.)
4.9.0-1.0-17	• Use negative pedestrian phasing to prevent an overlap conflicting with a pedestrian walk/don't walk
4.10	**4.10 Monitoring and control**
4.10.0-1	The system operator needs to monitor and control all required features of adaptive operation from the City's:

User Needs Reference Number	Concept of Operations Needs Statements
4.10.0-1.0-1	• Traffic Engineering Division Building
4.10.0-1.0-3	• LAN Workstations
4.10.0-1.0-5	• Local controller cabinets
4.10.0-1.0-7	• Remote locations via VPN
4.10.0-2	The operator needs to access to the database management, monitoring and reporting features and functions of the signal controllers and any related signal management system from the access points defined for those system components. (e.g. Traffic Engineering and individual office workstation)
4.11	**4.11 Performance reporting**
4.11.0-1	The agency needs the TACTICS system to be able to monitor status of the signal system during ASCT operation.
4.11.0-2	The system operator needs to store and report data used to calculate signal timing and have the data available for subsequent analysis.
4.11.0-3	The system operator needs to store and report data that can be used to measure traffic performance under adaptive control.
4.11.0-4	The system operator needs to store all operational data and signal timing parameters calculated by the adaptive system, and export selected data to Microsoft Excel spreadsheets, text files, CSV files, or an open SQL database.
4.11.0-6	The system operator needs to be able to report the exact state of signal timing and input data for a specified period, to allow historical analysis of the system operation.
4.11.0-7	The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.
4.12	**4.12 Failure notification**
4.12.0-1	The system operator needs to immediately notify maintenance and operations staff of alarms and alerts.
4.12.0-2	The system operator needs to immediately and automatically pass alarms and alerts to

User Needs Reference Number	Concept of Operations Needs Statements
	the City's O&M personnel
4.12.0-3	The system operator needs to maintain a complete log of alarms and failure events.
4.13	**4.13 Preemption and priority**
4.13.0-2	The system operator needs to accommodate emergency vehicle preemption
4.13.0-3	The System Operator needs to accommodate bus rapid transit.
4.14	**4.14 Failure and fallback**
4.14.0-1	The system operator needs to fall back to TOD or isolated free operation, as specified by the operator, without causing disruption to traffic flow, in the event of equipment, communications and software failure.
4.15	**4.15 Constraints**
4.15.0-1	The system operator is constrained to use the following equipment:
4.15.0-1.0-1	• Controller type - Siemens M34, M42, M52 series controllers
4.15.0-1.0-2	• Detector type – Iteris video detection, inductive loops, Sensys magnetometers, microwave radar
4.15.0-1.0-3	• Communication system - hardwire/fiber and wireless IP/Ethernet
4.15.0-1.0-4	• Cabinet type and size NEMA TS1, NEMA TS2, Type 2
4.15.0-1.0-5	• Traffic signal system software – the adaptive system must not prevent the existing Siemens TACTICS central system from monitoring and recording intersection status, including the collection of all detection data and any signal failures being reported by the Controller.
4.15.0-2	The system operator needs to use equipment and software acceptable under the City's current technology policies and procedures (Windows-PC, Windows 7 operating system).
4.16	**4.16 Training and support**
4.16.0-1	The Cities need all staff involved in operation and maintenance to receive appropriate training.
4.16.0-2	The Cities need the system to fulfill all requirements for the life of the system. The Cities

User Needs Reference Number	Concept of Operations Needs Statements
	therefore need the system to be maintained to repair faults that are not defects in materials and workmanship.
4.16.0-3	The Cities need the system to fulfill all requirements for the life of the system. The Cities therefore needs the system to remain free of defects in materials and workmanship that result in requirements no longer being fulfilled.
4.16.0-4	The Cities need the system to fulfill all requirements for the life of the system. The Cities therefore need support to keep software and software environment updated as necessary to prevent requirements no longer being fulfilled.
4.17	**4.17 External interfaces**
	N/A
4.18	**4.18 Maintenance**
4.18.0-1	Each maintenance crew of the maintenance agency (currently the City of North Little Rock) needs all applicable equipment to be readily accessible for maintenance and support activities in the field and at other locations within the maintaining agency. Special access equipment not normally available to them for maintenance will not be allowed.

needs list 20140911.docx

3.2 System Requirements List

The System requirements are listed as follows. The adaptive signal control software shall meet the requirements listed herein. The software provider will be required to verify that they meet these requirements, or list what more may be required for their system to meet the requirements, as discussed in the Verification Plan.

Requirements Reference Number	System Requirements
1	**1 Network Characteristics**
1.0-1	The ASCT shall control a minimum of 200 signals concurrently
1.0-2	The ASCT shall support groups of signals.
1.0-2.0-2	The ASCT shall control a minimum of 10 groups of signals per corridor.
1.0-2.0-4	Each group shall operate independently
1.0-2.0-1	The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the ASCT system according to configured parameters.
1.0-2.0-1.0-1	The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system according to a time of day schedule. (For example: this may be achieved by assigning signals to different groups or by combining groups.)
1.0-2.0-1.0-2	The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system according to traffic conditions. (For example: this may be achieved by assigning signals to different groups or by combining groups.)
1.0-2.0-1.0-3	The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system when commanded by the user.
2	**2 Type of Operation**
2.1	**2.1 General**
2.1.1	**2.1.1 Mode of Operation**

Requirements Reference Number	System Requirements
2.1.1.0-1	The ASCT shall operate non-adaptively during the presence of a defined condition.
2.1.1.0-2	The ASCT shall operate non-adaptively when adaptive control equipment fails.
2.1.1.0-2.0-1	The ASCT shall operate non-adaptively when a user-specified detector fails.
2.1.1.0-2.0-2	The ASCT shall operate non-adaptively when the number of failed detectors connected to a signal controller exceeds a user-defined value.
2.1.1.0-2.0-3	The ASCT shall operate non-adaptively when the number of failed detectors in a group exceeds a user-defined value.
2.1.1.0-2.0-4	The ASCT shall operate non-adaptively when a user-defined communications link fails.
2.1.1.0-3	The ASCT shall operate non-adaptively when a user manually commands the ASCT to cease adaptively controlling a group of signals.
2.1.1.0-4	The ASCT shall operate non-adaptively when a user manually commands the ASCT to cease adaptive operation.
2.1.1.0-5	The ASCT shall operate non-adaptively in accordance with a user-defined time-of-day schedule.
2.1.1.0-7	The ASCT shall alter the adaptive operation to achieve required objectives in user-specified conditions. (The required objectives are specified in Needs Statement 4.1.0-1. Responding to this requirement demonstrates how the proposed system allows the user to define the conditions at which the objectives shift and their associated requirements are fulfilled.) (The alteration may be made by adjusting parameters or by directly controlling the state of signal controllers.)
2.1.1.0-7.0-1	When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of the signal controllers, maximizing the throughput of the coordinated route.
2.1.1.0-7.0-2	When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of signal controllers, preventing queues from exceeding the storage capacity at user-specified locations.
2.1.1.0-7.0-3	When current measured traffic conditions meet user-specified criteria, the ASCT

Requirements Reference Number	System Requirements
	shall alter the state of signal controllers providing equitable distribution of green times during non-peak times
2.1.1.0-7.0-4	When current measured traffic conditions meet user-defined criteria, the ASCT shall alter the state of signal controllers providing two-way progression on a coordinated route.
2.1.1.0-8	The ASCT shall provide maximum and minimum phase times.
2.1.1.0-8.0-1	The ASCT shall provide a user-specified maximum value for each phase at each signal controller.
2.1.1.0-8.0-1.0-1	The ASCT shall not provide a phase length longer that the maximum value.
2.1.1.0-8.0-2	The ASCT shall provide a user-specified minimum value for each phase at each signal controller.
2.1.1.0-8.0-2.0-1	The ASCT shall not provide a phase length shorter than the minimum value.
2.1.1.0-9	The ASCT shall detect repeated phases that do not serve all waiting vehicles. (These phase failures may be inferred, such as by detecting repeated max-out.)
2.1.1.0-9.0-1	The ASCT shall alter operations, to minimize repeated phase failures.
2.1.1.0-10	The ASCT shall determine the order of phases at a user-specified intersection. (The calculation will be based on the optimization function.)
2.1.1.0-11	The ASCT shall provide coordination along a route.
2.1.1.0-11.0-1	The ASCT shall coordinate along a user-defined route.
2.1.1.0-11.0-2	The ASCT shall determine the coordinated route based on traffic conditions.
2.1.1.0-11.0-3	The ASCT shall determine the coordinated route based on a user-defined schedule.
2.1.1.0-11.0-4	The ASCT shall store a minimum of 10 user-defined coordination routes.
2.1.1.0-11.0-4.0-1	The ASCT shall implement a stored coordinated route by operator command.
2.1.1.0-11.0-4.0-2	The ASCT shall implement a stored coordinated route based on traffic conditions.

Requirements Reference Number	System Requirements
2.1.1.0-11.0-4.0-3	The ASCT shall implement a stored coordinated route based on a user-defined schedule.
2.1.1.0-12	The ASCT shall not prevent the use of phase timings in the local controller set by agency policy.
2.1.2	**2.1.2 Allowable Phases**
2.1.2.0-1	The ASCT shall not prevent protected/permissive left turn phase operation.
2.1.2.0-2	The ASCT shall not prevent the protected left turn phase to lead or lag the opposing through phase based upon user-specified conditions.
2.1.2.0-3	The ASCT shall prevent skipping a user-specified phase when the user-specified phase sequence is operating.
2.1.2.0-4	The ASCT shall prevent skipping a user-specified phase based on the state of a user-specified external input.
2.1.2.0-5	The ASCT shall prevent skipping a user-specified phase according to a time of day schedule.
2.1.2.0-6	The ASCT shall omit a user-specified phase when the cycle length is below a user-specified value.
2.1.2.0-7	The ASCT shall omit a user-specified phase based on measured traffic conditions.
2.1.2.0-8	The ASCT shall omit a user-specified phase according to a time of day schedule
2.1.2.0-10	The ASCT shall assign unused time from a preceding phase that terminates early to a user-specified phase as follows: • next phase; • next coordinated phase; • user-specified phase.

Requirements Reference Number	System Requirements
2.1.2.0-11	The ASCT shall assign unused time from a preceding phase that is skipped to a user-specified phase as follows: • previous phase; • next phase; • next coordinated phase; • user-specified phase.
2.1.2.0-12	The ASCT shall not alter the order of phases at a user-specified intersection.
2.1.3	**2.1.3 Oversaturation**
2.1.3.0-1	The ASCT shall detect the presence of queues at pre-configured locations.
2.1.3.0-2	When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational modes, specifically during potential spill out onto freeway and queuing at closely spaced signals.
2.1.3.0-3	When queues are detected at user-specified locations, the ASCT shall execute user-specified adaptive operation strategy.
2.1.3.0-4	When queues are detected at user-specified locations, the ASCT shall omit a user-specified phase at a user-specified signal controller.
2.1.3.0-5	The ASCT shall meter traffic into user-specified bottlenecks by storing queues at user-specified locations.
2.1.3.0-6	The ASCT shall store queues at user-specified locations.
2.1.3.0-7	The ASCT shall maintain capacity flow through user-specified bottlenecks.
2.1.3.0-8	When queues are detected at user-specified locations, the ASCT shall limit the cycle length of the group to a user-specified value.
2.2	**2.2 Sequence-based Adaptive Coordination**
2.2.0-2	**(Sequence-based only)** The ASCT shall select cycle length based on a time of day schedule.
2.2.0-3	**(Sequence-based only)** The ASCT shall calculate phase lengths for all phases at

Requirements Reference Number	System Requirements
	each signal controller to suit the current coordination strategy.
2.2.0-4	(Sequence-based only) The ASCT shall calculate offsets to suit the current coordination strategy for the user-specified reference point for each signal controller along a coordinated route within a group.
2.2.0-4.0-1	(Sequence-based only) The ASCT shall apply offsets for the user-specified reference point of each signal controller along a coordinated route.
2.2.0-5.0-2	(Sequence-based only) The ASCT shall limit cycle lengths to a user-specified range that is acceptable to the City.
2.2.0-5.0-3	(Sequence-based only) The ASCT shall calculate optimum cycle length according to the user-specified coordination strategy.
2.2.0-5.0-4	(Sequence-based only) The ASCT shall limit changes in cycle length to not exceed a user-specified value. Those changes/steps shall be stated by the vendor.
2.2.0-5.0-4.0-1	(Sequence-based only) The ASCT shall increase the limit for the following 3 cycles based on a change in conditions.
2.2.0-5.0-4.0-1.0-1	(Sequence-based only) The change in conditions shall be defined by 3 successive adaptive increases in cycle length at the maximum rate.
2.2.0-5.0-4.0-1.0-2	(Sequence-based only) The increased limit shall be user-defined.
2.2.0-5.0-5	(Sequence-based only) The ASCT shall adjust offsets to minimize the chance of stopping vehicles approaching a signal that have been served by a user-specified phase at an upstream signal.
2.3	**2.3 Non-sequence-based adaptive coordination**
2.3.0-2	(Non-sequence-based only) Data shall be passed between controllers by peer to peer exchange. The ASCT shall calculate the appropriate state of the signal to suit the current coordination strategy at the critical signal controller. (A critical signal controller is defined by the user.)
2.3.0-3	(Non-sequence-based only) At non-critical intersections within a group, the ASCT shall calculate the time at which a user-specified phase shall be green, relative to a reference point at the critical intersection, to suit the current coordination

Requirements Reference Number	System Requirements
	strategy.
2.3.0-4	(Non-sequence-based only) When demand is present, the ASCT shall implement a user-specified maximum time between successive displays of each phase at each intersection.
2.4	**2.4 Single intersection adaptive operation**
2.4.0-2	The ASCT shall calculate a cycle length of a single intersection, based on current measured traffic conditions. (The calculation is based on the optimization objectives.)
2.4.0-3.0-1	The ASCT shall limit the difference between the length of a given phase and the length of the same phase during its next service to a user-specified value.
2.4.0-3.0-2	When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational mode.
2.4.0-3	The ASCT shall calculate optimum phase lengths, based on current measured traffic conditions. (The calculation is based on the optimization objectives.)
2.5	**2.5 Phase-based adaptive coordination**
2.5.0-2	(Phase-based only) The ASCT shall alter the state of the signal controller for all phases at the user-specified intersection.
2.5.0-3	(Phase-based only) The ASCT shall calculate the time at which a user-specified phase shall be green at an intersection.
2.5.0-4	(Phase-based only) When demand is present, the ASCT shall implement a user-specified maximum time between successive displays of each phase at each intersection.
2.5.0-5	(Phase-based only) The ASCT shall alter the operation of the non-critical intersections to minimize stopping of traffic arriving at user-specified phases at the user-specified critical intersection.
2.5.0-6	(Phase-based only) The ASCT shall alter the operation of the non-critical intersections to minimize stopping of traffic arriving at user-specified phases at the user-specified critical intersection.

Requirements Reference Number	System Requirements
2.6	**2.6 Responsiveness**
2.6.0-1	The ASCT shall limit the change in consecutive cycle lengths to be less than a user-specified value.
2.6.0-2	The ASCT shall limit the change in phase times between consecutive cycles to be less than a user-specified value. (This does not apply to early gap-out or actuated phase skipping.)
2.6.0-3	The ASCT shall limit the changes in the direction of primary coordination to a user-specified frequency.
2.6.0-4	When a large change in traffic demand is detected, the ASCT shall respond and make large changes in cycle/offsets/splits in less than 5 minutes
2.6.0-5	The ASCT shall select cycle length from a list of user-defined cycle lengths.
3	**3 External/Internal Interfaces**
3.0-1.0-3	The ASCT shall not prevent TACTICS from monitoring signal status
4	**4 Crossing Arterials and Boundaries**
4.0-1	The ASCT shall conform its operation to an external system's operation in that commands from TACTICS, such as upload and download of timing parameters, or report generation shall be allowed by the ASCT.
4.0-1.0-1	The ASCT shall alter its operation to minimize interruption of traffic entering the system. (This may be achieved via detection, with no direct connection to the other system.)
4.0-1.0-2	The ASCT shall be able to operate a fixed cycle length to match the cycle length of an adjacent system.
4.0-1.0-4	The ASCT shall support adaptive coordination on crossing routes. It is expected that side street signalized intersections in close proximity of the main adaptive corridor be coordinated and integrated into the adaptive system, as identified.

Requirements Reference Number	System Requirements
5	**5 Access and Security**
5.0-1	The ASCT shall be implemented with a security policy that addresses the following selected elements:
5.0-1.0-1	• Local access to the ASCT.
5.0-1.0-2	• Remote access to the ASCT.
5.0-1.0-3	• System monitoring.
5.0-1.0-4	• System manual override.
5.0-1.0-5	• Development
5.0-1.0-6	• Operations
5.0-1.0-7	• User login
5.0-1.0-8	• User password
5.0-1.0-9	• Administration of the system
5.0-1.0-10	• Signal controller group access
5.0-1.0-11	• Access to classes of equipment
5.0-1.0-12	• Access to equipment by jurisdiction
5.0-1.0-13	• Output activation
5.0-1.0-14	• System parameters
5.0-1.0-15	• Report generation
5.0-1.0-16	• Configuration
5.0-1.0-17	• Security alerts
5.0-1.0-18	• Security logging
5.0-1.0-19	• Security reporting

Requirements Reference Number	System Requirements
5.0-1.0-20	• Database
5.0-1.0-21	• Signal controller
5.0-2	The ASCT shall provide monitoring and control access at the following locations:
5.0-2.0-1	• Traffic Engineering Division Building
5.0-2.0-3	• Agency LAN or WAN
5.0-2.0-5	• Local controller cabinets
5.0-2.0-7	• Remote locations via secure VPN
5.0-3	The ASCT shall comply with the current City's IT security policy at the time of bid, and as outlined in this document.
5.0-4	The ASCT shall not prevent access to the local signal controller database, monitoring or reporting functions by any installed signal management system.
6	**6 Data Log**
6.0-1	The ASCT shall log the following events:
6.0-1.0-1	• Time-stamped vehicle phase calls
6.0-1.0-2	• Time-stamped pedestrian phase calls
6.0-1.0-3	• Time-stamped emergency vehicle preemption calls
6.0-1.0-4	• Time-stamped transit priority calls
6.0-1.0-5	• Time-stamped railroad preemption calls
6.0-1.0-6	• Time-stamped start and end of each phase
6.0-1.0-7	• Time-stamped controller interval changes
6.0-1.0-8	• Time-stamped start and end of each transition to a new timing plan
6.0-2	The ASCT shall export its systems log in the following formats:

Requirements Reference Number	System Requirements
	(edit as appropriate) • MS Excel • Text • CVS • Open source SQL database
6.0-3	The ASCT shall store the event log for a minimum of 30 days
6.0-4	The ASCT shall store results of all signal timing parameter calculations for a minimum of 30 days.
6.0-5	The ASCT shall store the following measured data in the form used as input to the adaptive algorithm for a minimum of 30 days: (edit as appropriate) • volume • occupancy • queue length • phase utilization • arrivals in green • green band efficiency
6.0-6	The ASCT system shall archive all data automatically after a user-specified period not less than 30 days.
6.0-7	The ASCT shall provide data storage for a system size of 200 signal controllers. The data to be stored shall include the following: • Controller state data • Reports • Log data • Security data

Requirements Reference Number	System Requirements
	• ASCT parameters • Detector status data
6.0-8	The ASCT shall calculate and report relative data quality including: • The extent data is affected by detector faults • Other applicable items
6.0-9	The ASCT shall report comparisons of logged data when requested by the user: • Day to day • Hour to hour • Hour of day to hour of day • Hour of week to hour of week • Day of week to day week • Day of year to day of year
6.0-10	The ASCT shall store data logs in a standard database export to be opened and readable in MS Excel (CSV or XLS files).
6.0-11	The ASCT shall report stored data in a form suitable to provide explanations of system behavior to public and politicians and to troubleshoot the system, such as graphs, HTML, etc.
7	**7 Advanced Controller Operation**
7.0-1	When specified by the user, the ASCT shall serve a vehicle phase more than once for each time the coordinated phase is served.
7.0-2	The ASCT shall provide a minimum of 8 phase overlaps.
7.0-3	The ASCT shall accommodate a minimum of 16 phases at each signal
7.0-4	The ASCT shall accommodate a minimum of 4 rings at each signal.

Requirements Reference Number	System Requirements
7.0-5	The ASCT shall accommodate a minimum of 4 phases per ring
7.0-6.0-1	Each permissible phase sequence shall be user-assignable to any signal timing plan.
7.0-6.0-2	Each permissible phase sequence shall be executable by a time of day schedule.
7.0-6.0-3	Each permissible phase sequence shall be executable based on measured traffic conditions
7.0-7	The ASCT shall not prevent a phase/overlap output by time-of-day.
7.0-8	The ASCT shall not prevent a phase/overlap output based on an external input.
7.0-9	The ASCT shall not prevent the following phases to be designated as coordinated phases. (Phases 1 – 8)
7.0-10	The ASCT shall have the option for a coordinated phase to be released early based on a user-definable point in the phase or cycle. (User select phase or cycle.)
7.0-11	The ASCT shall not prevent the controller from displaying flashing yellow arrow left turn or right turn.
7.0-12	The ASCT shall not prevent the local signal controller from performing actuated phase control using 4 extension/passage timers as assigned to user-specified vehicle detector input channels in the local controller.
7.0-12.0-1	The ASCT shall operate adaptively using user-specified detector channels.
7.0-13	When adaptive operation is used in conjunction with normal coordination, the ASCT shall not prevent a controller serving a cycle length different from the cycles used at adjacent intersections.
8	**8 Pedestrians**
8.0-1	When a pedestrian phase is called, the ASCT shall execute leading pedestrian phases up to 5 seconds before the vehicle green of the related vehicle phase.
8.0-2	When a pedestrian phase is called, the ASCT shall accommodate pedestrian crossing times during adaptive operations.

Requirements Reference Number	System Requirements
8.0-5	The ASCT shall execute pedestrian recall on user-defined phases in accordance with a time of day schedule.
8.0-6	The ASCT shall begin a non-coordinated phase later than its normal starting point within the cycle when all of the following conditions exist: • The user enables this feature • Sufficient time in the cycle remains to serve the minimum green times for the phase and the subsequent non-coordinated phases before the beginning of the coordinated phase. • The phase is called after its normal start time. • The associated pedestrian phase is not called.
8.0-7	When specified by the user, the ASCT shall execute pedestrian recall on pedestrian phase adjacent to coordinated phases.
8.0-8	When the pedestrian phases are on recall, the ASCT shall accommodate pedestrian timing during adaptive operation.
8.0-9	The ASCT shall not inhibit negative vehicle and pedestrian phase timing.
9	**9 Special Functions**
9.0-1	The ASCT shall set a specific state for each special function output based on the occupancy on a user-specified detector.
10	**10 Detection**
10.0-1	The ASCT shall be compatible with the following detector technologies (agency to specify): • Detector type A Video Detection • Detector type B Inductive Loops • Detector type C Microwave Radar

Requirements Reference Number	System Requirements
	• Detector type D Magnetometers
11	**11 Railroad and EV Preemption**
11.0-1	The ASCT shall maintain adaptive operation at non-preempted intersections during railroad preemption. It is highly desirable that railroad preempted intersection stays in adaptive control.
11.0-2	The ASCT shall maintain adaptive operation at non-preempted intersections during emergency vehicle preemption.
11.0-4	The ASCT shall resume adaptive control of signal controllers when preemptions are released. Preference shall be given to ASCT that can accommodate preemption within/during adaptive operations.
11.0-5	The ASCT shall execute user-specified actions at non-preempted signal controllers during preemption. (E.g., inhibit a phase, activate a sign, display a message on a DMS)
11.0-6	The ASCT shall operate normally at non-preempted signal controllers when special functions are engaged by a preemption event. (Examples of such special functions are a phase omit, a phase maximum recall or a fire route.)
11.0-7	The ASCT shall release user-specified signal controllers to local control when one signal in a group is preempted.
11.0-8	The ASCT shall not prevent the local signal controller from operating in normally detected limited-service actuated mode during preemption, however, it is highly desirable to stay in adaptive operation during railroad preemption.
12	**12 Transit Priority**
12.0-1	The ASCT shall continue adaptive operations of a group when one of its signal controllers has a transit priority call.
12.0-2	The ASCT shall advance the start of a user-specified green phase in response to a transit priority call.

Requirements Reference Number	System Requirements
12.0-2.0-1	The advance of start of green phase shall be user-defined.
12.0-2.0-2	Adaptive operations shall continue during the advance of the start of green phase.
12.0-3	The ASCT shall delay the end of a green phase, in response to a priority call.
12.0-3.0-1	The delay of end of green phase shall be user-defined.
12.0-3.0-2	Adaptive operations shall continue during the delay of the end of green phase.
12.0-4	The ASCT shall permit at least 2 exclusive transit phases.
12.0-4.0-1	Adaptive operations shall continue when there is an exclusive transit phase call.
12.0-5	The ASCT shall control vehicle phases independently of the following:
12.0-5.0-1	• LRT only phases
12.0-5.0-2	• Bus only phases
12.0-6	The ASCT shall list acceptable external bus transit priority systems
12.0-7	The ASCT shall list acceptable external light rail transit priority systems
12.0-8	The ASCT shall accept a transit priority call from: • A signal controller/transit vehicle detector as listed by the ASCT vendor • An external system, listed by the ASCT vendor
13	**13 Failure Events and Fallback**
13.1	**13.1 Detector Failure**
13.1.0-1	The ASCT shall take user-specified action in the absence of valid detector data from 25% of detectors from the group:
13.1.0-1.0-1	• The ASCT shall release control to central system control.

Requirements Reference Number	System Requirements
13.1.0-1.0-2	• The ASCT shall release control to local operations to operate under its own time-of-day schedule.
13.1.0-2	The ASCT shall use the following alternate data sources for operations in the absence of the real-time data from a detector:
13.1.0-2.0-1	• Data from a user-specified alternate detector.
13.1.0-2.0-2	• Stored historical data from the failed detector.
13.1.0-2.0-3	• The ASCT shall switch to the alternate source in real time without operator intervention.
13.1.0-3	In the event of a detector failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system.)
13.1.0-4	In the event of a failure, the ASCT shall log details of the failure in a permanent log.
13.1.0-5	The permanent failure log shall be searchable, archival and exportable.
13.2	**13.2 Communications Failure**
13.2-1	The ASCT shall execute user-specified actions when communications to one or more signal controllers fails within a group.
13.2-1.0-1	In the event of loss of communication to a user-specified signal controller, the ASCT shall release control of all signal controllers within a user-specified group to local control.
13.2-1.0-2	The ASCT shall switch to the alternate operation in real time without operator intervention.
13.2-2	In the event of communications failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system.

Requirements Reference Number	System Requirements
13.2-3	The ASCT shall issue an alarm within 2 minutes of detection of a failure.
13.2-4	In the event of a communications failure, the ASCT shall log details of the failure in a permanent log.
13.2-5	The permanent failure log shall be searchable, archival and exportable.
13.3	**13.3 Adaptive Processor Failure**
13.3-1	The ASCT shall execute user-specified actions when adaptive control fails:
13.3-1.0-1	• The ASCT shall release control to central system control.
13.3-1.0-2	• The ASCT shall release control to local operations to operate under its own time-of-day schedule.
13.3-2	In the event of adaptive processor failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system.)
13.3-3	The permanent failure log shall be searchable, archival and exportable.
13.3-4	During adaptive processor failure, the ASCT shall provide all local detector inputs to the local controller.
14	**14 Software**
14.0-1	The vendor's adaptive software shall be fully operational within the following platform: • Windows-PC 64 bit Windows 7 • Able to Port to handheld Android & iOS.
14.0-2	The ASCT shall fully satisfy all requirements when connected with detectors from Iteris and Sensys, various microwave and inductive loops.
14.0-3	The ASCT shall fully satisfy all requirements when connected with Siemens M34, M42 and M52 controllers.

Requirements Reference Number	System Requirements
14.0-4	The ASCT shall fully satisfy all requirements when connected with the following cabinet types:
14.0-4.0-1	• NEMA TS1
14.0-4.0-2	• NEMA TS2 - Type 2
14.0-5	The ASCT shall fully satisfy all requirements when connected to an Ethernet communications system via hardwire/fiber, wireless IP/Ethernet
14.0-6	The ASCT shall fully satisfy all requirements without inhibiting any feature of Siemens TACTICS central system and its controller communications.
15	**15 Training**
15.0-1	The vendor shall provide the following training.
15.0-1.0-1	The vendor shall provide training on the operations of the adaptive system.
15.0-1.0-2	The vendor shall provide training on troubleshooting the system.
15.0-1.0-3	The vendor shall provide training on preventive maintenance and repair of equipment.
15.0-1.0-4	The vendor shall provide training on system configuration.
15.0-1.0-5	The vendor shall provide training on administration of the system.
15.0-1.0-6	The vendor shall provide training on system calibration.
15.0-1.0-7	The vendor's training delivery shall include: printed course materials and references, electronic copies of presentations and references.
15.0-1.0-8	The vendor's training shall be delivered in the North Little Rock or Maumelle area
15.0-1.0-9	The vendor shall provide a minimum of 40 hours training to a minimum of 5 staff.
15.0-1.0-10	The vendor shall provide a minimum of 2 training sessions over 3 months. These training sessions shall be an initial training and after ASCT training, after the agency has used the ASCT over a period of 3 months. This training shall be tailored to the proficiency of the operations staff experience.

Requirements Reference Number	System Requirements
16	**16 Maintenance, Support and Warranty**
16.0-1	The Maintenance Vendor shall provide maintenance according to a separate maintenance contract. That contract should identify repairs necessary to preserve requirements fulfillment, responsiveness in effecting those repairs, and all requirements on the maintenance provider while performing the repairs.
16.0-2	The Vendor shall provide routine updates to the software and software environment necessary to preserve the fulfillment of requirements for a period of 5 years following final acceptance. Preservation of requirements fulfillment especially includes all IT management requirements as previously identified.
16.0-3	The Vendor shall warrant the system to be free of defects in materials and workmanship for a period of 5 years following final acceptance. Warranty is defined as correcting defects in materials and workmanship (subject to other language included in the purchase documents). Defect is defined as any circumstance in which the material does not perform according to its specification.
16.0-4	All equipment and other elements of the ASCT shall be located and installed in a fashion that will permit City staff to access it for maintenance and support activities in the field, at the Traffic Engineering building, and at other locations within the Cities, without special access equipment not normally available to them.
17	**17 Schedule**
	N/A
18	**18 Performance Measurement, Monitoring and Reporting**
18.0-1	The ASCT shall report measures of current traffic conditions on which it bases signal state alterations.
18.0-2	The ASCT shall report all intermediate calculated values that are affected by

Requirements Reference Number	System Requirements
	calibration parameters.
18.0-3	The ASCT shall maintain a log of all signal state alterations directed by the ASCT.
18.0-3.0-1	The ASCT log shall include all events directed by the external inputs.
18.0-3.0-2	The ASCT log shall include all external output state changes.
18.0-3.0-3	The ASCT log shall include all actual parameter values that are subject to user-specified values.
18.0-3.0-4	The ASCT shall maintain the records in this ASCT log for 30 days.
18.0-3.0-5	The ASCT shall archive the ASCT log so that it may be readable in an MS Excel format (CSV, XLS, etc)

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4.0 Verification Plan

The System Requirements document and list statements in the previous section are the minimum required for the City of Maumelle, North Little Rock and and Pulaski County AR ASCT. Each of these requirements will need to be verified by the vendor during the procurement process. If a requirement is not attainable or applicable to the ASCT vendor, then those requirements shall be revisited to determine if need is necessary for their operation.

The successful vendor will be required to submit a requirements verification plan with complete system requirement reference numbers and verification statement for each requirement. It will be required that a verification traceability matrix be created by the vendor to test the requirements against the objectives as a submitted test document during the submittal process.

The verification plan will be submitted to the City of North Little Rock or an Engineering representative for approval prior to implementing the ASCT. All verification procedures will require the presence of the vendor and City or Engineering representative to be onsite at the City of North Little Rock's Traffic Engineering building and in the field, as necessary, during the verification of the ASCT. Each system requirement will be verified by the vendor in the presence of the City of North Little Rock or the City of North Little Rock's engineering representative to their satisfaction.

Full documentation and print of the final verification will be prepared by the vendor to the satisfaction of the City or Engineering representative. A record shall be maintained of each verification in the plan, the outcome of the verification recorded, and the record signed by the verifier and City or Engineering representative.

The outcome of each verification shall be recorded as one of the following:

- Complied
- Partially complied, with a statement of acceptable supplementary testing
- Failed, verification procedure to be repeated

The verification shall use one or more of the following methods. This section does not explicitly state each method required for each system requirement since one ASCT system might verify a requirement differently than another. Each approved procedure shall clearly state which method(s) are to be used on the verification plan document.

- **Demonstration:** used for a requirement that the system can demonstrate without external test equipment.
- **Test:** used for a requirement that requires some external piece of test equipment (such as logic analyzer and volt meter). The test and required equipment shall be clearly documented in the procedure.
- **Analyze:** used for a requirement that is met indirectly through a logical conclusion or mathematical analysis of a result. For example, algorithms for calculation of headway; setting of "late" flag; generation of priority request
- **Inspection** is used for verification through a visual comparison. For example, quality of welding may be done through a visual comparison against an in-house standard.

Appendix A – Traceability Matrices

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4	# 4 Chapter 4: Operational Needs		
4.0-1	This chapter describes the operational needs of the users that should be satisfied by the proposed ASCT system. Each of these statements describes something that the system operators need to be able to achieve. Each of these needs will be satisfied by compliance with one or more system requirements. In the attached list of requirements, each one is linked to one or more of these needs statements.		
4.1	## 4.1 Adaptive Strategies		
4.1.0-1	The system operator needs the ability to implement different strategies individually or in combination to suit different prevailing traffic conditions. These strategies include:		3.4 3.5
4.1.0-1.0-1	• Maximize the throughput on coordinated routes Note to user when selecting these requirements: Select from requirements in the 2.2 group when	2.2.0-4 (Sequence-based only) The ASCT shall calculate offsets to suit the current coordination strategy for the user-specified reference point for each signal	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
	sequence-based systems are allowed (sequence-based systems explicitly calculate cycle, offset, and split). Select from requirements in the 2.3 group when non-sequence-based systems are allowed (non-sequence-based systems do not explicitly calculate cycle, offset, and split). (Select requirements from both groups when the vendor is given the choice of supplying one type of adaptive operation or the other.)	controller along a coordinated route within a group. 2.2.0-4.0-1 (Sequence-based only) The ASCT shall apply offsets for the user-specified reference point of each signal controller along a coordinated route. 2.1.1.0-7.0-1 When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of the signal controllers, maximizing the throughput of the coordinated route. 2.2.0-5.0-3 (Sequence-based only) The ASCT shall calculate optimum cycle length according to the user-specified coordination strategy. 2.2.0-5 (Sequence-based only) The ASCT shall calculate a cycle length for each cycle based on its optimization objectives (as required elsewhere, e.g., progression, queue management, equitable distribution of green).	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.3.0-3 (Non-sequence-based only) At non-critical intersections within a group, the ASCT shall calculate the time at which a user-specified phase shall be green, relative to a reference point at the critical intersection, to suit the current coordination strategy. 2.3.0-2 (Non-sequence-based only) The ASCT shall calculate the appropriate state of the signal to suit the current coordination strategy at the critical signal controller. (A critical signal controller is defined by the user.) 2.3.0-4 (Non-sequence-based only) When demand is present, the ASCT shall implement a user-specified maximum time between successive displays of each phase at each intersection. 2.1.1.0-7 The ASCT shall alter the adaptive operation to achieve required objectives in user-specified	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		conditions. (The required objectives are specified in Needs Statement 4.1.0-1. Responding to this requirement demonstrates how the proposed system allows the user to define the conditions at which the objectives shift and their associated requirements are fulfilled.) (The alteration may be made by adjusting parameters or by directly controlling the state of signal controllers.) 2.2.0-2 **(Sequence-based only)** The ASCT shall select cycle length based on a time of day schedule. 2.2.0-5.0-1 (Sequence-based only) The ASCT shall limit cycle lengths to user-specified values. 2.2.0-5.0-2 (Sequence-based only) The ASCT shall limit cycle lengths to a user-specified range. 2.2.0-5.0-4 (Sequence-based only) The ASCT shall limit changes in cycle length to not exceed a user-specified value.	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.2.0-5.0-4.0-1 (Sequence-based only) The ASCT shall increase the limit for the following XX cycles based on a change in conditions. 2.2.0-5.0-4.0-1.0-2 (Sequence-based only) The increased limit shall be user-defined. 2.2.0-5.0-4.0-1.0-1 (Sequence-based only) The change in conditions shall be defined by 3 successive adaptive increases in cycle length at the maximum rate. 2.1.1.0-10 The ASCT shall determine the order of phases at a user-specified intersection. (The calculation will be based on the optimization function.)	
4.1.0-1.0-2	• Provide smooth flow along coordinated routes Note to user when selecting these requirements: Select from requirements in the 2.2 group when sequence-based systems are allowed (sequence-based	2.2.0-4 (Sequence-based only) The ASCT shall calculate offsets to suit the current coordination strategy for the user-specified reference point for each signal	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
	systems explicitly calculate cycle, offset, and split). Select from requirements in the 2.3 group when non-sequence-based systems are allowed (non-sequence-based systems do not explicitly calculate cycle, offset, and split). (Select requirements from both groups when the vendor is given the choice of supplying one type of adaptive operation or the other.)	controller along a coordinated route within a group. 2.2.0-4.0-1 (Sequence-based only) The ASCT shall apply offsets for the user-specified reference point of each signal controller along a coordinated route. 2.1.1.0-7.0-4 When current measured traffic conditions meet user-defined criteria, the ASCT shall alter the state of signal controllers providing two-way progression on a coordinated route. 2.2.0-5.0-3 (Sequence-based only) The ASCT shall calculate optimum cycle length according to the user-specified coordination strategy. 2.2.0-5 (Sequence-based only) The ASCT shall calculate a cycle length for each cycle based on its optimization objectives (as required elsewhere, e.g., progression, queue management, equitable distribution of green).	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.3.0-3 (Non-sequence-based only) At non-critical intersections within a group, the ASCT shall calculate the time at which a user-specified phase shall be green, relative to a reference point at the critical intersection, to suit the current coordination strategy. 2.3.0-2 (Non-sequence-based only) The ASCT shall calculate the appropriate state of the signal to suit the current coordination strategy at the critical signal controller. (A critical signal controller is defined by the user.) 2.3.0-4 (Non-sequence-based only) When demand is present, the ASCT shall implement a user-specified maximum time between successive displays of each phase at each intersection. 2.2.0-2 **(Sequence-based only)** The ASCT shall select cycle length based on a time of day schedule.	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.2.0-5.0-1 (Sequence-based only) The ASCT shall limit cycle lengths to user-specified values. 2.2.0-5.0-2 (Sequence-based only) The ASCT shall limit cycle lengths to a user-specified range. 2.2.0-5.0-4 (Sequence-based only) The ASCT shall limit changes in cycle length to not exceed a user-specified value. 2.2.0-5.0-4.0-1 (Sequence-based only) The ASCT shall increase the limit for the following XX cycles based on a change in conditions. 2.2.0-5.0-4.0-1.0-2 (Sequence-based only) The increased limit shall be user-defined. 2.2.0-5.0-4.0-1.0-1 (Sequence-based only) The change in conditions shall be defined by 3 successive adaptive increases	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		in cycle length at the maximum rate. 2.1.1.0-10 The ASCT shall determine the order of phases at a user-specified intersection. (The calculation will be based on the optimization function.)	
4.1.0-1.0-3	• Distribute phase times in an equitable fashion Note to user when selecting these requirements: Select from requirements in the 2.2 group when sequence-based systems are allowed (sequence-based systems explicitly calculate cycle, offset, and split). Select from requirements in the 2.3 group when non-sequence-based systems are allowed (non-sequence-based systems do not explicitly calculate cycle, offset, and split). (Select requirements from both groups when the vendor is given the choice of supplying one type of adaptive operation or the other.)	2.1.1.0-7.0-3 When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of signal controllers providing equitable distribution of green times during Non-peak times 2.2.0-3 (Sequence-based only) The ASCT shall calculate phase lengths for all phases at each signal controller to suit the current coordination strategy. 2.2.0-5.0-3 (Sequence-based only) The ASCT shall calculate optimum cycle length according to the user-	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		specified coordination strategy. 2.2.0-5 (Sequence-based only) The ASCT shall calculate a cycle length for each cycle based on its optimization objectives (as required elsewhere, e.g., progression, queue management, equitable distribution of green). 2.4.0-3 The ASCT shall calculate optimum phase lengths, based on current measured traffic conditions. (The calculation is based on the optimization objectives.) 2.3.0-3 (Non-sequence-based only) At non-critical intersections within a group, the ASCT shall calculate the time at which a user-specified phase shall be green, relative to a reference point at the critical intersection, to suit the current coordination strategy. 2.3.0-2 (Non-sequence-based only) The ASCT shall calculate the appropriate state of the signal to suit the	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		current coordination strategy at the critical signal controller. (A critical signal controller is defined by the user.) 2.3.0-4 (Non-sequence-based only) When demand is present, the ASCT shall implement a user-specified maximum time between successive displays of each phase at each intersection. 2.1.1.0-7 The ASCT shall alter the adaptive operation to achieve required objectives in user-specified conditions. (The required objectives are specified in Needs Statement 4.1.0-1. Responding to this requirement demonstrates how the proposed system allows the user to define the conditions at which the objectives shift and their associated requirements are fulfilled.) (The alteration may be made by adjusting parameters or by directly controlling the state of signal controllers.)	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.2.0-2 **(Sequence-based only)** The ASCT shall select cycle length based on a time of day schedule. 2.1.1.0-8.0-1 The ASCT shall provide a user-specified maximum value for each phase at each signal controller. 2.1.1.0-8.0-1.0-1 The ASCT shall not provide a phase length longer that the maximum value. 2.1.1.0-8.0-2 The ASCT shall provide a user-specified minimum value for each phase at each signal controller. 2.1.1.0-8.0-2.0-1 The ASCT shall not provide a phase length shorter than the minimum value. 2.2.0-5.0-1 (Sequence-based only) The ASCT shall limit cycle lengths to user-specified values.	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.2.0-5.0-2 (Sequence-based only) The ASCT shall limit cycle lengths to a user-specified range. 2.2.0-5.0-4 (Sequence-based only) The ASCT shall limit changes in cycle length to not exceed a user-specified value. 2.2.0-5.0-4.0-1 (Sequence-based only) The ASCT shall increase the limit for the following XX cycles based on a change in conditions. 2.2.0-5.0-4.0-1.0-2 (Sequence-based only) The increased limit shall be user-defined. 2.2.0-5.0-4.0-1.0-1 (Sequence-based only) The change in conditions shall be defined by 3 successive adaptive increases in cycle length at the maximum rate. 2.1.1.0-8 The ASCT shall provide maximum and minimum	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		phase times. 2.4.0-3.0-1 The ASCT shall limit the difference between the length of a given phase and the length of the same phase during its next service to a user-specified value. 2.4.0-3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational mode.	
4.1.0-1.0-4	• Manage the lengths of queues Note to user when selecting these requirements: Select from requirements in the 2.2 group when sequence-based systems are allowed (sequence-based systems explicitly calculate cycle, offset, and split). Select from requirements in the 2.3 group when non-sequence-based systems are allowed (non-sequence-based systems do not explicitly calculate cycle, offset,	2.1.3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational modes, specifically during potential spill out onto freeway and queuing at closely spaced signals. 2.2.0-4 (Sequence-based only) The ASCT shall calculate offsets to suit the current coordination strategy for the user-specified reference point for each signal controller along a coordinated route within a group.	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
	and split). (Select requirements from both groups when the vendor is given the choice of supplying one type of adaptive operation or the other.)	2.2.0-4.0-1 (Sequence-based only) The ASCT shall apply offsets for the user-specified reference point of each signal controller along a coordinated route. 2.1.1.0-7.0-2 When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of signal controllers, preventing queues from exceeding the storage capacity at user-specified locations. 2.2.0-5.0-3 (Sequence-based only) The ASCT shall calculate optimum cycle length according to the user-specified coordination strategy. 2.2.0-5 (Sequence-based only) The ASCT shall calculate a cycle length for each cycle based on its optimization objectives (as required elsewhere, e.g., progression, queue management, equitable distribution of green).	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.3.0-3 (Non-sequence-based only) At non-critical intersections within a group, the ASCT shall calculate the time at which a user-specified phase shall be green, relative to a reference point at the critical intersection, to suit the current coordination strategy. 2.1.3.0-1 The ASCT shall detect the presence of queues at pre-configured locations. 2.3.0-2 (Non-sequence-based only) The ASCT shall calculate the appropriate state of the signal to suit the current coordination strategy at the critical signal controller. (A critical signal controller is defined by the user.) 2.3.0-4 (Non-sequence-based only) When demand is present, the ASCT shall implement a user-specified maximum time between successive displays of each phase at each intersection.	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.2.0-2 **(Sequence-based only)** The ASCT shall select cycle length based on a time of day schedule. 2.1.3.0-3 When queues are detected at user-specified locations, the ASCT shall execute user-specified adaptive operation strategy. 2.1.3.0-4 When queues are detected at user-specified locations, the ASCT shall omit a user-specified phase at a user-specified signal controller. 2.2.0-5.0-1 (Sequence-based only) The ASCT shall limit cycle lengths to user-specified values. 2.2.0-5.0-2 (Sequence-based only) The ASCT shall limit cycle lengths to a user-specified range. 2.2.0-5.0-4 (Sequence-based only) The ASCT shall limit changes	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		in cycle length to not exceed a user-specified value. 2.2.0-5.0-4.0-1 (Sequence-based only) The ASCT shall increase the limit for the following 3 cycles based on a change in conditions. 2.2.0-5.0-4.0-1.0-2 (Sequence-based only) The increased limit shall be user-defined. 2.2.0-5.0-4.0-1.0-1 (Sequence-based only) The change in conditions shall be defined by 3 successive adaptive increases in cycle length at the maximum rate. 2.1.1.0-10 The ASCT shall determine the order of phases at a user-specified intersection. (The calculation will be based on the optimization function.) 2.1.3.0-5 The ASCT shall meter traffic into user-specified bottlenecks by storing queues at user-specified	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		locations. 2.1.3.0-6 The ASCT shall store queues at user-specified locations.	
4.1.0-1.0-5	• Manage the locations of queues within the network Note to user when selecting these requirements: Select from requirements in the 2.2 group when sequence-based systems are allowed (sequence-based systems explicitly calculate cycle, offset, and split). Select from requirements in the 2.3 group when non-sequence-based systems are allowed (non-sequence-based systems do not explicitly calculate cycle, offset, and split). (Select requirements from both groups when the vendor is given the choice of supplying one type of adaptive operation or the other.)	2.1.3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational modes, specifically during potential spill out onto freeway and queuing at closely spaced signals. 2.2.0-3 (Sequence-based only) The ASCT shall calculate phase lengths for all phases at each signal controller to suit the current coordination strategy . 2.1.3.0-1 The ASCT shall detect the presence of queues at pre-configured locations. 2.1.3.0-3 When queues are detected at user-specified	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		locations, the ASCT shall execute user-specified adaptive operation strategy. 2.1.3.0-4 When queues are detected at user-specified locations, the ASCT shall omit a user-specified phase at a user-specified signal controller. 2.1.3.0-5 The ASCT shall meter traffic into user-specified bottlenecks by storing queues at user-specified locations. 2.1.3.0-6 The ASCT shall store queues at user-specified locations. 2.1.3.0-8 When queues are detected at user-specified locations, the ASCT shall limit the cycle length of the group to a user-specified value.	
4.1.0-1.0-6	• At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).	2.4.0-2 The ASCT shall calculate a cycle length of a single	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		intersection, based on current measured traffic conditions. (The calculation is based on the optimization objectives.) 2.4.0-3 The ASCT shall calculate optimum phase lengths, based on current measured traffic conditions. (The calculation is based on the optimization objectives.) 2.4.0-4 The ASCT shall calculate phase order, based on current measured traffic conditions. (The calculation is based on the optimization objectives.) 2.1.1.0-8.0-1 The ASCT shall provide a user-specified maximum value for each phase at each signal controller. 2.1.1.0-8.0-1.0-1 The ASCT shall not provide a phase length longer that the maximum value. 2.1.1.0-8.0-2 The ASCT shall provide a user-specified minimum	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		value for each phase at each signal controller. 2.1.1.0-8.0-2.0-1 The ASCT shall not provide a phase length shorter than the minimum value. 2.1.1.0-8 The ASCT shall provide maximum and minimum phase times. 2.4.0-3.0-1 The ASCT shall limit the difference between the length of a given phase and the length of the same phase during its next service to a user-specified value. 2.4.0-3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational mode.	
4.1.0-2	The system operator needs to manage the coordination in small groups of signals to link phase service at some intersections with phase service at adjacent	2.5.0-3 (Phase-based only) The ASCT shall calculate the time at which a user-specified phase shall be green	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
	intersections. Note that phase-based systems do not explicitly calculate cycle, offset and split at all intersections.	at an intersection. 2.5.0-2 (Phase-based only) The ASCT shall alter the state of the signal controller for all phases at the user-specified intersection. 2.5.0-4 (Phase-based only) When demand is present, the ASCT shall implement a user-specified maximum time between successive displays of each phase at each intersection. 2.5.0-5 (Phase-based only) The ASCT shall alter the operation of the non-critical intersections to minimize stopping of traffic released from user-specified phases at the user-specified critical intersection. 2.5.0-6 (Phase-based only) The ASCT shall alter the operation of the non-critical intersections to minimize stopping of traffic arriving at user-specified phases at the user-specified critical	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		intersection. 2.5.0-7 (Phase-based only) The ASCT shall adjust the state of the signal controller so that vehicles approaching a signal that have been served during a user-specified phase at an upstream signal do not stop.	
4.1.0-3	The system operator needs to change the operational strategy (for example, from smooth flow to maximizing throughput or managing queues) based on changing traffic conditions.	2.1.1.0-7.0-1 When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of the signal controllers, maximizing the throughput of the coordinated route. 2.1.1.0-7.0-2 When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of signal controllers, preventing queues from exceeding the storage capacity at user-specified locations. 2.1.1.0-7.0-3 When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of signal controllers providing equitable distribution	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		of green times. 2.1.1.0-7.0-4 When current measured traffic conditions meet user-defined criteria, the ASCT shall alter the state of signal controllers providing two-way progression on a coordinated route. 2.1.1.0-7 The ASCT shall alter the adaptive operation to achieve required objectives in user-specified conditions. (The required objectives are specified in Needs Statement 4.1.0-1. Responding to this requirement demonstrates how the proposed system allows the user to define the conditions at which the objectives shift and their associated requirements are fulfilled.) (The alteration may be made by adjusting parameters or by directly controlling the state of signal controllers.)	
4.1.0-4	The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue	2.1.3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational mode.	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
	resulting from the trailing end of the through green from blocking the storage needed by an entering side-street left turn in the subsequent phase. An overall queue management strategy, particularly when congestion is present, is covered under 4.1.0-1.0-5.	2.2.0-3 (Sequence-based only) The ASCT shall calculate phase lengths for all phases at each signal controller to suit the current coordination strategy. 2.1.3.0-1 The ASCT shall detect the presence of queues at pre-configured locations. 2.1.1.0-9 The ASCT shall detect repeated phases that do not serve all waiting vehicles. (These phase failures may be inferred, such as by detecting repeated max-out.) 2.1.1.0-9.0-1 The ASCT shall alter operations, to minimize repeated phase failures. 2.1.3.0-3 When queues are detected at user-specified locations, the ASCT shall execute user-specified adaptive operation strategy.	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.1.3.0-4 When queues are detected at user-specified locations, the ASCT shall omit a user-specified phase at a user-specified signal controller.	
4.1.0-5	The system operator needs to minimize the chance that a queue forms at a specified location. Note to user when selecting these requirements: Select from requirements in the 2.2 group when sequence-based systems are allowed (sequence-based systems explicitly calculate cycle, offset, and split). Select from requirements in the 2.3 group when non-sequence-based systems are allowed (non-sequence-based systems do not explicitly calculate cycle, offset, and split). Select from requirements in the 2.5 group when phase-based systems are allowed (phase-based systems do not explicitly calculate cycle, offset and split at all intersections). (Select requirements from two or all three groups when the vendor is given the choice of supplying the type of	2.3.0-5 (Non-sequence-based only) The ASCT shall adjust signal timing so that vehicles approaching a signal that have been served during a user-specified phase at an upstream signal do not stop. 2.5.0-7 (Phase-based only) The ASCT shall adjust the state of the signal controller so that vehicles approaching a signal that have been served during a user-specified phase at an upstream signal do not stop. 2.2.0-5.0-5 (Sequence-based only) The ASCT shall adjust offsets to minimize the chance of stopping vehicles approaching a signal that have been served by a user-specified phase at an upstream signal.	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
	adaptive operation.)		
4.1.0-6	The system operator needs to modify the sequence of phases to support the various operational strategies.	7.0-6 7.0-6.0-1 Each permissible phase sequence shall be user-assignable to any signal timing plan. 7.0-6.0-2 Each permissible phase sequence shall be executable by a time of day schedule. 7.0-6.0-3 Each permissible phase sequence shall be executable based on measured traffic conditions 7.0-7 The ASCT shall not prevent a phase/overlap output by time-of-day. 7.0-8 The ASCT shall not prevent a phase/overlap output based on an external input.	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		7.0-9 The ASCT shall not prevent the following phases to be designated as coordinated phases. (User to list all required phases.)	
4.1.0-7	The system operator needs to fix the sequence of phases at any specified location. For example, the operator may need to fix the phase order at a diamond interchange.	2.1.2.0-12 The ASCT shall not alter the order of phases at a user-specified intersection.	3.4 3.5
4.1.0-8	The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.	2.1.1.0-11 The ASCT shall provide coordination along a route. 2.1.1.0-11.0-1 The ASCT shall coordinate along a user-defined route. 2.1.1.0-11.0-2 The ASCT shall determine the coordinated route based on traffic conditions. 2.1.1.0-11.0-3 The ASCT shall determine the coordinated route based on a user-defined schedule.	3.4 3.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.1.1.0-11.0-4 The ASCT shall store a minimum of 10 user-defined coordination routes. 2.1.1.0-11.0-4.0-1 The ASCT shall implement a stored coordinated route by operator command. 2.1.1.0-11.0-4.0-2 The ASCT shall implement a stored coordinated route based on traffic conditions. 2.1.1.0-11.0-4.0-3 The ASCT shall implement a stored coordinated route based on a user-defined schedule.	
4.1.0-9	The system operator needs to set signal timing parameters (such as minimum green, maximum green and extension time) to comply with agency policies.	2.1.1.0-12 The ASCT shall not prevent the use of phase timings in the local controller set by agency policy.	3.4 3.5
4.2	**4.2 Network characteristics**		4.1
4.2.0-1	The system operator needs to eventually adaptively control up to 200 signals.	1.0-1 The ASCT shall control a minimum of 200 signals	4.1

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		concurrently	
4.2.0-2	The system operator needs to be able to adaptively control up to 10 independent groups of signals per corridor	1.0-2 The ASCT shall support groups of signals. 1.0-2.0-2 The ASCT shall control a minimum of 10 groups of signals per corridor. 1.0-2.0-4 Each group shall operate independently 1.0-2.0-1 The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the ASCT system according to configured parameters.	4.1
4.2.0-3	The system operator needs to vary the number of signals in an adaptively controlled group to accommodate the prevailing traffic conditions.	1.0-2 The ASCT shall support groups of signals. 1.0-2.0-3	4.1

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		. 1.0-2.0-1.0-1 The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system according to a time of day schedule. (For example: this may be achieved by assigning signals to different groups or by combining groups.) 1.0-2.0-1.0-2 The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system according to traffic conditions. (For example: this may be achieved by assigning signals to different groups or by combining groups.) 1.0-2.0-1.0-3 The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system when commanded by the user.	
4.3	**4.3 Coordination across boundaries**		4.2 4.3

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4.3.0-1	The system operator needs to adaptively control signals operated by (specify jurisdictions).		4.2 4.3
4.3.0-3	The system operator needs to adaptively coordinate signals on two crossing routes simultaneously. (All signals within the group are under the control of City Maumelle, City of North Little Rock, or Pulaski County.)	4.0-1.0-4 The ASCT shall support adaptive coordination on crossing routes.	4.2 4.3
4.3.0-5	The system operator needs to constrain the adaptive system to operate a cycle length compatible with the crossing arterial.	4.0-1.0-2 The ASCT shall operate a fixed cycle length to match the cycle length of an adjacent system.	4.2 4.3
4.3.0-6	The system operator needs to detect traffic approaching from a neighboring system and coordinate the ASCT operation with the adjacent system.	4.0-1.0-1 The ASCT shall alter its operation to minimize interruption of traffic entering the system. (This may be achieved via detection, with no direct connection to the other system.) 4.0-1 The ASCT shall conform its operation to an external system's operation.	4.2 4.3
4.4	**4.4 Security**		4.3.4

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4.4.0-1	The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.	5.0-1 The ASCT shall be implemented with a security policy that addresses the following selected elements: 5.0-1.0-1 • Local access to the ASCT. 5.0-1.0-2 • Remote access to the ASCT. 5.0-1.0-3 • System monitoring. 5.0-1.0-4 • System manual override. 5.0-1.0-5 • Development 5.0-1.0-6 • Operations	4.3.4

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		5.0-1.0-7 • User login 5.0-1.0-8 • User password 5.0-1.0-9 • Administration of the system 5.0-1.0-10 • Signal controller group access 5.0-1.0-11 • Access to classes of equipment 5.0-1.0-12 • Access to equipment by jurisdiction 5.0-1.0-13 • Output activation 5.0-1.0-14	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		• System parameters 5.0-1.0-15 • Report generation 5.0-1.0-16 • Configuration 5.0-1.0-17 • Security alerts 5.0-1.0-18 • Security logging 5.0-1.0-19 • Security reporting 5.0-1.0-20 • Database 5.0-1.0-21 • Signal controller	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		5.0-3 The ASCT shall comply with the agency's security policy as described in (specify appropriate policy document).	
4.5	**4.5 Queuing interactions**		4.4
4.5.0-1	The system operator needs to detect queues from outside the system and modify the ASCT operation to accommodate the queuing.	2.1.3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational modes, specifically during potential spill out onto freeway and queuing at closely spaced signals.2.1.3.0-1 The ASCT shall detect the presence of queues at pre-configured locations. 2.1.3.0-3 When queues are detected at user-specified locations, the ASCT shall execute user-specified adaptive operation strategy.	4.4
4.5.0-2	The system operator needs to detect queues within the system's boundaries and modify the ASCT operation to accommodate the queuing.	2.1.3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified	4.4

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		timing plan/operational modes, specifically during potential spill out onto freeway and queuing at closely spaced signals.2.1.3.0-1 The ASCT shall detect the presence of queues at pre-configured locations. 2.1.3.0-3 When queues are detected at user-specified locations, the ASCT shall execute user-specified adaptive operation strategy.	
4.5.0-3	The system operator needs to detect queues propagating outside its boundaries from within the ASCT boundaries, and modify its operation to accommodate the queuing.	2.1.3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational modes, specifically during potential spill out onto freeway and queuing at closely spaced signals.2.1.3.0-1 The ASCT shall detect the presence of queues at pre-configured locations. 2.1.3.0-3 When queues are detected at user-specified locations, the ASCT shall execute user-specified	4.4

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		adaptive operation strategy.	
4.5.0-4	The system operator needs to store queues in locations where they can be accommodated without adversely affecting adaptive operation.	2.1.3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational mode. 2.1.3.0-1 The ASCT shall detect the presence of queues at pre-configured locations. 2.1.3.0-3 When queues are detected at user-specified locations, the ASCT shall execute user-specified adaptive operation strategy. 2.1.3.0-4 When queues are detected at user-specified locations, the ASCT shall omit a user-specified phase at a user-specified signal controller. 2.1.3.0-5 The ASCT shall meter traffic into user-specified bottlenecks by storing queues at user-specified	4.4

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		locations. 2.1.3.0-6 The ASCT shall store queues at user-specified locations. 2.1.3.0-7 The ASCT shall maintain capacity flow through user-specified bottlenecks.	
4.5.0-5	The system operator needs to prevent queues forming at user-specified locations.	2.1.3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational mode. 2.1.3.0-1 The ASCT shall detect the presence of queues at pre-configured locations. 2.1.3.0-3 When queues are detected at user-specified locations, the ASCT shall execute user-specified adaptive operation strategy.	4.4

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		2.1.3.0-4 When queues are detected at user-specified locations, the ASCT shall omit a user-specified phase at a user-specified signal controller. 2.1.3.0-5 The ASCT shall meter traffic into user-specified bottlenecks by storing queues at user-specified locations. 2.1.3.0-6 The ASCT shall store queues at user-specified locations. 2.1.3.0-7 The ASCT shall maintain capacity flow through user-specified bottlenecks.	
4.6	**4.6 Pedestrians**		4.5
4.6.0-1		8.0-3 When a pedestrian phase is called, the ASCT shall accommodate pedestrian crossing times then resume adaptive operation.	4.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4.6.0-2	The system operator needs to accommodate infrequent pedestrian operation while maintaining adaptive operation.	8.0-2 When a pedestrian phase is called, the ASCT shall accommodate pedestrian crossing times during adaptive operations.	4.5
4.6.0-3	The system operator needs to incorporate frequent pedestrian operation into routine adaptive operation.	8.0-2 When a pedestrian phase is called, the ASCT shall accommodate pedestrian crossing times during adaptive operations. 8.0-5 The ASCT shall execute pedestrian recall on user-defined phases in accordance with a time of day schedule. 8.0-7 When specified by the user, the ASCT shall execute pedestrian recall on pedestrian phase adjacent to coordinated phases. 8.0-8 When the pedestrian phases are on recall, the ASCT shall accommodate pedestrian timing during	4.5

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		adaptive operation.	
4.6.0-5	The system operator needs to accommodate early start of walk.	8.0-1 When a pedestrian phase is called, the ASCT shall execute pedestrian phases up to 5 seconds before the vehicle green of the related vehicle phase.	4.5
4.7	**4.7 Non-adaptive situations**		4.6
4.7.0-1	The system operator needs to detect traffic conditions during which adaptive control is not the preferred operation, and implement some pre-defined operation while that condition is present.	2.1.1.0-1 The ASCT shall operate non-adaptively during the presence of a defined condition.	4.6
4.7.0-2	The system operator needs to schedule pre-determined operation by time of day.	2.1.1.0-5 The ASCT shall operate non-adaptively in accordance with a user-defined time-of-day schedule.	4.6
4.7.0-3	The system operator needs to over-ride adaptive operation.	2.1.1.0-3 The ASCT shall operate non-adaptively when a user manually commands the ASCT to cease adaptively	4.6

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		controlling a group of signals. 2.1.1.0-4 The ASCT shall operate non-adaptively when a user manually commands the ASCT to cease adaptive operation. 2.1.1.0-5 The ASCT shall operate non-adaptively in accordance with a user-defined time-of-day schedule.	
4.8	**4.8 System Responsiveness**		4.7
4.8.0-1	The system operator needs to modify the ASCT operation to closely follow changes in traffic conditions. Should conditions change, such as a change in strategy from smooth flow to reducing total intersection delay at particular intersections, the system operator needs to identify the deficiency and adjust the operation accordingly.	2.6.0-1 The ASCT shall limit the change in consecutive cycle lengths to be less than a user-specified value. 2.6.0-2 The ASCT shall limit the change in phase times between consecutive cycles to be less than a user-specified value. (This does not apply to early gap-out or actuated phase skipping.) 2.6.0-3	4.7

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		The ASCT shall limit the changes in the direction of primary coordination to a user-specified frequency.	
4.8.0-2	The system operator needs to constrain the selection of cycle lengths to those that provide acceptable operations, such as when "resonant" progression solutions are desired to provide two-way coordination along one or more arterial routes.	2.6.0-3 The ASCT shall limit the changes in the direction of primary coordination to a user-specified frequency. 2.6.0-5 The ASCT shall select cycle length from a list of user-defined cycle lengths.	4.7
4.8.0-3	The system operator needs to respond quickly to sudden large shifts in traffic conditions.	2.6.0-4 When a large change in traffic demand is detected, the ASCT shall respond and make large changes in cycle/offsets/splits in less than 5 minutes	4.7
4.9	**4.9 Complex coordination and controller features**		4.8
4.9.0-1	The system operator needs to implement the following advanced controller features while maintaining adaptive operation:		4.8
4.9.0-1.0-1	• Service a phase more than once per cycle	7.0-1 When specified by the user, the ASCT shall serve a	4.8

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		vehicle phase more than once for each time the coordinated phase is served.	
4.9.0-1.0-2	• Operate at least eight overlap phases	7.0-2 The ASCT shall provide a minimum of 8 phase overlaps.	4.8
4.9.0-1.0-3	• Operate four rings, 16 phases and up to four phases per ring	7.0-3 The ASCT shall accommodate a minimum of 16 phases at each signal 7.0-4 The ASCT shall accommodate a minimum of 4 rings at each signal. 7.0-5 The ASCT shall accommodate a minimum of four phases per ring	4.8
4.9.0-1.0-4	• Permit different phase sequences under different traffic conditions while avoiding the yellow trap.	7.0-6 7.0-6.0-1 Each permissible phase sequence shall be user-assignable to any signal timing plan.	4.8

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		7.0-6.0-2 Each permissible phase sequence shall be executable by a time of day schedule. 7.0-6.0-3 Each permissible phase sequence shall be executable based on measured traffic conditions	
4.9.0-1.0-5	• Allow one or more phases to be omitted (disabled) under certain traffic conditions or signal states.	2.1.2.0-6 The ASCT shall omit a user-specified phase when the cycle length is below a user-specified value. 2.1.2.0-8 The ASCT shall omit a user-specified phase according to a time of day schedule 2.1.2.0-7 The ASCT shall omit a user-specified phase based on measured traffic conditions.	4.8
4.9.0-1.0-6	• Prevent one or more phases being skipped under certain traffic conditions or signal states.	2.1.2.0-5 The ASCT shall prevent skipping a user-specified	4.8

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		phase according to a time of day schedule. 2.1.2.0-3 The ASCT shall prevent skipping a user-specified phase when the user-specified phase sequence is operating. 2.1.2.0-4 The ASCT shall prevent skipping a user-specified phase based on the state of a user-specified external input.	
	•		
4.9.0-1.0-9	• Allow any phase to be designated as the coordinated phase	7.0-9 The ASCT shall not prevent the following phases to be designated as coordinated phases. (User to list all required phases.)	4.8
4.9.0-1.0-10	• Allow the operator to specify which phase receives unused time from a preceding phase	2.1.2.0-10 The ASCT shall assign unused time from a preceding phase that terminates early to a user-specified	4.8

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		phase as follows: • next phase; • next coordinated phase; • user-specified phase. 2.1.2.0-11 The ASCT shall assign unused time from a preceding phase that is skipped to a user-specified phase as follows: • previous phase; • next phase; • next coordinated phase; • user-specified phase.	
4.9.0-1.0-11	• Allow the controller to respond independently to individual lanes of an approach. This may allow the adaptive operation to be based on data from a specific detector, or by excluding specific detectors.	7.0-12 The ASCT shall not prevent the local signal controller from performing actuated phase control using 4 extension/passage timers as assigned to user-specified vehicle detector input channels in the local controller.	4.8

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		9.0-1 The ASCT shall set a specific state for each special function output based on the occupancy on a user-specified detector. 7.0-12.0-1 The ASCT shall operate adaptively using user-specified detector channels.	
4.9.0-1.0-12		7.0-10 The ASCT shall have the option for a coordinated phase to be released early based on a user-definable point in the phase or cycle. (User select phase or cycle.)	4.8
4.9.0-1.0-13	• Allow flexible timing of non-coordinated phases (such as late start of a phase) while maintaining coordination	8.0-6 The ASCT shall begin a non-coordinated phase later than its normal starting point within the cycle when all of the following conditions exist: • The user enables this feature • Sufficient time in the cycle remains to serve the minimum green times for the phase and the subsequent non-coordinated phases before the	4.8

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		beginning of the coordinated phase • The phase is called after its normal start time • The associated pedestrian phase is not called	
4.9.0-1.0-14	• Allow Protected/permissive phasing and alternate left turn phase sequences.	2.1.2.0-1 The ASCT shall not prevent protected/permissive left turn phase operation. 2.1.2.0-2 The ASCT shall not prevent the protected left turn phase to lead or lag the opposing through phase based upon user-specified conditions.	4.8
4.9.0-1.0-15	• Use flashing yellow arrow to control permissive left turns and right turns.	7.0-11 The ASCT shall not prevent the controller from displaying flashing yellow arrow left turn or right turn.	4.8
4.9.0-1.0-16	• Service side streets and pedestrian phases at minor locations more often than at adjacent signals when this can be done without compromising the quality of the coordination. (E.g., double-cycle mid-block pedestrian crossing signals.)	7.0-13 When adaptive operation is used in conjunction with normal coordination, the ASCT shall not prevent a controller serving a cycle length different from the cycles used at adjacent intersections.	4.8

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4.9.0-1.0-17	• Use negative pedestrian phasing to prevent an overlap conflicting with a pedestrian walk/don't walk	8.0-9 The ASCT shall not inhibit negative vehicle and pedestrian phase timing.	4.8
4.10	4.10 Monitoring and control		4.9
4.10.0-1	The system operator needs to monitor and control all required features of adaptive operation from the following locations: (Edit and select as appropriate to suit your situation.)	5.0-2 The ASCT shall provide monitoring and control access at the following locations:	4.9
4.10.0-1.0-1	• Traffic Engineering Division Building	5.0-2.0-1 • Traffic Engineering Division Building	4.9
	•	•	
4.10.0-1.0-3	• LAN Workstations	5.0-2.0-3 • Agency LAN or WAN	4.9
		•	
4.10.0-1.0-5	• Local controller cabinets	5.0-2.0-5 • Local controller cabinets	4.9
		•	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4.10.0-1.0-7	• Remote locations via VPN	5.0-2.0-7 • Remote locations via secure VPN	4.9
4.10.0-2	The operator needs to access to the database management, monitoring and reporting features and functions of the signal controllers and any related signal management system from the access points defined for those system components. (e.g. Traffic Engineering and individual office workstation)	5.0-4 The ASCT shall not prevent access to the local signal controller database, monitoring or reporting functions by any installed signal management system.	4.9
4.11	**4.11 Performance reporting**		4.10
4.11.0-1	The agency needs the TACTICS system to be able to monitor status of the signal system during ASCT operation.	3.0-1.0-3 The ASCT shall not prevent TACTICS from monitoring signal status	4.10
4.11.0-2	The system operator needs to store and report data used to calculate signal timing and have the data available for subsequent analysis.	6.0-4 The ASCT shall store results of all signal timing parameter calculations for a minimum of XX days. 6.0-5 The ASCT shall store the following measured data in the form used as input to the adaptive algorithm for a minimum of 30 days: (edit as appropriate)	4.10

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		• volume • occupancy • queue length • phase utilization • arrivals in green • green band efficiency 6.0-12 The ASCT shall store the following data in 15 minute increments: (edit as appropriate) • volume • occupancy • queue length 18.0-1 The ASCT shall report measures of current traffic conditions on which it bases signal state alterations. 18.0-2 The ASCT shall report all intermediate calculated	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		values that are affected by calibration parameters. 18.0-3 The ASCT shall maintain a log of all signal state alterations directed by the ASCT.	
4.11.0-3	The system operator needs to store and report data that can be used to measure traffic performance under adaptive control.	6.0-4 The ASCT shall store results of all signal timing parameter calculations for a minimum of 30 days. 6.0-5 The ASCT shall store the following measured data in the form used as input to the adaptive algorithm for a minimum of 30 days: (edit as appropriate) • volume • occupancy • queue length • phase utilization • arrivals in green • green band efficiency	4.10

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		6.0-12 The ASCT shall store the following data in 15 minute increments: (edit as appropriate) • volume • occupancy • queue length	
4.11.0-4	The system operator needs to store all operational data and signal timing parameters calculated by the adaptive system, and export selected data to Microsoft Excel spreadsheets, text files, CSV files, or an open SQL database.	6.0-2 The ASCT shall export its systems log in the following formats: (edit as appropriate) • MS Excel • Text • CSV • Open source SQL database 6.0-3 The ASCT shall store the event log for a minimum of 30 days 6.0-6	4.10

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		The ASCT system shall archive all data automatically after a user-specified period not less than 30 days. 6.0-7 The ASCT shall provide data storage for a system size of 200 signal controllers. The data to be stored shall include the following: (edit as appropriate) • Controller state data • Reports • Log data • Security data • ASCT parameters • Detector status data 6.0-10 The ASCT shall store data logs in a standard SQL database	
4.11.0-6		6.0-1	4.10

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		The ASCT shall log the following events: (edit as appropriate) 6.0-1.0-1 Time-stamped vehicle phase calls 6.0-1.0-2 Time-stamped pedestrian phase calls 6.0-1.0-3 Time-stamped emergency vehicle preemption calls 6.0-1.0-4 Time-stamped transit priority calls 6.0-1.0-5 Time-stamped railroad preemption calls 6.0-1.0-6 Time-stamped start and end of each phase 6.0-1.0-7 Time-stamped controller interval changes	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		6.0-1.0-8 Time-stamped start and end of each transition to a new timing plan	
4.11.0-7	The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.	6.0-5 The ASCT shall store the following measured data in the form used as input to the adaptive algorithm for a minimum of 30 days: (edit as appropriate) • volume • occupancy • queue length • phase utilization • arrivals in green • green band efficiency 6.0-8 The ASCT shall calculate and report relative data quality including: • The extent data is affected by detector faults	4.10

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		• Other applicable items 6.0-9 The ASCT shall report comparisons of logged data when requested by the user: • Day to day, • Hour to hour • Hour of day to hour of day • Hour of week to hour of week • day of week to day week * Day of year to day of year 6.0-11 The ASCT shall report stored data in a form suitable to provide explanations of system behavior to public and politicians and to troubleshoot the system. 18.0-3 The ASCT shall maintain a log of all signal state	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		alterations directed by the ASCT. 18.0-3.0-4 The ASCT shall maintain the records in this ASCT log for a 30 day period. 18.0-3.0-5 The ASCT shall archive the ASCT log so that it may be readable in an MS Excel format (CSV, XLS, etc) 18.0-3.0-1 The ASCT log shall include all events directed by the external inputs. 18.0-3.0-2 The ASCT log shall include all external output state changes. 18.0-3.0-3 The ASCT log shall include all actual parameter values that are subject to user-specified values.	
4.12	**4.12 Failure notification**		4.11

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4.12.0-1	The system operator needs to immediately notify maintenance and operations staff of alarms and alerts.	13.1.0-3 In the event of a detector failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system. 13.2-2 In the event of communications failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system. 13.3-2 In the event of adaptive processor failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system.	4.11

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		13.2-3 The ASCT shall issue an alarm within 2 minutes of detection of a failure.	
4.12.0-2	The system operator needs to immediately and automatically pass alarms and alerts to the Operation and Maintenance personnel.	13.1.0-3 In the event of a detector failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system. 13.2-2 In the event of communications failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system. 13.3-2 In the event of adaptive processor failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the	4.11

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		alarm to a designated list of recipients by a designated means, or by using an external maintenance management system. 13.2-3 The ASCT shall issue an alarm within two minutes of detection of a failure.	
4.12.0-3	The system operator needs to maintain a complete log of alarms and failure events.	13.1.0-4 In the event of a failure, the ASCT shall log details of the failure in a permanent log. 13.1.0-5 The permanent failure log shall be searchable, archivable and exportable. 13.2-4 In the event of a communications failure, the ASCT shall log details of the failure in a permanent log. 13.2-5 The permanent failure log shall be searchable, archivable and exportable.	4.11

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4.13	**4.13 Preemption and priority**		4.12
4.13.0-2	The system operator needs to accommodate emergency vehicle preemption.	11.0-4 The ASCT shall resume adaptive control of signal controllers when preemptions are released. 11.0-5 The ASCT shall execute user-specified actions at non-preempted signal controllers during preemption. (E.g., inhibit a phase, activate a sign, display a message on a DMS) 11.0-6 The ASCT shall operate normally at non-preempted signal controllers when special functions are engaged by a preemption event. (Examples of such special functions are a phase omit, a phase maximum recall or a fire route.) 11.0-7 The ASCT shall release user-specified signal controllers to local control when one signal in a	4.12

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		group is preempted. 11.0-8 The ASCT shall not prevent the local signal controller from operating in normally detected limited-service actuated mode during preemption however, it is highly desirable to stay in adaptive operation during railroad preemption. 11.0-2 The ASCT shall maintain adaptive operation at non-preempted intersections during emergency vehicle preemption.	
4.13.0-3	The System Operator needs to accommodate bus rapid transit.	12.0-1 The ASCT shall continue adaptive operations of a group when one of its signal controllers has a transit priority call. 12.0-2 The ASCT shall advance the start of a user-specified green phase in response to a transit priority call. 12.0-3	4.12

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		The ASCT shall delay the end of a green phase, in response to a priority call. 12.0-4 The ASCT shall permit at least 2 exclusive transit phases. 12.0-5 The ASCT shall control vehicle phases independently of the following: 12.0-6 The ASCT shall interface with external bus transit priority system in the following fashion….. (explain the external system and refer to other interfaces as appropriate) 12.0-2.0-1 The advance of start of green phase shall be user-defined. 12.0-2.0-2 Adaptive operations shall continue during the advance of the start of green phase.	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		12.0-3.0-1 The delay of end of green phase shall be user-defined. 12.0-3.0-2 Adaptive operations shall continue during the delay of the end of green phase. 12.0-4.0-1 Adaptive operations shall continue when there is an exclusive transit phase call. 12.0-5.0-1 • LRT only phases 12.0-5.0-2 • Bus only phases 12.0-8 The ASCT shall accept a transit priority call from: • a signal controller/transit vehicle detector; • an external system.	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		12.0-7 The ASCT shall interface with external light rail transit priority system in the following fashion….. (explain the external system and refer to other interfaces as appropriate)	
4.14	**4.14 Failure and fallback**		4.13
4.14.0-1	The system operator needs to fall back to TOD or isolated free operation, as specified by the operator, without causing disruption to traffic flow, in the event of equipment, communications and software failure.	13.1.0-2 The ASCT shall use the following alternate data sources for operations in the absence of the real-time data from a detector: 13.1.0-2.0-3 The ASCT shall switch to the alternate source in real time without operator intervention. 13.1.0-1 The ASCT shall take user-specified action in the absence of valid detector data from 25% of the vehicle detectors within a group. 13.1.0-1.0-1	4.13

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		The ASCT shall release control to central system control. 13.2-1 The ASCT shall execute user-specified actions when communications to one or more signal controllers fails within a group. 13.2-1.0-1 In the event of loss of communication to a user-specified signal controller, the ASCT shall release control of all signal controllers within a user-specified group to local control. 13.3-1 The ASCT shall execute user-specified actions when adaptive control fails: 13.3-1.0-1 The ASCT shall release control to central system control. 2.1.1.0-2 The ASCT shall operate non-adaptively when	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		adaptive control equipment fails. 2.1.1.0-2.0-1 The ASCT shall operate non-adaptively when a user-specified detector fails. 2.1.1.0-2.0-2 The ASCT shall operate non-adaptively when the number of failed detectors connected to a signal controller exceeds a user-defined value. 2.1.1.0-2.0-3 The ASCT shall operate non-adaptively when the number of failed detectors in a group exceeds a user-defined value. 2.1.1.0-2.0-4 The ASCT shall operate non-adaptively when a user-defined communications link fails. 13.1.0-2.0-1 • Data from a user-specified alternate detector. 13.1.0-2.0-2	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		• Stored historical data from the failed detector. 13.1.0-1.0-2 The ASCT shall release control to local operations to operate under its own time-of-day schedule. 13.2-1.0-2 The ASCT shall switch to the alternate operation in real time without operator intervention. 13.3-1.0-2 The ASCT shall release control to local operations to operate under its own time-of-day schedule. 13.3-4 During adaptive processor failure, the ASCT shall provide all local detector inputs to the local controller.	
4.15	**4.15 Constraints**		4.14
4.15.0-1	The system operator is constrained to use the following equipment:		4.14
4.15.0-1.0-1	• Controller type Siemens M34, M42, M52 series controllers	14.0-3	4.14

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		The ASCT shall fully satisfy all requirements when connected with Siemens M34, M42, M52 series controllers	
4.15.0-1.0-2	• Detector type – Iteris video detection, inductive loops, Sensys magnetometers, microwave radar •	14.0-2 The ASCT shall fully satisfy all requirements when connected with detectors from Iteris and Sensys, various microwave and inductive loops.	4.14
4.15.0-1.0-3	• Communication system hardwire/fiber and wireless IP/Ethernet	System Requirement shall follow Needs Statement	4.14
4.15.0-1.0-4	• Cabinet type and size NEMA TS1, NEMA TS2, Type 2	System Requirement shall follow Needs Statement	4.14
4.15.0-1.0-5	• Traffic signal system software – the adaptive system must not prevent the existing Siemens TACTICS central system from monitoring and recording intersection status, including the collection of all detection data and any signal failures being reported by the Controller.	System Requirement shall follow Needs Statement	4.14
4.15.0-2	The system operator needs to use equipment and software acceptable under the City's current technology policies and procedures (Windows-PC, Windows 7 operating system).	14.0-1 The vendor's adaptive software shall be fully operational within the following platform: (edit as appropriate) • Windows-PC, • Able to Port to handheld Android & iOS.	4.14

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
4.16	**4.16 Training and support**		
4.16.0-1	The Cities need all staff involved in operation and maintenance to receive appropriate training.	15.0-1.0-1 The vendor shall provide training on the operations of the adaptive system. 15.0-1.0-9 The vendor shall provide a minimum of 40 hours training to a minimum of 10 staff. (specify how much training will be required) 15.0-1 The vendor shall provide the following training. (Edit as appropriate.) 15.0-1.0-2 The vendor shall provide training on troubleshooting the system. 15.0-1.0-3 The vendor shall provide training on preventive	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		maintenance and repair of equipment. 15.0-1.0-4 The vendor shall provide training on system configuration. 15.0-1.0-5 The vendor shall provide training on administration of the system. 15.0-1.0-6 The vendor shall provide training on system calibration. 15.0-1.0-7 The vendor's training delivery shall include: printed course materials and references, electronic copies of presentations and references. 15.0-1.0-8 The vendor's training shall be delivered at (specify locations for training). 15.0-1.0-10	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		The vendor shall provide a minimum of XX training sessions (specify how many sessions over what period).	
4.16.0-2	The Cities need the system to fulfill all requirements for the life of the system. The Cities therefore need the system to be maintained to repair faults that are not defects in materials and workmanship.	16.0-1 The Maintenance Vendor shall provide maintenance according to a separate maintenance contract. That contract should identify repairs necessary to preserve requirements fulfillment, responsiveness in effecting those repairs, and all requirements on the maintenance provider while performing the repairs.	
4.16.0-3	The Cities need the system to fulfill all requirements for the life of the system. The cities therefore need the system to remain free of defects in materials and workmanship that result in requirements no longer being fulfilled.	16.0-3 The Vendor shall warrant the system to be free of defects in materials and workmanship for a period of five (5) years once final acceptance is approved. Warranty is defined as correcting defects in materials and workmanship (subject to other language included in the purchase documents). Defect is defined as any circumstance in which the material does not perform according to its specification.	
4.16.0-4	The Cities need the system to fulfill all requirements for the life of the system. The Cities therefore need support	16.0-2	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
	to keep software and software environment updated as necessary to prevent requirements no longer being fulfilled.	The Vendor shall provide routine updates to the software and software environment necessary to preserve the fulfillment of requirements for a period of five (5) years after final acceptance. Preservation of requirements fulfillment especially includes all IT management requirements as previously identified.	
4.17	**4.17 External interfaces**		
4.17.0-1		17.0-1 The ASCT shall set the state of external input/output states according to a time-of-day schedule. 17.0-2 The ASCT output states shall be settable according to a time-of-day schedule 9.0-1 The ASCT shall set a specific state for each special function output based on the occupancy on a user-specified detector. 9.0-2	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		The ASCT shall set a specific state for each special function output based on the current cycle length. 9.0-3 The ASCT shall set a specific state for each special function output based on a time-of-day schedule.	
4.17.0-2		7.0-8 The ASCT shall not prevent a phase/overlap output based on an external input. 2.1.1.0-6 The ASCT shall operate non-adaptively when commanded by an external system process. 4.0-1 The ASCT shall conform its operation to an external system's operation. 2.1.2.0-4 The ASCT shall prevent skipping a user-specified phase based on the state of a user-specified external input.	

Con Ops Reference Number	Concept of Operations Sample Statements	System Requirements (Tailor as required - See Guidance)	Guidance Section
		3.0-1.0-6 The ASCT shall receive commands from the external system. 3.0-1.0-7 The ASCT shall implement the following commands from the external system when commanded in TOD ops • Specified cycle length • Specified direction of progression • Specified adaptive strategy	
4.18	**4.18 Maintenance**		
4.18.0-1	Each maintenance crew of the maintenance agency (currently the City of North Little Rock) needs all applicable equipment to be readily accessible for maintenance and support activities in the field and at other locations within the maintaining agency. Special access equipment not normally available to them for maintenance will not be allowed.	The ASCT shall provide for 20% spare equipment for items required for ASCT operation including but not limited to detection, processors, wiring harnesses, etc.	

Requirements Reference Number	System Requirements	User Need Satisfied
1	**1 Network Characteristics**	
1.0-1	The ASCT shall control a minimum of 200 signals concurrently	4.2.0-1 The system operator needs to eventually adaptively control up to 200 signals.
1.0-2	The ASCT shall support groups of signals.	4.2.0-2 The system operator needs to be able to adaptively control at least 10 independent groups of signals per corridor 4.2.0-3 The system operator needs to vary the number of signals in an adaptively controlled group to accommodate the prevailing traffic conditions.
1.0-2.0-1	The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the ASCT system according to configured parameters.	4.2.0-2 The system operator needs to be able to adaptively control at least 10 independent groups of signals per corridor
1.0-2.0-2	The ASCT shall control a minimum of 10 groups of signals per corridor	4.2.0-2 The system operator needs to be able to adaptively control at least 10 independent groups of signals per corridor
1.0-2.0-4	Each group shall operate independently	4.2.0-2

Requirements Reference Number	System Requirements	User Need Satisfied
		The system operator needs to be able to adaptively control at least 10 independent groups of signals per corridor
1.0-2.0-1	The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the ASCT system according to configured parameters.	4.2.0-3 The system operator needs to vary the number of signals in an adaptively controlled group to accommodate the prevailing traffic conditions.
1.0-2.0-1.0-1	The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system according to a time of day schedule. (For example: this may be achieved by assigning signals to different groups or by combining groups.)	4.2.0-3 The system operator needs to vary the number of signals in an adaptively controlled group to accommodate the prevailing traffic conditions.
1.0-2.0-1.0-2	The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system according to traffic conditions. (For example: this may be achieved by assigning signals to different groups or by combining groups.)	4.2.0-3 The system operator needs to vary the number of signals in an adaptively controlled group to accommodate the prevailing traffic conditions.
1.0-2.0-1.0-3	The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system when commanded by the user.	4.2.0-3 The system operator needs to vary the number of signals in an adaptively controlled group to accommodate the prevailing traffic conditions.
2	**2 Type of Operation**	
2.1	**2.1 General**	

Requirements Reference Number	System Requirements	User Need Satisfied
2.1.1	**2.1.1 Mode of Operation**	
2.1.1.0-1	The ASCT shall operate non-adaptively during the presence of a defined condition.	4.7.0-1 The system operator needs to detect traffic conditions during which adaptive control is not the preferred operation, and implement some pre-defined operation while that condition is present.
2.1.1.0-2	The ASCT shall operate non-adaptively when adaptive control equipment fails.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
2.1.1.0-2.0-1	The ASCT shall operate non-adaptively when a user-specified detector fails.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
2.1.1.0-2.0-2	The ASCT shall operate non-adaptively when the number of failed detectors connected to a signal controller exceeds a user-defined value.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
2.1.1.0-2.0-3	The ASCT shall operate non-adaptively when the number of failed detectors in a group exceeds a user-defined value.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.

Requirements Reference Number	System Requirements	User Need Satisfied
2.1.1.0-2.0-4	The ASCT shall operate non-adaptively when a user-defined communications link fails.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
2.1.1.0-3	The ASCT shall operate non-adaptively when a user manually commands the ASCT to cease adaptively controlling a group of signals.	4.7.0-3 The system operator needs to over-ride adaptive operation.
2.1.1.0-4	The ASCT shall operate non-adaptively when a user manually commands the ASCT to cease adaptive operation.	4.7.0-3 The system operator needs to over-ride adaptive operation.
2.1.1.0-5	The ASCT shall operate non-adaptively in accordance with a user-defined time-of-day schedule.	4.7.0-2 The system operator needs to schedule pre-determined operation by time of day. 4.7.0-3 The system operator needs to over-ride adaptive operation.
2.1.1.0-6	The ASCT shall operate non-adaptively when commanded by an external system process.	
2.1.1.0-7	The ASCT shall alter the adaptive operation to achieve required objectives in user-specified conditions. (The required objectives are specified in Needs Statement 4.1.0-1. Responding to this requirement demonstrates how the proposed	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-3

Requirements Reference Number	System Requirements	User Need Satisfied
	system allows the user to define the conditions at which the objectives shift and their associated requirements are fulfilled.) (The alteration may be made by adjusting parameters or by directly controlling the state of signal controllers.)	Distribute phase times in an equitable fashion 4.1.0-3 The system operator needs to change the operational strategy (for example, from smooth flow to maximizing throughput or managing queues) based on changing traffic conditions.
2.1.1.0-7.0-1	When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of the signal controllers, maximizing the throughput of the coordinated route.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-3 The system operator needs to change the operational strategy (for example, from smooth flow to maximizing throughput or managing queues) based on changing traffic conditions.
2.1.1.0-7.0-2	When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the state of signal controllers, preventing queues from exceeding the storage capacity at user-specified locations.	4.1.0-1.0-4 Manage the lengths of queues 4.1.0-3 The system operator needs to change the operational strategy (for example, from smooth flow to maximizing throughput or managing queues) based on changing traffic conditions.
2.1.1.0-7.0-3	When current measured traffic conditions meet user-specified criteria, the ASCT shall alter the	4.1.0-1.0-3

Requirements Reference Number	System Requirements	User Need Satisfied
	state of signal controllers providing equitable distribution of green times during non-peak times.	Distribute phase times in an equitable fashion 4.1.0-3 The system operator needs to change the operational strategy (for example, from smooth flow to maximizing throughput or managing queues) based on changing traffic conditions.
2.1.1.0-7.0-4	When current measured traffic conditions meet user-defined criteria, the ASCT shall alter the state of signal controllers providing two-way progression on a coordinated route.	4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-3 The system operator needs to change the operational strategy (for example, from smooth flow to maximizing throughput or managing queues) based on changing traffic conditions.
2.1.1.0-8	**T**he ASCT shall provide maximum and minimum phase times.	4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).

Requirements Reference Number	System Requirements	User Need Satisfied
2.1.1.0-8.0-1	The ASCT shall provide a user-specified maximum value for each phase at each signal controller.	4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2.1.1.0-8.0-1.0-1	The ASCT shall not provide a phase length longer that the maximum value.	4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2.1.1.0-8.0-2	The ASCT shall provide a user-specified minimum value for each phase at each signal controller.	4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2.1.1.0-8.0-2.0-1	The ASCT shall not provide a phase length shorter	4.1.0-1.0-3

Requirements Reference Number	System Requirements	User Need Satisfied
	than the minimum value.	Distribute phase times in an equitable fashion 4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2.1.1.0-9	The ASCT shall detect repeated phases that do not serve all waiting vehicles. (These phase failures may be inferred, such as by detecting repeated max-out.)	4.1.0-4 The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue resulting from the trailing end of the through green from blocking the storage needed by an entering side-street left turn in the subsequent phase.
2.1.1.0-9.0-1	The ASCT shall alter operations, to minimize repeated phase failures.	4.1.0-4 The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue resulting from the trailing end of the through green from blocking the storage needed by an entering side-street left turn in the subsequent phase.
2.1.1.0-10	The ASCT shall determine the order of phases at a user-specified intersection. (The calculation will be	4.1.0-1.0-1

Requirements Reference Number	System Requirements	User Need Satisfied
	based on the optimization function.)	Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-4 Manage the lengths of queues
2.1.1.0-11	The ASCT shall provide coordination along a route.	4.1.0-8 The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.
2.1.1.0-11.0-1	The ASCT shall coordinate along a user-defined route.	4.1.0-8 The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.
2.1.1.0-11.0-2	The ASCT shall determine the coordinated route based on traffic conditions.	4.1.0-8 The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.
2.1.1.0-11.0-3	The ASCT shall determine the coordinated route based on a user-defined schedule.	4.1.0-8 The system operator needs to designate the coordinated route based on

Requirements Reference Number	System Requirements	User Need Satisfied
		traffic conditions and the selected operational strategy.
2.1.1.0-11.0-4	The ASCT shall store a minimum of 10 user-defined coordination routes.	4.1.0-8 The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.
2.1.1.0-11.0-4.0-1	The ASCT shall implement a stored coordinated route by operator command.	4.1.0-8 The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.
2.1.1.0-11.0-4.0-2	The ASCT shall implement a stored coordinated route based on traffic conditions.	4.1.0-8 The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.
2.1.1.0-11.0-4.0-3	The ASCT shall implement a stored coordinated route based on a user-defined schedule.	4.1.0-8 The system operator needs to designate the coordinated route based on traffic conditions and the selected operational strategy.
2.1.1.0-12	The ASCT shall not prevent the use of phase timings in the local controller set by agency policy.	4.1.0-9 The system operator needs to set signal timing parameters (such as minimum green, maximum green and extension time) to comply with agency policies.
2.1.2	**2.1.2 Allowable Phases**	
2.1.2.0-1	The ASCT shall not prevent protected/permissive left turn phase operation.	4.9.0-1.0-14 Allow protected/permissive phasing and alternate left turn phase

Requirements Reference Number	System Requirements	User Need Satisfied
		sequences.
2.1.2.0-2	The ASCT shall not prevent the protected left turn phase to lead or lag the opposing through phase based upon user-specified conditions.	4.9.0-1.0-14 Allow protected/permissive phasing and alternate left turn phase sequences.
2.1.2.0-3	The ASCT shall prevent skipping a user-specified phase when the user-specified phase sequence is operating.	4.9.0-1.0-6 Prevent one or more phases being skipped under certain traffic conditions or signal states.
2.1.2.0-4	The ASCT shall prevent skipping a user-specified phase based on the state of a user-specified external input.	4.9.0-1.0-6 Prevent one or more phases being skipped under certain traffic conditions or signal states.
2.1.2.0-5	The ASCT shall prevent skipping a user-specified phase according to a time of day schedule.	4.9.0-1.0-6 Prevent one or more phases being skipped under certain traffic conditions or signal states.
2.1.2.0-6	The ASCT shall omit a user-specified phase when the cycle length is below a user-specified value.	4.9.0-1.0-4 Permit different phase sequences under different traffic conditions while avoiding the yellow trap.
2.1.2.0-7	The ASCT shall omit a user-specified phase based on measured traffic conditions.	4.9.0-1.0-4 Permit different phase sequences under different traffic conditions while avoiding the yellow trap.
2.1.2.0-8	The ASCT shall omit a user-specified phase	4.9.0-1.0-4

Requirements Reference Number	System Requirements	User Need Satisfied
	according to a time of day schedule	Permit different phase sequences under different traffic conditions while avoiding the yellow trap.
2.1.2.0-10	The ASCT shall assign unused time from a preceding phase that terminates early to a user-specified phase as follows: next phase; next coordinated phase; user-specified phase.	4.9.0-1.0-10 Allow the operator to specify which phase receives unused time from a preceding phase
2.1.2.0-11	The ASCT shall assign unused time from a preceding phase that is skipped to a user-specified phase as follows: previous phase; next phase; next coordinated phase; user-specified phase.	4.9.0-1.0-10 Allow the operator to specify which phase receives unused time from a preceding phase
2.1.2.0-12	The ASCT shall not alter the order of phases at a user-specified intersection.	4.1.0-7 The system operator needs to fix the sequence of phases at any specified location. For example, the operator may need to fix the phase order at a diamond interchange.
2.1.3	**2.1.3 Oversaturation**	

Requirements Reference Number	System Requirements	User Need Satisfied
2.1.3.0-1	The ASCT shall detect the presence of queues at pre-configured locations.	4.1.0-1.0-4 Manage the lengths of queues 4.1.0-1.0-5 Manage the locations of queues within the network 4.1.0-4 The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue resulting from the trailing end of the through green from blocking the storage needed by an entering side-street left turn in the subsequent phase. 4.5.0-1 The system operator needs to detect queues from outside the system and modify the ASCT operation to accommodate the queuing. 4.5.0-2 The system operator needs to detect queues within the system's boundaries and modify the ASCT operation to accommodate the queuing.

Requirements Reference Number	System Requirements	User Need Satisfied
		4.5.0-3 The system operator needs to detect queues propagating outside its boundaries from within the ASCT boundaries, and modify its operation to accommodate the queuing. 4.5.0-4 The system operator needs to prevent queues forming at user-specified locations.
2.1.3.0-2	When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational modes, specifically during potential spill out onto freeway and queuing at closely spaced signals.	4.1.0-1.0-4 Manage the lengths of queues 4.1.0-1.0-5 Manage the locations of queues within the network 4.1.0-4 The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue resulting from the trailing end of the through green from blocking the storage needed by an entering side-

Requirements Reference Number	System Requirements	User Need Satisfied
		street left turn in the subsequent phase. 4.5.0-1 The system operator needs to detect queues from outside the system and modify the ASCT operation to accommodate the queuing. 4.5.0-2 The system operator needs to detect queues within the system's boundaries and modify the ASCT operation to accommodate the queuing. 4.5.0-3 The system operator needs to detect queues propagating outside its boundaries from within the ASCT boundaries, and modify its operation to accommodate the queuing. 4.5.0-4 The system operator needs to prevent queues forming at user-specified locations.
2.1.3.0-3	When queues are detected at user-specified locations, the ASCT shall execute user-specified adaptive operation strategy.	4.1.0-1.0-4 Manage the lengths of queues 4.1.0-1.0-5 Manage the locations of queues within the network 4.1.0-4

Requirements Reference Number	System Requirements	User Need Satisfied
		The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue resulting from the trailing end of the through green from blocking the storage needed by an entering side-street left turn in the subsequent phase. 4.5.0-1 The system operator needs to detect queues from outside the system and modify the ASCT operation to accommodate the queuing. 4.5.0-2 The system operator needs to detect queues within the system's boundaries and modify the ASCT operation to accommodate the queuing. 4.5.0-3 The system operator needs to detect queues propagating outside its boundaries from within the ASCT boundaries, and modify its operation to accommodate the queuing.

Requirements Reference Number	System Requirements	User Need Satisfied
		4.5.0-5 The system operator needs to prevent queues forming at user-specified locations.
2.1.3.0-4	When queues are detected at user-specified locations, the ASCT shall omit a user-specified phase at a user-specified signal controller.	4.1.0-1.0-4 Manage the lengths of queues 4.1.0-1.0-5 Manage the locations of queues within the network 4.1.0-4 The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue resulting from the trailing end of the through green from blocking the storage needed by an entering side-street left turn in the subsequent phase. 4.5.0-5 The system operator needs to prevent queues forming at user-specified locations.

Requirements Reference Number	System Requirements	User Need Satisfied
2.1.3.0-5	The ASCT shall meter traffic into user-specified bottlenecks by storing queues at user-specified locations.	4.1.0-1.0-4 Manage the lengths of queues 4.1.0-1.0-5 Manage the locations of queues within the network 4.5.0-5 The system operator needs to prevent queues forming at user-specified locations.
2.1.3.0-6	The ASCT shall store queues at user-specified locations.	4.1.0-1.0-4 Manage the lengths of queues 4.1.0-1.0-5 Manage the locations of queues within the network 4.5.0-5 The system operator needs to prevent queues forming at user-specified locations.

Requirements Reference Number	System Requirements	User Need Satisfied
2.1.3.0-7	The ASCT shall maintain capacity flow through user-specified bottlenecks.	4.5.0-5 The system operator needs to prevent queues forming at user-specified locations.
2.1.3.0-8	When queues are detected at user-specified locations, the ASCT shall limit the cycle length of the group to a user-specified value.	4.1.0-1.0-5 Manage the locations of queues within the network
2.2	**2.2 Sequence-based Adaptive Coordination**	
2.2.0-2	**(Sequence-based only)** The ASCT shall select cycle length based on a time of day schedule.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4

Requirements Reference Number	System Requirements	User Need Satisfied
		Manage the lengths of queues
2.2.0-3	**(Sequence-based only)** The ASCT shall calculate phase lengths for all phases at each signal controller to suit the current coordination strategy.	4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-5 Manage the locations of queues within the network 4.1.0-4 The system operator needs to detect repeated phase failures and control signal timing to prevent phase failures building up queues. The operator in this case is trying to prevent a routine queue from forming where it will block another movement in the cycle unnecessarily. For example, the operator may need to prevent a queue resulting from the trailing end of the through green from blocking the storage needed by an entering side-street left turn in the subsequent phase.
2.2.0-4	**(Sequence-based only)** The ASCT shall calculate offsets to suit the current coordination strategy for the user-specified reference point for each signal controller along a coordinated route within a group.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes

Requirements Reference Number	System Requirements	User Need Satisfied
		4.1.0-1.0-4 Manage the lengths of queues
2.2.0-4.0-1	**(Sequence-based only)** The ASCT shall apply offsets for the user-specified reference point of each signal controller along a coordinated route.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-4 Manage the lengths of queues
2.2.0-5	**(Sequence-based only)** The ASCT shall calculate a cycle length for each cycle based on its optimization objectives (as required elsewhere, e.g., progression, queue management, equitable distribution of green).	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion

Requirements Reference Number	System Requirements	User Need Satisfied
		4.1.0-1.0-4 Manage the lengths of queues
2.2.0-5.0-1	**(Sequence-based only)** The ASCT shall limit cycle lengths to user-specified values.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4 Manage the lengths of queues
2.2.0-5.0-2	**(Sequence-based only)** The ASCT shall limit cycle lengths to a user-specified range.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2

Requirements Reference Number	System Requirements	User Need Satisfied
		Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4 Manage the lengths of queues
2.2.0-5.0-3	**(Sequence-based only)** The ASCT shall calculate optimum cycle length according to the user-specified coordination strategy.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4 Manage the lengths of queues

Requirements Reference Number	System Requirements	User Need Satisfied
2.2.0-5.0-4	**(Sequence-based only)** The ASCT shall limit changes in cycle length to not exceed a user-specified value.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4 Manage the lengths of queues
2.2.0-5.0-4.0-1	**(Sequence-based only)** The ASCT shall increase the limit for the following 3 cycles based on a change in conditions.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3

Requirements Reference Number	System Requirements	User Need Satisfied
		Distribute phase times in an equitable fashion 4.1.0-1.0-4 Manage the lengths of queues
2.2.0-5.0-4.0-1.0-1	**(Sequence-based only)** The change in conditions shall be defined by 3 successive adaptive increases in cycle length at the maximum rate.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4 Manage the lengths of queues
2.2.0-5.0-4.0-1.0-2	**(Sequence-based only)** The increased limit shall be user-defined.	4.1.0-1.0-1 Maximize the throughput on coordinated routes

Requirements Reference Number	System Requirements	User Need Satisfied
		4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4 Manage the lengths of queues
2.2.0-5.0-5	**(Sequence-based only)** The ASCT shall adjust offsets to minimize the chance of stopping vehicles approaching a signal that have been served by a user-specified phase at an upstream signal.	4.1.0-5 The system operator needs to minimize the chance that a queue forms at a specified location.
2.3	**2.3 Non-sequence-based adaptive coordination**	
2.3.0-1	**(Non-sequence-based only)** The ASCT shall calculate the appropriate state of the signal to suit the current coordination strategy at the critical signal controller. (A critical signal controller is defined by the user.)	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2

Requirements Reference Number	System Requirements	User Need Satisfied
		Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4 Manage the lengths of queues
2.3.0-3	**(Non-sequence-based only)** At non-critical intersections within a group, the ASCT shall calculate the time at which a user-specified phase shall be green, relative to a reference point at the critical intersection, to suit the current coordination strategy.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4

Requirements Reference Number	System Requirements	User Need Satisfied
		Manage the lengths of queues
2.3.0-4	**(Non-sequence-based only)** When demand is present, the ASCT shall implement a user-specified maximum time between successive displays of each phase at each intersection.	4.1.0-1.0-1 Maximize the throughput on coordinated routes 4.1.0-1.0-2 Provide smooth flow along coordinated routes 4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-4 Manage the lengths of queues
2.3.0-5	**(Non-sequence-based only)** The ASCT shall adjust signal timing so that vehicles approaching a signal that have been served during a user-specified phase at an upstream signal do not stop.	4.1.0-5 The system operator needs to minimize the chance that a queue forms at a specified location.
2.4	**2.4 Single intersection adaptive operation**	

Requirements Reference Number	System Requirements	User Need Satisfied
2.4.0-1	The ASCT shall calculate a cycle length of a single intersection, based on current measured traffic conditions. (The calculation is based on the optimization objectives.)	4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2.4.0-2	The ASCT shall calculate optimum phase lengths, based on current measured traffic conditions. (The calculation is based on the optimization objectives.)	4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2.4.0-2.0-1	The ASCT shall limit the difference between the length of a given phase and the length of the same phase during its next service to a user-specified value.	4.1.0-1.0-3 Distribute phase times in an equitable fashion 4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2.4.0-2.0-2	When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational mode.	4.1.0-1.0-3 Distribute phase times in an equitable fashion

Requirements Reference Number	System Requirements	User Need Satisfied
		4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2.4.0-3	The ASCT shall calculate phase order, based on current measured traffic conditions. (The calculation is based on the optimization objectives.)	4.1.0-1.0-6 At an isolated intersection, optimize operation with a minimum of phase failures (based on the optimization objectives).
2.5	**2.5 Phase-based adaptive coordination**	
2.5.0-1	**(Phase-based only)** The ASCT shall alter the state of the signal controller for all phases at the user-specified intersection.	4.1.0-2 The system operator needs to manage the coordination in small groups of signals to link phase service at some intersections with phase service at adjacent intersections.
2.5.0-3	**(Phase-based only)** The ASCT shall calculate the time at which a user-specified phase shall be green at an intersection.	4.1.0-2 The system operator needs to manage the coordination in small groups of signals to link phase service at some intersections with phase service at adjacent intersections.
2.5.0-4	**(Phase-based only)** When demand is present, the	4.1.0-2

Requirements Reference Number	System Requirements	User Need Satisfied
	ASCT shall implement a user-specified maximum time between successive displays of each phase at each intersection.	The system operator needs to manage the coordination in small groups of signals to link phase service at some intersections with phase service at adjacent intersections.
2.5.0-6	**(Phase-based only)** The ASCT shall alter the operation of the non-critical intersections to minimize stopping of traffic released from user-specified phases at the user-specified critical intersection.	4.1.0-2 The system operator needs to manage the coordination in small groups of signals to link phase service at some intersections with phase service at adjacent intersections.
2.5.0-5	**(Phase-based only)** The ASCT shall alter the operation of the non-critical intersections to minimize stopping of traffic arriving at user-specified phases at the user-specified critical intersection.	4.1.0-2 The system operator needs to manage the coordination in small groups of signals to link phase service at some intersections with phase service at adjacent intersections.
2.5.0-6	**(Phase-based only)** The ASCT shall adjust the state of the signal controller so that vehicles approaching a signal that have been served during a user-specified phase at an upstream signal do not stop.	4.1.0-5 The system operator needs to minimize the chance that a queue forms at a specified location. 4.1.0-2 The system operator needs to manage the coordination in small groups of signals to link phase service at some intersections with phase service at

Requirements Reference Number	System Requirements	User Need Satisfied
		adjacent intersections.
2.6	**2.6 Responsiveness**	
2.6.0-1	The ASCT shall limit the change in consecutive cycle lengths to be less than a user-specified value.	4.8.0-1 The system operator needs to modify the ASCT operation to closely follow changes in traffic conditions. Should conditions change, such as a change in strategy from smooth flow to reducing total intersection delay at particular intersections, the system operator needs to identify the deficiency and adjust the operation accordingly.
2.6.0-2	The ASCT shall limit the change in phase times between consecutive cycles to be less than a user-specified value. (This does not apply to early gap-out or actuated phase skipping.)	4.8.0-1 The system operator needs to modify the ASCT operation to closely follow changes in traffic conditions. Should conditions change, such as a change in strategy from smooth flow to reducing total intersection delay at particular intersections, the system operator needs to identify the deficiency and adjust the operation accordingly.
2.6.0-3	The ASCT shall limit the changes in the direction of primary coordination to a user-specified frequency.	4.8.0-1 The system operator needs to modify the ASCT operation to closely follow changes in traffic conditions. Should conditions change, such as a change in strategy from smooth flow to reducing total intersection delay at particular intersections, the system operator needs to identify the deficiency and adjust the operation accordingly. 4.8.0-2 The system operator needs to constrain the selection of cycle lengths to those that provide acceptable operations, such as when “resonant”

Requirements Reference Number	System Requirements	User Need Satisfied
		progression solutions are desired to provide two-way coordination along one or more arterial routes.
2.6.0-4	When a large change in traffic demand is detected, the ASCT shall within five minutes.	4.8.0-3 The system operator needs to respond quickly to sudden large shifts in traffic conditions.
2.6.0-5	The ASCT shall select cycle length from a list of user-defined cycle lengths.	4.8.0-2 The system operator needs to constrain the selection of cycle lengths to those that provide acceptable operations, such as when "resonant" progression solutions are desired to provide two-way coordination along one or more arterial routes.
3	**3 External/Internal Interfaces**	
3.0-1.0-3	The ASCT shall not prevent TACTICS from monitoring signal status	4.11.0-1 The agency needs the TACTICS system to be able to monitor status of the signal system during ASCT operation.
4	**4 Crossing Arterials and Boundaries**	

Requirements Reference Number	System Requirements	User Need Satisfied
4.0-1.0-1	The ASCT shall alter its operation to minimize interruption of traffic entering the system. (This may be achieved via detection, with no direct connection to the other system.)	4.3.0-6 The system operator needs to detect traffic approaching from a neighboring system and coordinate the ASCT operation with the adjacent system.
4.0-1.0-2	The ASCT shall operate a fixed cycle length to match the cycle length of an adjacent system.	4.3.0-5 The system operator needs to constrain the adaptive system to operate a cycle length compatible with the crossing arterial.
4.0-1.0-4	The ASCT shall support adaptive coordination on crossing routes.	4.3.0-3 The system operator needs to adaptively coordinate signals on two crossing routes simultaneously. (All signals within the group are under the control of City Maumelle, City of North Little Rock, or Pulaski County.)
5	**5 Access and Security**	
5.0-1	The ASCT shall be implemented with a security policy that addresses the following selected	4.4.0-1 The system operator needs to have a security management and

Requirements Reference Number	System Requirements	User Need Satisfied
	elements:	administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-1	Local access to the ASCT.	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-2	Remote access to the ASCT.	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-3	System monitoring.	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-4	System manual override.	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-5	Development	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.

Requirements Reference Number	System Requirements	User Need Satisfied
5.0-1.0-6	Operations	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-7	User login	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-8	User password	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-9	Administration of the system	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-10	Signal controller group access	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-11	Access to classes of equipment	4.4.0-1 The system operator needs to have a security management and

Requirements Reference Number	System Requirements	User Need Satisfied
		administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-12	Access to equipment by jurisdiction	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-13	Output activation	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-14	System parameters	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-15	Report generation	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-16	Configuration	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.

Requirements Reference Number	System Requirements	User Need Satisfied
5.0-1.0-17	Security alerts	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-18	Security logging	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-19	Security reporting	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-20	Database	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-1.0-21	Signal controller	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-2	The ASCT shall provide monitoring and control access at the following locations:	4.10.0-1 The system operator needs to monitor and control all required features of

Requirements Reference Number	System Requirements	User Need Satisfied
		adaptive operation from the City's:
5.0-2.0-1	Traffic Engineering Division Building	4.10.0-1.0-1 Traffic Engineering Division Building
5.0-2.0-3	Agency LAN or WAN	4.10.0-1.0-3 LAN Workstations
5.0-2.0-5	Local controller cabinets	4.10.0-1.0-5
5.0-2.0-7	Remote locations via secure VPN	4.10.0-1.0-5 Remote locations via VPN
5.0-3	The ASCT shall comply with the agency's security policy as described in (specify appropriate policy document).	4.4.0-1 The system operator needs to have a security management and administrative system that allows access and operational privileges to be assigned, monitored and controlled by an administrator.
5.0-4	The ASCT shall not prevent access to the local signal controller database, monitoring or reporting functions by any installed signal management system.	4.10.0-2 The operator needs to access to the database management, monitoring and reporting features and functions of the signal controllers and any related signal management system from the access points defined for those system components. (e.g. Traffic Engineering and individual office

Requirements Reference Number	System Requirements	User Need Satisfied
		workstation)
6	**6 Data Log**	
6.0-2	The ASCT shall export its systems log in the following formats: MS Excel Text CVS Open source SQL database	4.11.0-4 The system operator needs to store all operational data and signal timing parameters calculated by the adaptive system, and export selected data to Microsoft Excel spreadsheets, text files, CSV files, or an open SQL database.
6.0-3	The ASCT shall store the event log for a minimum of 30 days	4.11.0-3 The system operator needs to store all operational data and signal timing parameters calculated by the adaptive system, and export selected data to Microsoft Excel spreadsheets.
6.0-4	The ASCT shall store results of all signal timing parameter calculations for a minimum of 30 days.	4.11.0-1 The agency needs the TACTICS system to be able to monitor status of the signal system during ASCT operation. 4.11.0-2 The system operator needs to store and report data used to calculate signal timing and have the data available for subsequent analysis.

Requirements Reference Number	System Requirements	User Need Satisfied
		4.11.0-3 The system operator needs to store and report data that can be used to measure traffic performance under adaptive control.
6.0-5	The ASCT shall store the following measured data in the form used as input to the adaptive algorithm for a minimum of 30 days: volume occupancy queue length phase utilization arrivals in green green band efficiency	4.11.0-3 The system operator needs to store and report data that can be used to measure traffic performance under adaptive control. 4.11.0-2 The system operator needs to store and report data used to calculate signal timing and have the data available for subsequent analysis.
6.0-6	The ASCT system shall archive all data automatically after a user-specified period not less than 30 days.	4.11.0-4 The system operator needs to store all operational data and signal timing parameters calculated by the adaptive system, and export selected data to Microsoft Excel spreadsheets, text files, CSV files, or an open SQL database.
6.0-7	The ASCT shall provide data storage for a system size of 200 signal controllers. The data to be stored shall include the following: (edit as	4.11.0-4

Requirements Reference Number	System Requirements	User Need Satisfied
	appropriate) Controller state data Reports Log data Security data ASCT parameters Detector status data	The system operator needs to store all operational data and signal timing parameters calculated by the adaptive system, and export selected data to Microsoft Excel spreadsheets, text files, CSV files, or an open SQL database.
6.0-8	The ASCT shall calculate and report relative data quality including: The extent data is affected by detector faults Other applicable items	4.11.0-7 The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.
6.0-9	The ASCT shall report comparisons of logged data when requested by the user: • Day to day, • Hour to hour • Hour of day to hour of day • Hour of week to hour of week • day of week to day of week	4.11.0-7 The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.

Requirements Reference Number	System Requirements	User Need Satisfied
	* Day of year to day of year	
6.0-10	The ASCT shall store data logs in a standard SQL database	4.11.0-4 The system operator needs to store all operational data and signal timing parameters calculated by the adaptive system, and export selected data to Microsoft Excel spreadsheets, text files, CSV files, or an open SQL database.
6.0-11	The ASCT shall report stored data in a form suitable to provide explanations of system behavior to public and politicians and to troubleshoot the system.	4.11.0-7 The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.
6.0-12	The ASCT shall store the following data in 15 minute increments: volume occupancy queue length	4.11.0-1 The agency needs the TACTICS system to be able to monitor status of the signal system during ASCT operation. 4.11.0-2 The system operator needs to store and report data used to calculate signal timing and have the data available for subsequent analysis. 4.11.0-3 The system operator needs to store and report data that can be used to measure traffic performance under adaptive control.
7	**7 Advanced Controller Operation**	

Requirements Reference Number	System Requirements	User Need Satisfied
7.0-1	When specified by the user, the ASCT shall serve a vehicle phase more than once for each time the coordinated phase is served.	4.9.0-1.0-1 Service a phase more than once per cycle
7.0-2	The ASCT shall provide a minimum of 8 phase overlaps.	4.9.0-1.0-2 Operate at least eight overlap phases
7.0-3	The ASCT shall accommodate a minimum of 16 phases at each signal	4.9.0-1.0-3 Operate four rings, 16 phases and up to four phases per ring
7.0-4	The ASCT shall accommodate a minimum of 4 rings at each signal.	4.9.0-1.0-3 Operate four rings, 16 phases and up to four phases per ring
7.0-5	The ASCT shall accommodate a minimum of 4 phases per ring	4.9.0-1.0-3 Operate four rings, 16 phases and up to four phases per ring.
7.0-6	The ASCT shall provide a minimum of 8 different user-defined phase sequences for each signal.	4.1.0-6 The system operator needs to modify the sequence of phases to support the various operational strategies. 4.9.0-1.0-4 Permit different phase sequences under different traffic conditions while avoiding the yellow trap.
7.0-6.0-1	Each permissible phase sequence shall be user-	4.1.0-6

Requirements Reference Number	System Requirements	User Need Satisfied
	assignable to any signal timing plan.	The system operator needs to modify the sequence of phases to support the various operational strategies. 4.9.0-1.0-4 Permit different phase sequences under different traffic conditions while avoiding the yellow trap.
7.0-6.0-2	Each permissible phase sequence shall be executable by a time of day schedule.	4.1.0-6 The system operator needs to modify the sequence of phases to support the various operational strategies. 4.9.0-1.0-4 Permit different phase sequences under different traffic conditions while avoiding the yellow trap.
7.0-6.0-3	Each permissible phase sequence shall be executable based on measured traffic conditions	4.1.0-6 The system operator needs to modify the sequence of phases to support the various operational strategies. 4.9.0-1.0-4 Permit different phase sequences under different traffic conditions while avoiding the yellow trap.
7.0-7	The ASCT shall not prevent a phase/overlap output by time-of-day.	4.1.0-6 The system operator needs to modify the sequence of phases to support the various operational strategies.

Requirements Reference Number	System Requirements	User Need Satisfied
7.0-8	The ASCT shall not prevent a phase/overlap output based on an external input.	4.1.0-6 The system operator needs to modify the sequence of phases to support the various operational strategies.
7.0-9	The ASCT shall not prevent the following phases to be designated as coordinated phases. (User to list all required phases.)	4.1.0-6 The system operator needs to modify the sequence of phases to support the various operational strategies. 4.9.0-1.0-9 Allow any phase to be designated as the coordinated phase
7.0-10	The ASCT shall have the option for a coordinated phase to be released early based on a user-definable point in the phase or cycle. (User select phase or cycle.)	
7.0-11	The ASCT shall not prevent the controller from displaying flashing yellow arrow left turn or right turn.	4.9.0-1.0-15 Use flashing yellow arrow to control permissive left turns and right turns.
7.0-12	The ASCT shall not prevent the local signal controller from performing actuated phase control using 4 extension/passage timers as assigned to user-specified vehicle detector input channels in the local controller.	4.9.0-1.0-11 Allow the controller to respond independently to individual lanes of an approach. This may allow the adaptive operation to be based on data from a specific detector, or by excluding specific detectors.
7.0-12.0-1	The ASCT shall operate adaptively using user-specified detector channels.	4.9.0-1.0-11 Allow the controller to respond independently to individual lanes of an

Requirements Reference Number	System Requirements	User Need Satisfied
		approach. This may allow the adaptive operation to be based on data from a specific detector, or by excluding specific detectors.
7.0-13	When adaptive operation is used in conjunction with normal coordination, the ASCT shall not prevent a controller serving a cycle length different from the cycles used at adjacent intersections.	4.9.0-1.0-16 Service side streets and pedestrian phases at minor locations more often than at adjacent signals when this can be done without compromising the quality of the coordination. (E.g., double-cycle mid-block pedestrian crossing signals.)
8	**8 Pedestrians**	
8.0-1	When a pedestrian phase is called, the ASCT shall execute pedestrian phases up to 5 seconds before the vehicle green of the related vehicle phase.	4.6.0-5 The system operator needs to accommodate early start of walk.
8.0-2	When a pedestrian phase is called, the ASCT shall accommodate pedestrian crossing times during adaptive operations.	4.6.0-2 The system operator needs to accommodate infrequent pedestrian operation while maintaining adaptive operation.
8.0-3	When a pedestrian phase is called, the ASCT shall accommodate pedestrian crossing times then resume adaptive operation.	4.6.0-2 The system operator needs to accommodate infrequent pedestrian operation while maintaining adaptive operation.
8.0-5	The ASCT shall execute pedestrian recall on user-defined phases in accordance with a time of day	4.6.0-3 The system operator needs to incorporate frequent pedestrian operation

Requirements Reference Number	System Requirements	User Need Satisfied
	schedule.	into routine adaptive operation.
8.0-6	The ASCT shall begin a non-coordinated phase later than its normal starting point within the cycle when all of the following conditions exist: The user enables this feature Sufficient time in the cycle remains to serve the minimum green times for the phase and the subsequent non-coordinated phases before the beginning of the coordinated phase The phase is called after its normal start time The associated pedestrian phase is not called	4.9.0-1.0-13 Allow flexible timing of non-coordinated phases (such as late start of a phase) while maintaining coordination
8.0-7	When specified by the user, the ASCT shall execute pedestrian recall on pedestrian phase adjacent to coordinated phases.	4.6.0-3 The system operator needs to incorporate frequent pedestrian operation into routine adaptive operation.
8.0-8	When the pedestrian phases are on recall, the ASCT shall accommodate pedestrian timing during adaptive operation.	4.6.0-3 The system operator needs to incorporate frequent pedestrian operation into routine adaptive operation.
8.0-9	The ASCT shall not inhibit negative vehicle and pedestrian phase timing.	4.9.0-1.0-17 Use negative pedestrian phasing to prevent an overlap conflicting with a pedestrian walk/don't walk

Requirements Reference Number	System Requirements	User Need Satisfied
10	**10 Detection**	
10.0-1	The ASCT shall be compatible with the following detector technologies (agency to specify): Inductive loop Wavetronix Matrix and Advance microwave radar	
11	**11 Railroad and EV Preemption**	
		.
11.0-4	The ASCT shall resume adaptive control of signal controllers when preemptions are released.	4.13.0-2 The system operator needs to accommodate emergency vehicle preemption.
11.0-5	The ASCT shall execute user-specified actions at non-preempted signal controllers during preemption. (E.g., inhibit a phase, activate a sign, display a message on a DMS)	4.13.0-2 The system operator needs to accommodate emergency vehicle preemption.
11.0-6	The ASCT shall operate normally at non-preempted signal controllers when special	4.13.0-2 The system operator needs to accommodate emergency vehicle

Requirements Reference Number	System Requirements	User Need Satisfied
	functions are engaged by a preemption event. (Examples of such special functions are a phase omit, a phase maximum recall or a fire route.)	preemption.
11.0-7	The ASCT shall release user-specified signal controllers to local control when one signal in a group is preempted.	4.13.0-2 The system operator needs to accommodate emergency vehicle preemption.
11.0-8	The ASCT shall not prevent the local signal controller from operating in normally detected limited-service actuated mode during preemption however, it is highly desirable to stay in adaptive operation during railroad preemption.	4.13.0-2 The system operator needs to accommodate emergency vehicle preemption.
11.0-9	The ASCT shall be fully compatible with Global Traffic Technologies (GTT) Opticom infrared/ GPS/ multimode pre-emption detection systems	4.13.0-2 The system operator needs to accommodate emergency vehicle preemption
12	**12 Transit Priority**	
12.0-1	The ASCT shall continue adaptive operations of a group when one of its signal controllers has a transit priority call.	
12.0-2	The ASCT shall advance the start of a user-specified green phase in response to a transit priority call.	

Requirements Reference Number	System Requirements	User Need Satisfied
12.0-2.0-1	The advance of start of green phase shall be user-defined.	
12.0-2.0-2	Adaptive operations shall continue during the advance of the start of green phase.	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
12.0-3	The ASCT shall delay the end of a green phase, in response to a priority call.	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
12.0-3.0-1	The delay of end of green phase shall be user-defined.	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
12.0-3.0-2	Adaptive operations shall continue during the delay of the end of green phase.	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
12.0-4	The ASCT shall permit at least 2 exclusive transit phases.	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
12.0-4.0-1	Adaptive operations shall continue when there is an exclusive transit phase call.	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
12.0-5	The ASCT shall control vehicle phases independently of the following:	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
12.0-5.0-1	• LRT only phases	4.13.0-3

Requirements Reference Number	System Requirements	User Need Satisfied
		The System Operator needs to accommodate bus rapid transit.
12.0-5.0-2	• Bus only phases	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
12.0-6	The ASCT shall list acceptable external bus transit priority systems	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
12.0-8	The ASCT shall accept a transit priority call from: • A signal controller/transit vehicle detector as listed by the ASCT vendor • An external system, listed by the ASCT vendor	4.13.0-3 The System Operator needs to accommodate bus rapid transit.
13	**13 Failure Events and Fallback**	
13.1	**13.1 Detector Failure**	
13.1.0-1	The ASCT a user-specified action in the absence of valid detector data from 25% of the detectors from a group	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
13.1.0-1.0-1	The ASCT shall release control to central system control.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment,

Requirements Reference Number	System Requirements	User Need Satisfied
		communications and/or software failure.
13.1.0-1.0-2	The ASCT shall release control to local operations to operate under its own time-of-day schedule.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
13.1.0-2	The ASCT shall use the following alternate data sources for operations in the absence of the real-time data from a detector:	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
13.1.0-2.0-1	Data from a user-specified alternate detector.	
13.1.0-2.0-2	Stored historical data from the failed detector.	
13.1.0-2.0-3	The ASCT shall switch to the alternate source in real time without operator intervention.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
13.1.0-3	In the event of a detector failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system.	4.12.0-1 The system operator needs to immediately notify maintenance and operations staff of alarms and alerts.
13.1.0-4	In the event of a failure, the ASCT shall log details	4.12.0-3

Requirements Reference Number	System Requirements	User Need Satisfied
	of the failure in a permanent log.	The system operator needs to maintain a complete log of alarms and failure events.
13.1.0-5	The permanent failure log shall be searchable, archival and exportable.	4.12.0-3 The system operator needs to maintain a complete log of alarms and failure events.
13.2	**13.2 Communications Failure**	
13.2-1	The ASCT shall execute user-specified actions when communications to one or more signal controllers fails within a group.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
13.2-1.0-1	In the event of loss of communication to a user-specified signal controller, the ASCT shall release control of all signal controllers within a user-specified group to local control.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
13.2-1.0-2	The ASCT shall switch to the alternate operation in real time without operator intervention.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
13.2-2	In the event of communications failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a	4.12.0-1 The system operator needs to immediately notify maintenance and operations staff of alarms and alerts.

Requirements Reference Number	System Requirements	User Need Satisfied
	designated means, or by using an external maintenance management system.	
13.2-3	The ASCT shall issue an alarm within 2 minutes of detection of a failure.	4.12.0-1 The system operator needs to immediately notify maintenance and operations staff of alarms and alerts.
13.2-4	In the event of a communications failure, the ASCT shall log details of the failure in a permanent log.	4.12.0-3 The system operator needs to maintain a complete log of alarms and failure events.
13.2-5	The permanent failure log shall be searchable, archival and exportable.	4.12.0-3 The system operator needs to maintain a complete log of alarms and failure events.
13.3	**13.3 Adaptive Processor Failure**	
13.3-1	The ASCT shall execute user-specified actions when adaptive control fails:	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
13.3-1.0-1	The ASCT shall release control to central system control.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.

Requirements Reference Number	System Requirements	User Need Satisfied
13.3-1.0-2	The ASCT shall release control to local operations to operate under its own time-of-day schedule.	4.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
13.3-2	In the event of adaptive processor failure, the ASCT shall issue an alarm to user-specified recipients. (This requirement may be fulfilled by sending the alarm to a designated list of recipients by a designated means, or by using an external maintenance management system.	4.12.0-1 The system operator needs to immediately notify maintenance and operations staff of alarms and alerts.
13.3-3	The permanent failure log shall be searchable, archival and exportable.	4.12.0-1 The system operator needs to immediately notify maintenance and operations staff of alarms and alerts.
13.3-4	During adaptive processor failure, the ASCT shall provide all local detector inputs to the local controller.	1.14.0-1 The system operator needs to fall back automatically to TOD or isolated free operation, as specified by the operator, in the event of equipment, communications and/or software failure.
14	**14 Software**	

Requirements Reference Number	System Requirements	User Need Satisfied
14.0-1	The vendor's adaptive software shall be fully operational within the following platform: 64-bit Windows 7-PC Able to Port to handheld Android and iOS	4.15.0-2 The system operator needs to use equipment and software acceptable under current agency IT policies and procedures.
14.0-2	The ASCT shall fully satisfy all requirements when connected with detectors from manufacturer Iteris and Sensys, various microwave and inductive loops	4.15.0-1.0-2 Detector type – Iteris video detection, inductive loops, Sensys magnetometers, microwave radar
14.0-3	The ASCT shall fully satisfy all requirements when connected with Siemens M34, M42, and M52 series controllers	4.15.0-1.0-1 Controller type - Siemens M34, M42, and M52 series controllers
14.0-4	The ASCT shall fully satisfy all requirements when connected with the following cabinet types:	4.15.0-1.0-4 Cabinet type and size - NEMA TS1 and NEMA TS2 (Type 2)
14.0-4.0-1	NEMA TS1	4.15.0-1.0-4 Cabinet type and size - NEMA TS1 and NEMA TS2 (Type 2)

Requirements Reference Number	System Requirements	User Need Satisfied
14.0-4.0-2	NEMA TS2 - Type 2	4.15.0-1.0-4 Cabinet type and size - NEMA TS1 and NEMA TS2 (Type 2)
14.0-5	The ASCT shall fully satisfy all requirements when connected an Ethernet over fiber communications system	4.15.0-1.0-3 Communication system - hardwire/fiber and wireless IP/Ethernet
14.0-6	The ASCT shall fully satisfy all requirements without inhibiting any feature of Siemens TACTICS central system.	4.15.0-1.0-5 Traffic signal system software – the adaptive system must not prevent the existing Siemens TACTICS central system from monitoring and recording intersection status, including the collection of all detection data and any signal failures being reported by the Controller.
15	**15 Training**	
15.0-1	The vendor shall provide the following training.	4.16.0-1 The City needs all staff involved in operation and maintenance to receive The Cities need all staff involved in operation and maintenance to receive appropriate training.
15.0-1.0-1	The vendor shall provide training on the operations of the adaptive system.	4.16.0-1 The Cities need all staff involved in operation and maintenance to receive appropriate training.
15.0-1.0-2	The vendor shall provide training on troubleshooting the system.	4.16.0-1 The Cities need all staff involved in operation and maintenance to receive

Requirements Reference Number	System Requirements	User Need Satisfied
		appropriate training.
15.0-1.0-3	The vendor shall provide training on preventive maintenance and repair of equipment.	4.16.0-1 The Cities need all staff involved in operation and maintenance to receive appropriate training.
15.0-1.0-4	The vendor shall provide training on system configuration.	4.16.0-1 The Cities need all staff involved in operation and maintenance to receive appropriate training.
15.0-1.0-5	The vendor shall provide training on administration of the system.	4.16.0-1 The Cities need all staff involved in operation and maintenance to receive appropriate training.
15.0-1.0-6	The vendor shall provide training on system calibration.	4.16.0-1 The Cities need all staff involved in operation and maintenance to receive appropriate training.
15.0-1.0-7	The vendor's training delivery shall include: printed course materials and references, electronic copies of presentations and references.	4.16.0-1 The Cities need all staff involved in operation and maintenance to receive appropriate training.
15.0-1.0-8	The vendor's training shall be delivered at a location specified by the Cities	4.16.0-1 The Cities need all staff involved in operation and maintenance to receive appropriate training.
15.0-1.0-9	The vendor shall provide a minimum of 40 hours	4.16.0-1

Requirements Reference Number	System Requirements	User Need Satisfied
	training to a minimum of 10 staff.	The Cities need all staff involved in operation and maintenance to receive appropriate training.
15.0-1.0-10	The vendor shall provide a minimum of 2 training sessions over 3 months. These training sessions shall be an initial training and after ASCT training, after the agency has used the ASCT over a period of 3 months	The Cities need all staff involved in operation and maintenance to receive appropriate training.
16	**16 Maintenance, Support and Warranty**	
16.0-1	After the initial 1st year of maintenance included in bid, the Maintenance Vendor shall provide maintenance according to a separate maintenance contract with the City. That contract should identify repairs necessary to preserve requirements	4.16.0-2 The Cities need the system to fulfill all requirements for the life of the system. The Cities therefore need the system to be maintained to repair faults that are not defects in materials and workmanship.
16.0-2	The Vendor shall provide routine updates to the software and software environment necessary to preserve the fulfillment of requirements for a period of 5 years following final acceptance years. Preservation of requirements fulfillment especially includes all IT management requirements as previously identified.	4.16.0-4 The Cities need the system to fulfill all requirements for the life of the system. The Cities therefore need support to keep software and software environment updated as necessary to prevent requirements no longer being fulfilled.
16.0-3	The Vendor shall warrant the system to be free of defects in materials and workmanship for a period	4.16.0-3 The Cities need the system to fulfill all requirements for the life of the

Requirements Reference Number	System Requirements	User Need Satisfied
	of five (5) years once final acceptance is approved. Warranty is defined as correcting defects in materials and workmanship (subject to other language included in the purchase documents). Defect is defined as any circumstance in which the material does not perform according to its specification.	system. The Cities therefore need the system to remain free of defects in materials and workmanship that result in requirements no longer being fulfilled.
16.0-4	All equipment and other elements of the ASCT shall be located and installed in a fashion that will permit City staff to access it for maintenance and support activities in the field, at the Traffic Engineering building, and at other locations within the Cities, without special access equipment not normally available to them.	4.18.0-1 Each maintenance crew of the maintenance agency (currently the City of North Little Rock) needs all applicable equipment to be readily accessible for maintenance and support activities in the field and at other locations within the maintaining agency. Special access equipment not normally available to them for maintenance will not be allowed.
17	**17 Schedule**	
17.0-1	The ASCT shall set the state of external input/output states according to a time-of-day schedule.	
17.0-2	The ASCT output states shall be settable according to a time-of-day schedule	
17.0-3	The ASCT operational parameters shall be settable according to a Time of Day schedule	
18	**18 Performance Measurement,**	

Requirements Reference Number	System Requirements	User Need Satisfied
	Monitoring and Reporting	
18.0-1	The ASCT shall report measures of current traffic conditions on which it bases signal state alterations.	4.11.0-2 The system operator needs to store and report data used to calculate signal timing and have the data available for subsequent analysis.
18.0-2	The ASCT shall report all intermediate calculated values that are affected by calibration parameters.	4.11.0-2 The system operator needs to store and report data used to calculate signal timing and have the data available for subsequent analysis.
18.0-3	The ASCT shall maintain a log of all signal state alterations directed by the ASCT.	4.11.0-1 The agency needs the TACTICS system to be able to monitor status of the signal system during ASCT operation. 4.11.0-2 The system operator needs to store and report data used to calculate signal timing and have the data available for subsequent analysis.
18.0-3.0-1	The ASCT log shall include all events directed by the external inputs.	4.11.0-7 The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.
18.0-3.0-2	The ASCT log shall include all external output state changes.	4.11.0-7 The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system

Requirements Reference Number	System Requirements	User Need Satisfied
		performance and traffic conditions.
18.0-3.0-3	The ASCT log shall include all actual parameter values that are subject to user-specified values.	4.11.0-7 The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.
18.0-3.0-4	The ASCT shall maintain the records in this ASCT log for 30 days.	4.11.0-7 The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.
18.0-3.0-5	The ASCT shall archive the ASCT log so that it may be readable in an MS Excel format (CSV, XLS, etc)	4.11.0-7 The system operator needs to generate historic and real-time reports that effectively support operation, maintenance and reporting of system performance and traffic conditions.

Metroplan CARTS Adaptive Signal Project

ASCT Validation Plan

By

GRESHAM SMITH AND PARTNERS

and

NEEL-SCHAFFER
Solutions you can build upon

October 14, 2015

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1.0 ASCT System Validation Plan

This document will be a guide to the validation plan of the adaptive signal control technology (ASCT) that will be implemented within the City of Maumelle, the City of North Little Rock, and Pulaski County AR. This document is part of the total System Engineering Analysis (SEA) developed to select and deploy an ASCT system for the area. This document reiterates the scope of the project; the referenced documents that are used to prepare the validation plan, details on the actual conduct of validation, and provides a list of the validation and methods to be used.

It will be the City's ultimate responsibility to carry out measuring the performance of the ASCT through acceptance and commitment to this Validation Plan. It is imperative that operations and maintenance (O&M) personnel understand the importance of validating the ASCT on a regular basis in order to quantify and qualify the benefits of the system.

2.0 Scope of Project

The purpose of this project is to define the area's signal needs and objectives for adaptive traffic signal control along Maumelle Blvd corridor, and to select a system that can best accommodate the area's needs and objectives. The PS&E portion of this project will design the adaptive traffic signal system that satisfies the documented system requirements.

This project involves consideration of application of ASCT initially to Maumelle Boulevard and Highway 365 (MacArthur Drive) between Northshore Drive, by the interchange of Interstate I-430, north to I-40 at the north terminus of the initial study corridor. However, to the extent that it appears feasible, consideration will also be given to application of ASCT to other future corridors, as the activities within the area grows. It is anticipated that not all corridors will be candidates for ASCT, as observed and studied in this project, however, this SEA will serve as the basis for the stakeholder's needs and objectives of what they want an adaptive signal strategy to be, and those corresponding requirements of an ASCT system within the area.

The primary objectives of the adaptive traffic signal system in this project are to accommodate the irregular traffic patterns within the project area, provide smoother traffic flow along the main arterials within the project, and accommodate future developments within and near the project area. The needs and requirements of the ASCT is as stated in the Concept of Operations and System Requirements documents within the SEA.

3.0 Referenced Documents

The following documents supported the preparation of the validation plan:

Planning Documents

- Regional Strategic Transportation Network: http://www.metroplan.org/files/53/2011-01Regional_Strategic_Network.pdf
- Transportation Planning Structure: http://www.metroplan.org/files/53/TransPlanStructure001.pdf

- CARTS Transportation Improvement Plan: http://www.metroplan.org/files/53/TIP-2013-16_02.pdf
- FY 2015 Unified Planning Work Program: http://www.metroplan.temp1000.com/files/53/2015UPWP.pdf
- CARTS Public Participation Plan: http://www.metroplan.org/files/53/2011CARTS_PPP.pdf
- The Long-Range Transportation Plan for Central Arkansas: http://draftplan.imaginecentralarkansas.org/draft-plan-chapter-7-long-range-metropolitan-transportation-plan

Adaptive Signals

- NCHRP Synthesis 403: "Adaptive Traffic Control Systems: Domestic and Foreign State of Practice", http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_403.pdf

ITS, Operations, Architecture, Others

- FHWA Rule 940, Federal Register / Vol. 66, No. 5 / Monday, January 8, 2001 / Rules and Regulations, DEPARTMENT OF TRANSPORTATION, Federal Highway Administration 23 CFR Parts 655 and 940, (FHWA Docket No. FHWA-99-5899) RIN 2125-AE65 Intelligent Transportation System Architecture and Standards
- Regional ITS Architecture Guidance Document, "Developing, Using, and Maintaining an ITS Architecture for your Region; National ITS Architecture Team; October, 2001
- CARTS Intelligent Transportation System Plan and Regional ITS Architecture http://www.metroplan.org/files/53/2010CARTS_ITS.pdf
- NTCIP 1211 version v02. "Signal Control and Prioritization (SCP)."
- NEMA TS1
- NEMA TS2

System Engineering

- FHWA. (2012, August). Model Systems Engineering Documents for Adaptive Signal Control Technology (ASCT) Systems - Final Guidance Document. U.S. Department of Transportation.
- FHWA. (2007, January). Systems Engineering for Intelligent Transportation Systems - An Introduction for Transportation Professionals. U.S. Department of Transportation.
- FHWA Systems Engineering Guidebook Version 3.0, http://www.fhwa.dot.gov/cadiv/segb/
- FHWA. (2013, July). Measures of Effectiveness and Validation Guidance for Adaptive Signal Control Technologies http://www.ops.fhwa.dot.gov/publications/fhwahop13031/index.htm

Procurement

- NCHRP 560 Guide to Contracting ITS Projects, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_560.pdf
- The Road to Successful ITS Software Acquisition, http://www.fhwa.dot.gov/publications/research/operations/its/98036/rdsuccessvol2.pdf

4.0 Conducting Validation

System validation contains both short and long term performance measure monitoring of the ASCT. The system validation will be conducted mostly by the traffic operations staff. The system operator of the adaptive signal control technology assigned by the stakeholders will conduct the validation tests, record the results, and prepare summary reports of the results with the appropriate engineering support from the stakeholders.

Before conducting any validation tests, the validation conductor will prepare a validation procedure for each validation test. The validation procedure will describe the equipment setup, responsible personnel and steps to be followed to conduct the validation test.

The validation tests will be conducted after the system deployment and verification tests are complete. The validation conductor will use the hardware and software setup for the adaptive signal operation as well as any available existing software and measurement devices. The system operator will configure system software to setup the required performance measure to collect and process data for validation tests. The system operator may need to observe traffic operation in the field or via traffic cameras (where available) to measure test outcomes of some of the validation tests.

Validation of several cases, identified as operational scenarios in the Concept of Operations, will require a comparison of operations before and after implementation of the ASCT system. Data to be used for validation should be collected prior to implementation of the ASCT or during a brief period after implementation when the system is turned off specifically for collecting before data.

Once before/after data has been collected and reported, it is imperative that ongoing performance measurements on the system be collected at various intervals over time to promote continual use of the ASCT, or to improve upon the ASCT operation by adjusting variables as deemed necessary. Those monitoring and collection intervals should be selected by the City of North Little Rock operations personnel to best fit their needs and schedule. It should be noted that variables within the ASCT system will specifically need adjustments throughout the life of the ASCT system periodically. The operations staff is expected to be trained on making minor adjustments to the system in order for the system to operate at its highest level.

5.0 Validation Identification

The following validation scenarios shall be tested and documented by the validation conductor. The validation tests will validate the user needs to evaluate the project goals and the key operational scenarios described in the Concept of Operations document. User needs related to system interface and control features will be tested through the system verification only (per the Verification Plan). The Validation Plan is intended to highlight ongoing performance measures that will need continued monitoring.

Objective	Performance Measure	Type of data collection and analysis
More rapidly adjust operations to changing traffic conditions	Assess suitability of timing pattern against traffic volumes	Continuous reports from ASCT system with validation from CCTV cameras or field observation
Reduce delays at traffic signals	Total intersection delay Pedestrian delay	Spot measurements, derived from or reported by the ASCT system. Schedule total intersection delay studies
Reduce travel times through the traffic signal system	Travel time	Floating car surveys Bluetooth and cell phone sources for monitoring should be reviewed for deployment and cost feasibility
Smooth the flow of traffic along coordinated routes	Number of stops on route Arrivals on red	Floating car surveys Purdue Coordination Diagram and associated statistics from advance detection. Plans for this method should be implemented through TACTICS and available detection devices
Maximize the throughput of traffic along coordinated routes	Volume at critical locations on route	Continuous flow volume measurement by ASCT system or TACTICS Volume measurement from temporary detection devices as needed
Equitably serve adjacent land uses	Avg. delay per vehicle per phase No. of phases with residual queues	Field observations Reason for phase termination – continuous measurement by ASCT system Derive estimate of phase failures from signal system data in TACTICS
Manage queues, to prevent	Queue spillover frequency and	Surveys at critical locations.

excessive queuing from reducing efficiency	severity	Ongoing queue detection and continuous reporting by ASCT or TACTICS CCTV camera validation and field observation
Allow remote monitoring and control of traffic signals	System availability (%)	Continuous reporting by ASCT system or TACTICS. Validation by CCTV
Adhere to applicable traffic signal and ITS design standards and the Regional ITS Architecture	Confirmation by demonstration	Query ASCT manufacturer for NTCIP updates periodically
Reduce vehicle emissions through improvements in appropriate determinants such as vehicle stops and delays	Estimated vehicle emissions	Derived from stops and delay measurements. If available, CCTV used to observe stops and measure delay through 3rd party software Option: Bluetooth and cell phone sources for continual monitoring of delay, or environmental sensor deployment
Objective Control arterial queue buildup and freeway off-ramps in order to prevent queue backup onto the freeway	Performance Measure Queue spillover frequency and severity	Type of data collection and analysis Ongoing queue detection and continuous reporting by ASCT or TACTICS CCTV camera validation and observation
Provide ease of maintenance and day-to-day operation of the traffic signals. Make more efficient use of the staff time available.	O&M Staff Hours at ASCT intersections vs other intersections	Noting Location of O&M activities by intersection and time spent at intersections with ASCT
Maintain the existing level of safety at ASCT intersections	Number, Type, Severity of crashes	Pull crash data from police database before and after ASCT