Butterfield Road Adaptive Signal Control

Concept of Operations

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Prepared for:

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1	**Chapter 1: Scope**
1.1	**Document Purpose and Scope**
1.1-1	The scope of this document covers the consideration of adaptive signal control technology (ASCT) for use along the Butterfield Road corridor in the Village of Libertyville, Vernon Hills and Mundelein. For corridor study limits, see the location map in **Figure 1**.

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	 **Figure 1 - Project Location Map**

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1.1-2	This document describes and provides a rationale for the expected operations of the proposed adaptive system.
1.1-3	It 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.
1.1-4	The intended audience of this document includes: system operators, administrators, decision-makers, elected officials, other nontechnical readers and other stakeholders who will share the operation of the system or be directly affected by it.
1.2	**Project Purpose and Scope**
1.2-1	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.
1.2-2	The purpose of providing adaptive control in this area is to improve traffic flow during the peak periods by reducing the number of stops and increasing throughput volume, provide an equitable distribution of green time during the non-peak periods and over capacity constraints caused by current roadway geometrics.
1.2-3	This project will add adaptive capabilities to the existing coordinated signal system.
1.2-4	This project will replace the existing coordinated traffic signal system to provide adaptive control.
1.2-5	All the capabilities of the existing coordinated system will be maintained.
1.2-7	Adaptive capability will be provided for all coordinated signals along Butterfield Road from Greggs Parkway/ Allanson Road to IL 137.
1.2-8	The adaptive capability will be provided for signals operated by Lake County Division of Transportation (LCDOT). LCDOT will operate and maintain all signals that are part of the ASCT system. Illinois Department of Transportation (IDOT) will maintain ownership of the signals at IL 137 and IL 176.
1.2-9	Interfaces will be provided to the signal system operated by the Illinois Department of Transportation (IDOT).

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1.2-10	The adaptive system will not prevent current integration between the controllers and the existing CENTRACS traffic signal system to allow for monitoring of traffic signal operations. Additionally, the adaptive system will be integrated with Lake County's *PASSAGE* network to provide central monitoring of traffic operations, to continue to provide the required volume and occupancy data utilized for congestion mapping, and to allow for a manual or time-of-day override in the case of an incident or scheduled events. *PASSAGE* is an intelligent transportation system (ITS) designed to provide motorists with real-time traffic congestion information due to crashes and construction events. Many of these events are communicated from the police department's Computer Aided Dispatch (CAD) system directly to the Lake County Transportation Management Center (TMC), then communicated back to highway users via www.lakecountypassage.com, the *PASSAGE* Highway advisory radio (HAR) system (1620 AM), and variable message signs. The PASSAGE system is a partnership between the Illinois Department of Transportation (IDOT), the Illinois State Toll Highway Authority, LCDOT, and various municipalities. The responsibility to operate the PASSAGE system on a daily basis rests with LCDOT.
1.3	**Procurement**
1.3.0-1	The ASCT system will be procured using:
1.3.0-2	A request for qualifications (RFQ) will be issued to all potential vendors. Responses will be used to develop a short list of suitable systems and a request for proposals (RFP) will be issued to those vendors. The selected system will be the one that provides the best value, subject to financial and schedule constraints.
1.3.0-3	Field equipment (parts and labor) will be procured using a low-bid process based on detailed plans and technical specifications.
1.3.0-4	A detailed procurement plan will be prepared after the system requirements have been determined.

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2	**Chapter 2: Referenced Documents**
2.0-1	The following documents have been used in the preparation of this Concept of Operations and stakeholder discussions. Some of these documents provide policy guidance for traffic signal operation in this area, some are standards with which the system must comply, while others report the conclusions of discussions, workshops and other research used to define the needs of the project and subsequently identify project requirements.
2.0-1.0-1	References Specific to the Adaptive Locations: • Lake County TMC Study and Implementation Plan System Architecture • Lake County TMC Study and Implementation Plan System Requirements • PASSAGE System Block Diagram • Agreements between IDOT and LCDOT for the operation of the PASSAGE system • Northeastern Illinois Regional ITS Architecture documents • Butterfield Road Allanson Road to IL 137 Work Order #2 – SCAT 2015
2.0-1.0-2	Systems Engineering • Model Systems Engineering Documents for Adaptive Signal Control Technology (ASCT) Systems, FHWA August 2012
2.0-1.0-3	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)
2.0-1.0-4	• Illinois Statewide Architecture and Strategic Plan • Northeastern Illinois Regional ITS Architecture documents
2.0-1.0-5	NTCIP • List applicable NTCIP standards: NTCIP 1211 v02 Object Definitions for Signal Control and Prioritization (SCP)

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	NTCIP 8007 v01	Testing and Conformity Assessment Documentation within NTCIP Standards Publications
	NTCIP 8003:2001	Profile Framework
	NTCIP 2306 v01	Application Profile for XML Message Encoding and Transport in ITS Center-to-Center Communications
	NTCIP 2303:2001	File Transfer Protocol Application Profile
	NTCIP 2302:2001	Trivial File Transfer Protocol Application Profile
	NTCIP 1210 v01	Field Management Stations (FMS)—Part 1: Object Definitions for Signal System Masters (SSM)
	NTCIP 1209 v02	Object Definitions for Transportation Sensor Systems (TSS)
	NTCIP 1208:2005	Object Definitions for Closed-Circuit Television (CCTV) Switching
	NTCIP 1206:2005	Object Definitions for Data Collection and Monitoring (DCM) Devices
	NTCIP 1205:2001	Object Definitions for Closed-Circuit Television (CCTV) Camera Control
	NTCIP 1202:2005	Object Definitions for Actuated Traffic Signal Controller (ASC) Units—Version 02

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	NTCIP 1201 v03	Global Object (GO) Definitions
	NTCIP 1103 v03	Transportation Management Protocols (TMP)
	NTCIP 1102:2004	Octet Encoding Rules (OER) Base Protocol
2.0-1.0-6	NEMA TS 2-2016	Traffic Controller Assemblies with NTCIP Requirements—Version 03.07
	NEMA ICS 20-2009 (R2015)	Informational Guide to Electrical Industrial Topics
	NEMA ICS 19-2002 (R2007, R2011, R2016))	Diagrams, Device Designations and Symbols
	NEMA WC 63.1-2005	Performance Standard for Twisted Pair Premise Voice and Data Communications Cables
	NEMA NS 1-2005	Guide for Preparation of NEMA Standards Publications
	NEMA IA 2.5-2005	Programmable Controllers (PLC), Part 5: Communications
	NEMA ICS 61131-1-2005 (R2013) (Formerly NEMA IA 2.1-2005)	Programmable Controllers (PLC), Part 1: General Information
3	**Chapter 3: User-Oriented Operational Description**	

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3.1	**The Existing Situation**
3.1.1	**Network Characteristics**
3.1.1.1	Arterial This project corridor along Butterfield Road includes eight (8) traffic signals and one railroad crossing, spanning through the Village of Libertyville, Village of Vernon Hills, and the Village of Mundelein. The eight (8) traffic signals are located at the intersections of: • Allanson Road/Greggs Parkway • Huntington Drive • Golf Road • Crane Boulevard • IL Route 176/W. Park Avenue • County A34/Winchester Road • Virginia Avenue/St. William Drive • IL Route 137/Peterson Road/Buckley Road A ninth traffic signal included in the project is located at IL 137 and the entrance to Butterfield Square shopping center. The traffic signals are interconnected with fiber optic communications and operate in a coordinated manner with a 140 second cycle length during the AM and PM peak periods and a 100 second cycle length during the midday peak. Most intersections are eight-phase intersections with protected or protected/permitted left turns on all approaches. The remaining intersections provide access to local businesses and residential areas. Those intersections have protected left turns on Butterfield Road and permissive left turns on the side streets. Butterfield Road is a four lane divided minor arterial with a 40 mph posted speed limit. The average annual daily traffic (AADT) on Butterfield Road ranges from 17,900 vehicles per day (vpd) at the IL 137/Peterson Road intersection to 21,100 vehicle per day near the IL 176 intersection.

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	Land use throughout the corridor varies. At the north end there is a mix of shopping center, commercial and office, manufacturing and distribution park. Heading south the corridor is mostly single family residential with some institutional buildings and Pine Meadow Golf Course along the west side of Butterfield. At the intersection of IL 176 land use changes to general commercial and professional services offices. South of IL 176 the corridor becomes residential again until the intersection of Allanson Road where the west side of the roadway is commercial. Within the study area, there are three schools: Butterfield Elementary School located at 1441 Lake Street, Libertyville High School just east of Butterfield along IL 176 and Carmel Catholic High School just west of Butterfield along IL 176. In addition, there is a large medical facility, Advocate Condell Medical Center located off Golf Road.

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	 **Figure 2 - Project Map**

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3.1.1.1.0-2	The free-flow travel time between IL 137 and Greggs Parkway/Allanson Road is approximately six minutes.
3.1.1.1.0-4	The arterial has irregularly spaced signalized intersections, and there is no "natural" cycle length that allows two-way progression.
3.1.1.5	**Jurisdictions**
3.1.1.5.0-1	The signals are owned and/or operated and/or maintained by two separate agencies. Lake County Division of Transportation operates and maintains all intersections and owns all intersections except IL 137 and IL 176; these signals are owned and operated by Illinois Department of Transportation (IDOT).
3.1.2	**Traffic Characteristics**
3.1.2.1	**Overview**
3.1.2.1.0-1	The traffic characteristics are directional with a strong southbound movement during the AM peak and northbound movement during the PM peak. Average traffic volumes do not vary significantly from Monday to Friday but weekend volumes are considerably lower and have a much flatter distribution throughout the day. Looking at traffic volumes from each day of the week from January, 2016 to March, 2017 exposes the fact that traffic of the same day of the week fluctuates from week to week. Beyond traffic fluctuations created by holidays, there are differences in 15 minute traffic volumes between "typical" weeks. Traffic volumes vary by 50 vehicles throughout most of the day and up to 150 vehicles during the AM and PM peak period in the dominant direction. Traffic operations were observed in both the AM and PM peak periods in the fall of 2016 and the spring of 2017. Based on these observations, the following deficiencies were noted: 1. AM Peak a. Significant SB queuing extending from Winchester Road to just south of Virginia Avenue/St William Drive (approx. 1,200 feet) b. Significant queuing SB and EB at IL 176. EB queues extended approximately 900 ft and SB queues 1150

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	feet. 2. PM Peak a. Northbound left turning queues at Winchester Road spilled out of the storage bay blocking through traffic. b. Westbound queues on IL 176 were incredibly lengthy extending approximately half a mile. c. Northbound queues at the IL 176 intersection spilled back to Crane Boulevard, approximately 1500 feet. The surrounding land use is quite variable including a shopping center, commercial and office use, a manufacturing and distribution park, residential and institutional buildings. There are three schools, a large medical center and a golf course located just off the corridor contributing to off peak traffic fluctuations. A commuter rail crossing is located near the northern end of the project area. Blockages at this location result in a sudden surge of northbound traffic at the Peterson Road/IL 137 intersection.
3.1.2.2	**Peak Periods**
3.1.2.2.0-1	There are heavily directional commuter peaks. During the AM peak, traffic is heavily directional in the Southbound direction. The peak hour volume in the Southbound direction is 1,600, while the peak hour volume in the Northbound direction is 916. During the PM peak, traffic is heavily directional in the Northbound direction. The peak hour volume in the Northbound direction is 1,792, while the peak hour volume in the Southbound direction is 1,036.
3.1.2.3	**Business Hours**
3.1.2.3.0-2	Traffic volumes during business hours are fairly balanced between the morning (predominantly southbound) and evening (predominately northbound) peaks. There is a small midday peak between 12-1 pm, with volumes that are lower than both the morning and evening peak in both directions. The shopping center has the highest hourly volume of ingress and egress traffic starting at 12:00 pm followed by 7:00am. However, the intersection of the shopping center has its highest hourly volume at 4:00pm due to IL 137 traffic.
3.1.2.4	**Evenings**

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3.1.2.4.0-1	During the evenings after the PM peak, the flows are:
3.1.2.4.0-1.0-2	Balanced
3.1.2.4.0-1.0-4	Light
3.1.2.5	**Weekends**
3.1.2.5.0-1	During the weekends, the flows are:
3.1.2.5.0-1.0-1	Balanced weekend flows
3.1.2.5.0-1.0-3	Saturday or Sunday peaks (Related to retail, recreation, worship and other factors.)
3.1.2.5.0-1.0-4	Weekend retail traffic
3.1.2.6	**Events and Incidents**
3.1.2.6.0-2	Heavily directional planned and unplanned incident-related traffic is experienced in this area when there is an incident on US 45 or IL 21. In addition, emergency vehicle preemption and the effects of queuing traffic at the crossing just south of IL 137 have adverse impacts on traffic flow in the corridor.
3.1.2.7	**General**
3.1.2.7.0-2	At some of the intersections there is a high proportion of turning traffic. These intersections include IL 137, Winchester Road, IL 176 and Allanson Road.
3.1.2.7.0-3	Queues often overflow from turn bays at Winchester Road in the northbound direction during the PM peak.
3.1.2.7.0-4	Traffic along the arterial is predominantly through traffic until the northern terminus at IL 137.

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3.1.2.7.0-6	There are significant turning movements onto and off the coordinated route at IL 137, Winchester Road, IL 176 and Allanson Road.
3.1.2.7.0-7	Traffic conditions change quickly when there is an emergency vehicle preemption event.
3.1.2.8	**Future Traffic Conditions**
3.1.2.8.0-1	Future development, e.g., the 148 lot Oak Trails residential project north of IL 176 and a 15 lot Swanson Associates development, will introduce new traffic volumes. In addition, a future extension of Winchester west to Freemont Center will also impact traffic flow.
3.1.3	**Signal Grouping**
3.1.3.0-1	The locations of signals to be operated under adaptive control are illustrated in Figure 3.

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	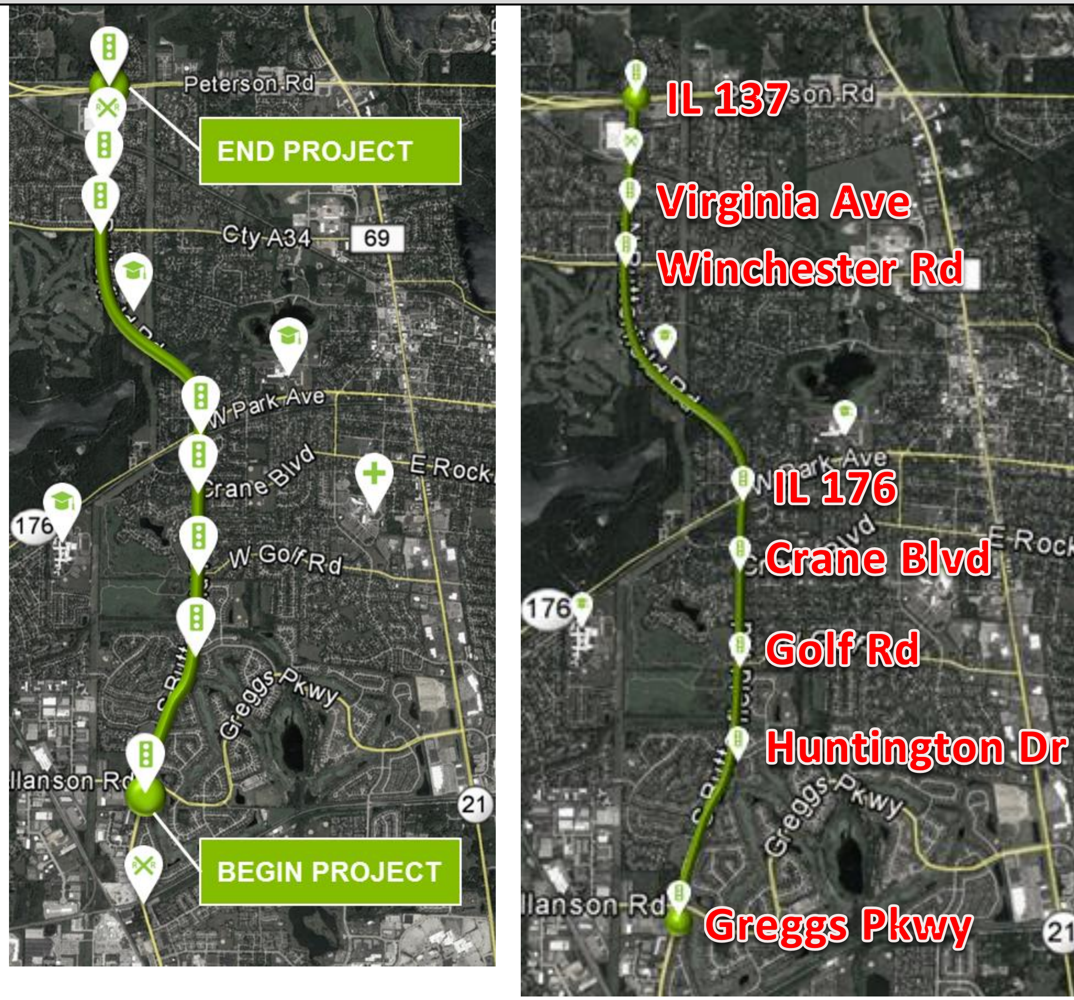 **Figure 3 – Corridor Signal Locations**

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3.1.3.0-4	While the signals are relatively close, the traffic conditions vary and sometimes they would be expected to be coordinated as one group, while at other times they may be coordinated as two (or more) separate and independent groups. The grouping of signals will depend on the time of day and measured traffic conditions.
3.1.4	**Land Use Characteristics**
3.1.4.1	**Existing Land Uses**
3.1.4.1.0-1	The arterial:
3.1.4.1.0-1.0-7	Serves a mixture of land uses, including residential, office, commercial, retail, manufacturing, and education including Butterfield Elementary School located at 1441 Lake Street, Libertyville High School just east of Butterfield along IL 176 and Carmel Catholic High School just west of Butterfield along IL 176. Commercial properties include a bank and gas station at Allanson Road, two gas stations at IL 176, Pine Meadow Golf Club at Lake Street, and a logistics facility and the Butterfield Square shopping center at IL 137.
3.1.4.2	**Future Land Use Changes**
3.1.4.2.0-1	Two significant residential subdivisions are planned for the corridor. The larger project, known as Oak Trails, would introduce 148 new homes along the west side of Butterfield Road north of IL 176. A second project consisting of fifteen single-family home lots is also proposed on the west side of Butterfield Road, between the North Shore Bike Path and Victory Dr.
3.1.4.3	**Pedestrians and Public Transit**
3.1.4.3.0-1	This section describes the influence of pedestrians on the signal operation.
3.1.4.3.0-1.0-1	Pedestrian delays are a factor in choosing phasing and timing parameters.
3.1.4.3.0-1.0-2	Pedestrians impede turning movements at Winchester, IL 176, and IL 137 during certain times of day.

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3.1.4.3.0-1.0-5	Pedestrian phases are rarely called at the remaining intersections in the corridor.
3.1.4.3.0-2	This section describes the influence of transit on the signal operation.
3.1.4.3.0-2.0-1	There is one bus line operating along the route. The bus operates at a frequency of one bus per hour during the AM and PM peak periods in the northbound and southbound direction between Winchester and IL 176 (#574- CLC- Hawthorn Mall).
3.1.4.3.0-2.0-2	Buses run along Butterfield Road, the coordinated route, from Winchester Road to IL 176 The bus route runs east of Butterfield Road at Winchester Road and to the west of Butterfield Road by Carmel High School at IL 176.
3.1.4.4	**Agencies**
3.1.4.4.0-1	The existing signal system is operated by Lake County Division of Transportation as part of its PASSAGE program. Some intersections are controlled by signals belonging to Illinois Department of Transportation. These are controlled by Illinois Department of Transportation agency.
3.1.4.4.0-2	The effectiveness of local law enforcement, fire departments and emergency medical transport services is affected by the operation of the signal system as congestion during peak periods can hamper their ability to respond to local emergencies.
3.1.4.5	**Existing Architecture**
3.1.4.5.0-1	The existing PASSAGE system architecture is illustrated in Figure 4.

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	 **Figure 4 - PASSAGE Architecture Diagram**
3.1.4.5.0-1.0-1	The focal point of the PASSAGE program is the Lake County Traffic Management Center (TMC) located at 600 W. Winchester Road in Libertyville. The TMC houses multiple workstations, a video wall, and network equipment for all PASSAGE field devices as shown in the schematic.
3.1.4.5.0-1.0-3	PASSAGE communications infrastructure consists of fiber optic cable with Ethernet communications.
3.1.4.5.0-1.0-4	Detection locations and technology include video detection placed at the stop line of all approaches and in advance of the intersection along Butterfield Road at most of the intersections under LCDOT intersection. At IL 176 there is stop bar loop detection and advanced loop detection along IL 176 while Butterfield Road has stop bar loop detection for the left turn

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	lanes and advanced loop detection for the through movements. At IL 137 there is stop bar loop detection along Butterfield Road and in the left turn bays along IL 137. IL 137 also has advanced loops in the through lanes. At Huntington Drive there is stop bar loop detection on Huntington Drive and in the left turn lanes along Butterfield Road. Butterfield Road also has advanced loops in the through lanes.
3.2	**Limitations of the Existing system**
3.2.0-1	The following statements summarize the limitations of the existing system that prevent it from satisfactorily accommodating the traffic situations described above.
3.2.0-2	The existing system cannot recognize the onset of peak periods, so the peak period coordination plan introduction times are set conservatively to ensure they cover the normal variation in duration and intensity of the peak. This means that the timing is often less efficient during the early and late parts of the peak periods.
3.2.0-4	The coordinated signal operation is often disrupted by emergency vehicle preemption. An adaptive system may be expected to recover from these disruptions more quickly than the existing system. In the existing system EVP occurrences knock the corridor out of coordination for anywhere between three to five cycles. LCDOT would like to see this reduced. There will be varied improvement based on the type of ASCT system selected.
3.2.0-5	The existing system cannot detect unexpected changes in traffic demand as a result of incidents on the adjacent roadways US Route 45 and IL 21. As a result, the congestion on the arterials is greater than would be the case if the signal timing could automatically adjust to the unexpected conditions. This would also reduce the need for manual intervention by operators when the incident is brought to their attention.
3.2.0-6	The existing system is not timed to accommodate changes in traffic conditions before and after games and other after school activities at Libertyville High School and Carmel Catholic High School. During certain times of day cycle failures are noted at IL 176 where vehicles are experiencing double and triple cycles. An adaptive system could be expected to reduce this inefficiency and match the signal timing more closely to the actual traffic patterns.
3.3	**Proposed Improvements to the System**
3.3.0-1	This section describes in broad terms the improvements that are desirable in order to address the limitations described

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	above. The main improvements that are desired are:
3.3.0-2	• Recognize changes in traffic conditions and react quickly and automatically to accommodate those changes.
3.3.0-4	• More efficiently accommodate rail crossing queue dissipation and more quickly recover from emergency vehicle preemption.
3.3.0-5	• Improve the management of queues within the network, especially extended delays on side streets.
3.3.0-6	• Recognize the existence of differing traffic conditions in various parts of the network and react in each section appropriately.
3.3.0-7	• Improve the productivity of staff by automating many of the routine processes.
3.3.0-8	• Keep signal timing current rather than letting its efficiency deteriorate between periodic signal re-timing efforts.
3.4	**Vision, Goals and Objectives for the Proposed System**
3.4.1	**Vision**
3.4.1-1	The vision of the ASCT system is to provide an advanced traffic control system that responds to changing traffic conditions, and reduces delays and corridor travel times or increases throughput, while still accommodating pedestrian needs.
3.4.2	**Goals**
3.4.2-1	The goals of the ASCT system are:
3.4.2-1.0-1	• Support vehicle, pedestrian and transit traffic mobility.
3.4.2-1.0-2	• Provide measurable improvements in personal mobility

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3.4.2-1.0-3	• Support interoperability between agencies
3.4.2-1.0-4	• Support regional systems
3.4.2-1.0-5	• Support congestion and environment policy objectives
3.4.2-1.0-6	• Meet a timely project implementation schedule
3.4.3	**User Objectives**
3.4.3.0-1	The objectives of the adaptive system that support the stated goals are:
3.4.3.0-1.0-1	To support vehicle, pedestrian and transit traffic mobility: • Allow effective use of all controller features currently in use or proposed to be used • Minimize adverse effects caused by preemption and unexpected events
3.4.3.0-1.0-2	To support measurable improvements in personal mobility: • Adjust operations to changing conditions • Reduce delays • Reduce travel times • Provide the same level of safety provided by the existing system to vehicles, pedestrians and transit.
3.4.3.0-1.0-3	To support agency interoperability: • Adhere to applicable traffic signal and ITS design standards
3.4.3.0-1.0-4	To support regional systems: • Be compliant with the regional ITS architecture
3.4.3.0-1.0-5	To support environmental objectives:

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	• Reduce vehicle emissions through improvements in appropriate determinants such as vehicle stops and delays
3.4.4	**Operational Objectives**
3.4.4.0-1	The operational objectives of the ASCT system will be to:
3.4.4.0-1.0-1	Smooth the flow of traffic along coordinated routes during nonpeak periods
3.4.4.0-1.0-2	Maximize the throughput of traffic along coordinated routes during peak periods
3.4.4.0-1.0-3	Equitably serve adjacent land uses during nonpeak periods.
3.4.4.0-1.0-4	Manage queues, to prevent excessive queuing from reducing efficiency
3.5	**Strategies to be Applied by the Improved System**
3.5.0-1	The adaptive coordination and control strategies that may be employed to achieve the operational objectives are:
3.5.0-1.0-1	• Provide a pipeline along a coordinated route to maximize the throughput during periods of high demand;
3.5.0-1.0-2	• Provide a pipeline along a coordinated route to smooth the flow of traffic in one or both directions;
3.5.0-1.0-3	• Distribute phase times in a way that equitably shares the green time between various movements and minimizes the risk of phase failures;
3.5.0-1.0-4	• Manage queues so they do not exceed the available storage capacity and are located so they do not affect the capacity of other movements;
3.5.0-1.0-6	• Employ a combination of these strategies when they are compatible.
3.6	**Alternative Non-Adaptive Strategies Considered**

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3.6.1	**Traffic Responsive Pattern Selection**
3.6.1.0-1	TRPS has been operated in the past. It has been not been successful due to detection issues.
3.6.1.0-2	Could TRPS operation be used? TRPS would be able to adjust to weekly fluctuations in traffic through extensive timing plan options and could be retained as an element of ASCT. However, TRPS lacks the ability to re-allocate green time and optimize progression along the corridor.
3.6.1.0-3	How successful would TRPS be if it were used? TRPS would not be as successful as ASCT since it would not react quickly enough for EVP events and fluctuations in traffic due to incidents along parallel corridors that create congestion in the project corridor.
3.6.2	**Complex Coordination Features**
3.6.2.0-1	The following features are currently used in coordination patterns. These features will need to remain available in fallback operation should the ASCT fail. • Omit phase under some circumstances • Detector switching • Coordinate beginning or end of green • Early release of hold • Stop-in-walk • Half cycle
3.6.2.0-2	The following features have not been used in the current coordination patterns. While they have been considered, they are not suitable in this situation for the following reasons. • Multiple (repeat) phases or phase reservice: This would improve operations during typical peak periods when arrivals are consistent and predictable. Could be harmful in other scenarios unless the phase sequence could be dynamically changed by ASCT. • Variable phase sequence: This would improve operations during typical peak periods when arrivals are consistent and

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	predictable but this function is currently restricted by controller limitations. Could be harmful in other scenarios unless the phase sequence could be dynamically changed. • Coordinate different phases at different times: This would improve operations during typical peak periods when the fluctuations are fairly small and predictable. Side street movements are not the major movements at any of the intersections within the corridor except for IL 176 and IL 137. • Coordinate turning movement phases: Turning movements are not the major movements at any of the intersections within the corridor, only at the northern terminus. • Hold the position of uncoordinated phases: This would improve operations during typical peak periods when the fluctuations are fairly small and predictable. However, it would not have a major benefit for quick changes in traffic demand due to incidents, events or EVP. This function could also have adverse effects on mainline traffic flow. • Late phase introduction: This function would not present a significant benefit to mainline traffic and could lead to split failures in certain situations. • Dynamic max: This function is not supported for coordinated signals.

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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	**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	2.2.0-2 (Sequence-based only) The ASCT shall select cycle length based on a time of day schedule.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.	3.4 3.5

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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). 2.2.0-5.0-1 (Sequence-based only) The ASCT shall limit cycle lengths to user-specified values. 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	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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 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.) 2.2.0-5.0-2 (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.	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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	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. 2.1.1.0-7.0-4 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	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		green). 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. 2.2.0-5.0-1 (Sequence-based only) The ASCT shall limit cycle	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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. 2.1.1.0-10 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	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. 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 each signal controller to suit the current coordination strategy. 2.2.0-5.0-3	3.4 3.5

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		(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). 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 current coordination strategy at the critical signal controller. (A critical signal controller is defined by the user.) 2.3.0-4	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		(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.)	
		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.	

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		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. 2.1.1.0-8 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.	
4.1.0-1.0-4	• Manage the lengths of queues	2.1.3.0-2 When queues are detected at user-specified	3.4 3.5

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		locations, the ASCT shall execute user-specified timing plan/operational mode. 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. 2.1.1.0-7.0-2 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).	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	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. 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	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	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. 2.2.0-5.0-1 (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. 2.1.1.0-10 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 locations.	

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		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	2.1.3.0-2 When queues are detected at user-specified locations, the ASCT shall execute user-specified timing plan/operational mode. 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 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.	3.4 3.5

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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 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.	3.4 3.5

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		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. 2.1.1.0-8 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.	
4.1.0-3	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	3.4 3.5

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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 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	2.1.3.0-2 When queues are detected at user-specified	3.4

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
	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. An overall queue management strategy, particularly when congestion is present, is covered under 4.1.0-1.0-5.	locations, the ASCT shall execute user-specified timing plan/operational mode. 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. 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.	3.5
4.1.0-5	The system operator needs to minimize the chance that	2.3.0-5	3.4

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
	a queue forms at a specified location.	(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. 2.2.0-5.0-5 (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.	3.5
4.1.0-6	The system operator needs to modify the sequence of phases to support the various operational strategies.	7.0-6 The ASCT shall provide a minimum of 16 different user-defined phase sequences for each signal. 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	3.4 3.5

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		based on an external input. 7.0-9 The ASCT shall not prevent any phases to be designated as coordinated 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. 2.1.1.0-11.0-4 The ASCT shall store 30 user-defined coordination routes. 2.1.1.0-11.0-4.0-1 The ASCT shall implement a stored coordinated route by operator command.	3.4 3.5

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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	**Network characteristics**		4.1
4.2.0-1	The system operator needs to eventually adaptively control up to 30 signals, up to four and a quarter miles from the TMC.	1.0-1 The ASCT shall control a minimum of 30 signals concurrently	4.1
4.2.0-2	The system operator needs to be able to adaptively control up to 15 independent groups of signals	1.0-2 The ASCT shall support groups of signals. 1.0-2.0-2 The ASCT shall control a minimum of 15 groups of signals. 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 defined by the user.	4.1

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
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 The size of a group shall range from 1 to 30 signals. 1.0-2.0-5.0-2 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.) 1.0-2.0-5 The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the ASCT system according to configured parameters. 1.0-2.0-5.0-3 The boundaries surrounding signal controllers that operate in a coordinated fashion shall be altered by the system when commanded by the user.	4.1
4.3	**Coordination across boundaries**		4.2 4.3
4.3.0-1	The system operator needs to adaptively control signals operated by LCDOT, IDOT and the municipal partners of the PASSAGE system.	3.0-1 The ASCT shall not prevent monitoring and manual override control from the CENTRACS traffic control software portion of the PASSAGE system.	4.2 4.3

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
4.3.0-2	The system operator needs to acquire and process detector volume and occupancy data through the CENTRACS traffic control software portion of the PASSAGE system.	3.0-1 The ASCT shall not prevent monitoring and manual override control from the CENTRACS traffic control software portion of the PASSAGE system. 3.0-1.0-1 The ASCT shall send operational data to the CENTRACS traffic control software portion of the PASSAGE system. 3.0-1.0-2 The ASCT shall send control data to the CENTRACS traffic control software portion of the PASSAGE system. 3.0-1.0-4 The ASCT shall send coordination data to the CENTRACS traffic control software portion of the PASSAGE system.	4.2 4.3
4.3.0-3	The system operator needs to adaptively coordinate signals on two crossing routes simultaneously.	4.0-1.0-4 The ASCT shall support adaptive coordination on crossing routes.	4.2 4.3
4.4	**Security**		4.3.4
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	5.0-1 The ASCT shall be implemented with a security policy that addresses the following selected elements:	4.3.4

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
	conform to the agency's access and network infrastructure security policies.	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	

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		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 5.0-1.0-20 • Database 5.0-1.0-21 • Signal controller 5.0-3 The ASCT shall comply with the agency's security policy as described in the Lake County Security Policy.	
4.5	**Queuing interactions**		4.4

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
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 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
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 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
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.	4.4

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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 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	4.4

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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 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	**Pedestrians**		4.5
4.6.0-2	The system operator needs to accommodate infrequent pedestrian operation while maintaining adaptive operation. (This is appropriate for pedestrian calls that are common but not so frequent that they drive the operational needs.)	8.0-2 When a pedestrian phase is called, the ASCT shall accommodate pedestrian crossing times during adaptive operations.	4.5

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4.6.0-3	The system operator needs to incorporate frequent pedestrian operation into routine adaptive operation. (This is appropriate when pedestrians are frequent enough that they must be assumed to be present every cycle or nearly every cycle.)	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 adaptive operation.	4.5
4.7	**Non-adaptive situations**		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 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.	4.6

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
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.	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.	4.7
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.	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 more quickly (e.g., three cycles or five minutes) than normal operation, subject to user-specified limits.	4.7
4.9	**Complex coordination and controller**		4.8

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
	features		
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 vehicle phase more than once for each time the coordinated phase is served.	4.8
4.9.0-1.0-2	• Operate at most eight overlap phases	7.0-2 The ASCT shall provide a maximum of eight phase overlaps.	4.8
4.9.0-1.0-3	• Operate four rings, 16 phases and up to three phases per ring.	7.0-3 The ASCT shall accommodate a minimum of eight phases at each signal 7.0-4 The ASCT shall accommodate a minimum of two 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	7.0-6.0-3 Each permissible phase sequence shall be executable based on measured traffic conditions	4.8
4.9.0-1.0-5	• Allow one or more phases to be omitted (disabled)	2.1.2.0-7	4.8

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
	under certain traffic conditions or signal states.	The ASCT shall omit a user-specified phase based on measured traffic conditions.	
4.9.0-1.0-9	• Allow any phase to be designated as the coordinated phase	7.0-9 The ASCT shall not prevent any phases to be designated as coordinated 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 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.	4.8
4.9.0-1.0-12	• Allow the coordinated phase to terminate early under prescribed traffic conditions	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

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
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 beginning of the coordinated phase • The phase is called after its normal start time • The associated pedestrian phase is not called	4.8
4.9.0-1.0-14	• 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.	7.0-11 The ASCT shall not prevent the controller from displaying flashing yellow arrow left 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	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	4.8

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
	crossing signals.)	from the cycles used at adjacent intersections.	
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:	5.0-2 The ASCT shall provide monitoring and control access at the following locations:	4.9
4.10.0-1.0-1	• LCDOT TMC	5.0-2.0-1 • LCDOT TMC	4.9
4.10.0-1.0-4	• IDOT	5.0-2.0-4 • IDOT	4.9
4.10.0-1.0-5	• TS2 cabinets	5.0-2.0-5 • Local controller cabinets	4.9
4.10.0-1.0-7	• Remote locations (web-based)	5.0-2.0-7 • Remote locations via virtual private network	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.	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	**Performance reporting**		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 60 days.	4.10

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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 60 days: • 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: • 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 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.	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
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 60 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 60 days: • 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: • volume • occupancy • queue length	4.10
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 the PASSAGE system.	6.0-2 The ASCT shall export its systems log in the following formats: • MS Excel • Text	4.10

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		• CSV • Open source SQL database 6.0-3 The ASCT shall store the event log for a minimum of 60 days. 6.0-6 The ASCT system shall archive all data automatically after a user-specified period not less than 60 days. 6.0-7 The ASCT shall provide data storage for a system size of 30 signal controllers. The data to be stored shall include the following: • 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 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.	6.0-1 The ASCT shall log the following events: 6.0-1.0-1	4.10

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		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	
4.11.0-7	Have the ability 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 60 days: • volume • occupancy • queue length • phase utilization	4.10

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		• 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 • 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 of 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 alterations directed by the ASCT. 18.0-3.0-4	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		The ASCT shall maintain the records in this ASCT log for 60 day period. 18.0-3.0-5 The ASCT shall archive the ASCT log in the following manner: format: MS Excel, Text, CSV, Open source SQL database, frequency: user definable) 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	**Failure notification**		4.11
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.	4.11

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		(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). 13.2-3 The ASCT shall issue an alarm within 1 minute of detection of a failure.	
4.12.0-2	The system operator needs to immediately and automatically pass alarms and alerts to the PASSAGE system.	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	4.11

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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). 13.2-3 The ASCT shall issue an alarm within 1 minute 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 (13.3-3) 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 (13.3-3) The permanent failure log shall be searchable, archivable and exportable.	4.11
4.13	**Preemption and priority**		4.12
4.13.0-2	The system operator needs to accommodate emergency	11.0-4	4.12

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
	vehicle preemption at all intersections along the corridor within the project limits.	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) 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. 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 transit signal priority.	12.0-1 The ASCT shall continue adaptive operations of a group when one of its signal controllers has a transit	4.12

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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 The ASCT shall delay the end of a green phase, in response to a priority call. 12.0-6 The ASCT shall not preclude adjusting traffic signal operations for TSP. System shall interface with PASSAGE. 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. 12.0-3.0-1 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.	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		12.0-8 The ASCT shall accept a transit priority call from: • a signal controller/transit vehicle detector; • an external system.	
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 two (2) vehicle detectors within a group. 13.1.0-1.0-1 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-	4.13

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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 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.	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		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. 13.1.0-1.0-2 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	**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	14.0-3 The ASCT shall fully satisfy all requirements when connected with Econolite controllers.	4.14
4.15.0-1.0-2	• Detector type	14.0-2	4.14

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		The ASCT shall fully satisfy all requirements when connected with the following detector technologies: • Video detection • Loop detectors • Radar	
4.15.0-1.0-3	• Communication system	Fiber optic	4.14
4.15.0-1.0-4	• Cabinet type and size	• Type IV • Type IV (modified) • Type V	4.14
4.15.0-1.0-5	• Signal management system	CENTRACS	4.14
4.15.0-2	The system operator needs to use equipment and software acceptable under current agency IT policies and procedures.	14.0-1 The vendor's adaptive software shall be fully operational within the following platform: • Windows-PC • Linux	4.14
4.16	**Training and support**		
4.16.0-1	The agency needs 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 24 hours training to a minimum of 15 staff. 15.0-1	

Concept of Operations Reference Number	Concept of Operations Sample Statements	System Requirements	Guidance Section
		The vendor shall provide the following training. 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 at the LCDOT TMC or a location within 15 miles. 15.0-1.0-10 The vendor shall provide a minimum of 2 training sessions.	

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4.16.0-2	The agency needs the system to fulfill all requirements for the life of the system. The agency therefore needs 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 agency needs the system to fulfill all requirements for the life of the system. The agency therefore needs 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 5 years. 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 agency needs the system to fulfill all requirements for the life of the system. The agency therefore needs support to keep software and software environment updated as necessary to prevent requirements no longer being fulfilled.	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. Preservation of requirements fulfillment especially includes all IT management requirements as previously identified.	
4.17	**External interfaces**		
4.18	**Maintenance**		

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4.18.0-1	Each maintaining agency needs all applicable equipment to be readily accessible.		

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5	**Chapter 5: Envisioned Adaptive System Overview**
5.1	**Size and grouping**
5.1.0-1	The agency has plans to adaptively control a total of 30 intersections.
5.1.0-2	The system will control intersections in groups that are defined by the operator.
5.1.0-3	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.
5.1.0-4	During some traffic conditions, there may be separate groups of intersections operating with different characteristics (e.g., different cycle lengths, some coordinated some not, offsets in different directions).
5.1.0-5	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**
5.2.0-1	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.
5.2.0-2	The objective of the coordination will be to maximize the throughput along the coordinated route while minimizing delay on side streets.
5.2.0-4	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 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.

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5.2.0-5	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.
5.2.0-7	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, provided it is safe to do so. This may be accomplished through a time of day schedule or based on the measured traffic conditions.
5.2.0-8	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.
5.2.0-10	At a small group of intersections, with the user defining one as being critical, while the adjacent intersections require a lower cycle length or progression must be provided for specific phases to minimize the formation of queues on the approaches to the critical intersection, the phase lengths of the critical intersection will be determined by the system based on the current traffic conditions. The operation of the adjacent intersections will then be set so that platoons departing the critical intersection are progressed through the non-critical intersections, or platoons arriving at the critical intersection do so at a time when they will have little or no delay waiting for the appropriate phase.
5.3	**Fallback operation**
5.3.0-1	The system will have a fallback state that allows coordination using a common cycle length for all signals within a coordinated group.
5.3.0-2	The system will have a fallback state that allows 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.

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5.3.0-3	The system will have a fallback state that allows one or more intersections to be slaved from a critical intersection in the event of failures of the adaptive processor software or hardware, detectors or communication.
5.4	**Crossing routes and adjacent systems**
5.4.0-1	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.
5.5	**Operator access**
5.5.0-1	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.
5.5.0-3	The system will be connected to the agency's LAN, allowing access to all authorized users.
5.5.0-4	The system will allow access by authorized users outside the agency
5.6	**Complex coordination and controller operation**
5.6.0-1	The agency will use the following complex coordination and controller features:
5.6.0-1.0-1	the ability to repeat a phase, such as running a left turn phase before and after its opposing through movement;
5.6.0-1.0-2	provision for the required number of rings, phases, phases per ring, and overlap phases;
5.6.0-1.0-3	the ability to operate different phase sequences based on different traffic conditions or by time-of-day;
5.6.0-1.0-4	the ability to omit a phase under some traffic conditions or based on external input to allow a shorter cycle length to operate, or to provide additional time to other phases;

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5.6.0-1.0-5	special features unique to this agency, such as:
5.6.0-1.0-5.0-1	the ability to use flashing yellow protected/permissive and permissive only phasing
5.6.0-1.0-6	The agency will permit phases or overlaps by time-of-day schedule or external input.
5.6.0-3	the ability to separately monitor each lane on an approach and take different action depending on the conditions measured in each lane;
5.6.0-4	the ability to allow the coordinated phase to terminate early if the coordinated platoon is short;
5.6.0-5	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;
5.6.0-6	protected/permissive and permissive only phasing
5.6.0-7	support for flashing yellow protected/permissive and permissive only phasing
5.6.0-8	The agency may operate external devices using discrete signal outputs from the ASCT including occupancy on a detector, cycle length, and time-of-day. (User selects desired features.)
6	**Chapter 6: Adaptive Operational Environment**
6.0-1	The system will be operated and monitored from the LCDOT TMC.
	The system will be operated and monitored from IDOT workstations.
6.0-5	The central server equipment will be housed at LCDOT in an air-conditioned environment.
6.0-6	Equipment compatibility constraints

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6.0-6.0-1	The central server will be a standard platform (maintained by the LCDOT TMC) and able to be replaced independently from the software.
6.0-6.0-2	The agency selection of controller will not be constrained by the adaptive software.
6.0-6.0-4	The agency prefers to use the following controller types: Econolite.
6.0-7	The operators will already be experienced in setting up and fine tuning traditional coordinated signal systems. They will require training specific to the adaptive system, sufficient to allow them to set up, adjust and fine tune all aspects of the system.
6.0-8	The set up and fine tuning of the system will be contracted out. A review of the system's operation will be performed quarterly.
6.0-9	Complaints or requests for changes in operation will be handled by the in-house operators on an as-needed basis.
6.0-11	Maintenance of all field equipment will be performed by contract (by others) staff.
6.0-13	Funding for maintenance of the adaptive system will come from the County's capital budget.
6.0-14	Additional communications equipment and annual fees will be incurred with the adaptive system.
6.0-15	Replacement or repair of defective or failed equipment will be covered for 5 years by the manufacturers' warranties. The labor cost of replacement during this period will be included in the purchase price.
6.0-16	The agency expects maintenance of parts and equipment for a period of 5 years will be included in the purchase price.
6.0-17	The agency expects maintenance of all adaptive system software for a period of 5 years will be included in the purchase price.
6.0-18	The agency expects to operate this system using the latest software for a period of 5 years.

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6.0-19	The agency will seek technical support from the vendor for assistance in using the adaptive software for 5 years.
6.0-20	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.
6.0-21	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.
6.0-21.0-1	The agency's experienced operators will be able to write customized routines using the ASCT's API (application program interface).
6.0-21.0-2	The vendor will be able to provide customized routines that take advantage of the ASCT's API.
7	**Chapter 7: Adaptive Support Environment**
7.1	**Institutions and Stakeholders**
7.1.0-1	Existing stakeholders of the traffic signal system include: • Lake County Division of Transportation • FHWA • Illinois Department of Transportation (District One Bureau of Traffic Operations and Bureau of Local Roads) • Illinois Tollway • Libertyville Fire Department • Mundelein Fire Department • Country Side Fire Department • Lake County Sheriff’s Department • Libertyville Police Department • Mundelein Police Department

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	• Vernon Hills Police Department • PACE • METRA • Village of Mundelein • Village of Vernon Hills • Village of Libertyville • Traveling public
7.1.0-2	The stakeholders who will be affected by or have a direct interest in the adaptive system are: LCDOT, IDOT, and the traveling public.
7.1.0-3	The activities that will be undertaken by the adaptive system stakeholders include: preparation of timing parameters, implementation and fine tuning, system monitoring and adjustment, system performance monitoring and evaluation.
7.2	**Facilities**
7.2.0-1	ASCT communications will be provided to the LCDOT TMC, located at 600 W Winchester Road in Libertyville, IL.
7.2.0-4	Air-conditioning is provided at the LCDOT TMC.
7.2.0-6	LCDOT is responsible for providing and maintaining staff facilities (e.g., personnel, public works, building services, etc.).
7.2.0-7	Lake County DOT Facilities is responsible for fire control facilities at the LCDOT TMC.
7.2.0-8	LCDOT is responsible for secure access to the LCDOT TMC that houses the adaptive system workstations.
7.3	**System Architecture Constraints**
7.3.0-1	The adaptive processor/server will be protected within the agency's firewalls. The IT Department will provide resources, equipment and system management so that operators will have appropriate access to the system locally, from within the

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	agency's LAN and from remote locations.
7.3.0-2	The communications media available for use by the system will consist of single mode fiber optic cable and Cisco switches on the PASSAGE network.
7.3.0-3	The Regional ITS Architecture is housed at http://data.cmap.illinois.gov/ITS/default.aspx. The adaptive system will operate within the local ITS Architecture of LCDOT. It will interact with the Regional ITS Architecture as shown in Figure 5Figure 5.

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	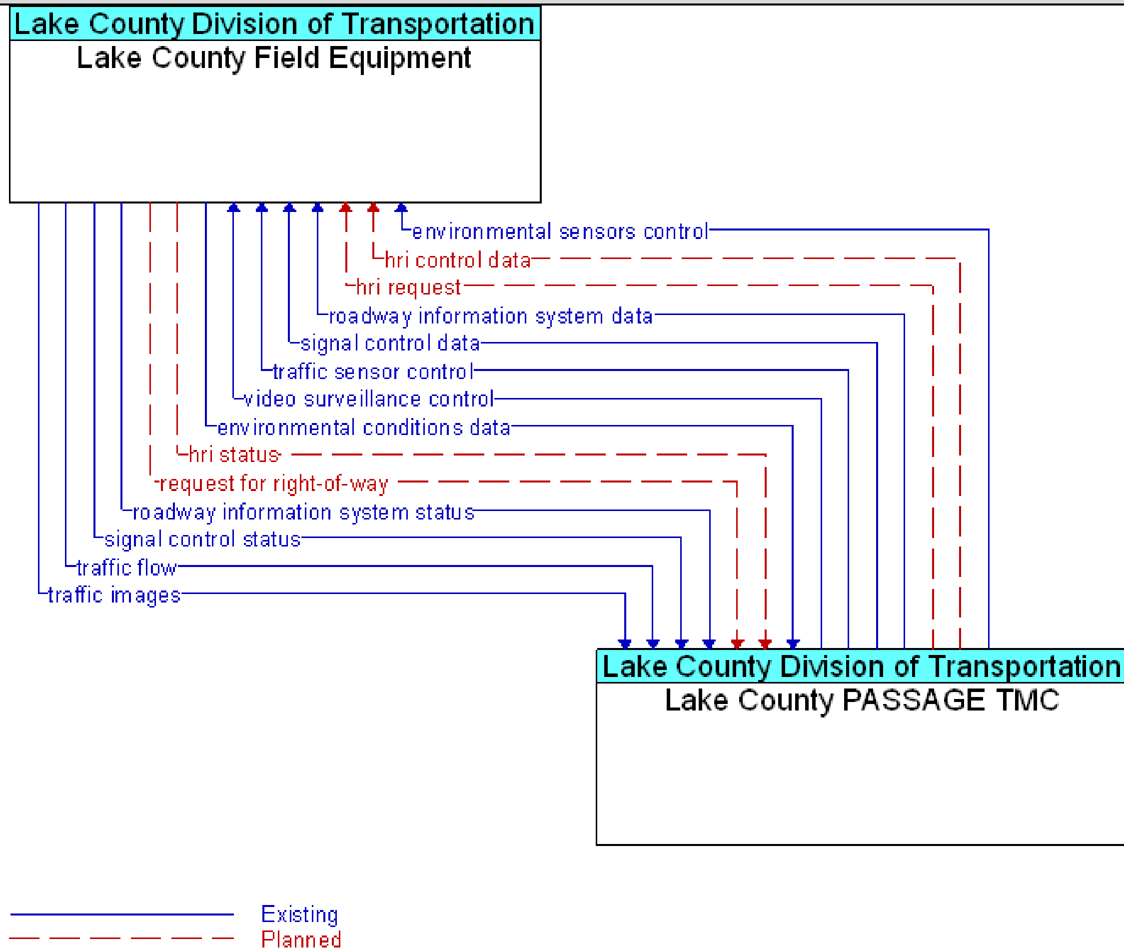 **Figure 5 - Regional ITS Architecture Interconnect Diagram**

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7.4	**Utilities**
7.4.0-1	Utilities to the LCDOT TMC are the responsibility of the LCDOT Facilities group.
7.5	**Equipment**
7.5.0-1	No test equipment, outside of the equipment needed for ASCT operation, will be needed.
7.7	**Software**
7.7.0-1	LCDOT is responsible for keeping software up to date.
7.7.0-2	LCDOT is responsible for keeping software licenses current.
7.7.0-3	Lake County Information Technology (IT) and TMC policies govern the software on LCDOT TMC workstations.
7.8	**Personnel**
7.8.0-1	Existing staff will be responsible for operation of the ASCT system.
7.8.0-2	LCDOT operators will be available from Monday through Friday from 6 am – 7 pm.
7.8.0-3	Operator training will be provided based on the ASCT system installed.
7.8.0-4	Maintenance will be provided by existing staff with LCDOT’s electrical maintenance contractor.
7.8.0-5	System maintenance staff will be required to successfully complete ASCT training modules.
7.9	**Operating procedures**

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7.9.0-1	LCDOT staff at the TMC will be responsible for backing up databases. Off-site backups will be required on a nightly basis.
7.10	**Maintenance**
7.10.0-1	System maintenance will be contracted out to LCDOT's electrical maintenance contractor.
7.11	**Disposal**
7.11.0-2	System components will be disposed of at the end of their useful life in accordance with applicable laws.
8	**Chapter 8: Operational Scenarios**
8.1	**Overview**
8.1.0-1	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 • Moderate unbalanced flows • Light balanced flows • Demand affecting event • Capacity affecting event • Fault conditions (communications, detection, adaptive processor) • Signal preemption • Pedestrians • Installation

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8.2	8.2 Typical Heavy (congested) Traffic
8.2.3	**Example: Arterial with several critical intersections**
8.2.3.1	**Road network**
8.2.3.1.0-1	The section of Butterfield Road to be coordinated using ASCT has eight signalized intersections. It is a four lane arterial road, with exclusive left turn lanes at each intersection and exclusive right turn lanes at some intersections. Two intersections, IL 137 and IL 176 are arterial roads that accommodate regional traffic rather than just providing local access. There is one signalized intersection 1000 feet to the east of IL 137 & Butterfield Road that is to be included in the ASCT system. This intersection provides access to a strip mall. Most intersections are eight-phase intersections with protected left turns on all approaches. The remaining intersections provide access to local businesses and residential areas. Those intersections have protected or protected/permitted left turns on Butterfield Road and permissive left turns on the side streets. Butterfield Road is classified by the MPO as a minor arterial road.
8.2.3.3	**Operational objectives**
8.2.3.3.0-1	The operational objectives for this arterial under these conditions are to: • Smooth the flow of traffic along coordinated routes during nonpeak periods; • Maximize the throughput of traffic along coordinated routes during peak periods; • Equitably serve adjacent land uses during nonpeak periods; and • Manage queues, to prevent excessive queuing from reducing efficiency.
8.2.3.4	**Coordination and signal timing strategies**
8.2.3.4.0-1	The signal timing strategies used by the system to accommodate this situation are:

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	• Determine the critical intersection • At the critical intersection, select phase times that eliminate phase failures • At the critical intersection, select phase sequence that eliminates queue overflow in left turn bays • At the critical intersection, distribute green time to maximize the throughput on Butterfield Road. • At the non-critical intersections, provide sufficient time to serve all turning and side street traffic without phase failures • At the non-critical intersections, provide green on the arterial road phases in a manner that minimizes the stops for through traffic along the arterial.
8.2.3.5	**Summary of operation**
8.2.3.5.0-1	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. The green time for the non-arterial phases at those intersections will be set to accommodate the traffic using those phases, while allocating the remaining time to the arterial road. The system will determine the sequence of phases on the arterial (lead-lead, lead-lag or lag-lag) that minimizes the stops in the non-coordinated direction under these conditions.
8.2.4	8.2.4 Example: Crossing arterials
8.2.4.2	8.2.4.2 Traffic conditions
8.2.4.2.0-1	During heavy traffic conditions (such as AM and PM peak) the Butterfield Road/Cross Street intersections is the critical intersection, and queues develop on all approaches. Typically, the northbound direction on Butterfield Road is significantly heavier than the southbound. Likewise, the eastbound traffic on Cross Street is significantly heavier that the westbound.
8.2.4.3	8.2.4.3 Operational objectives

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8.2.4.3.0-1	The operational objectives for these arterials under these conditions are to: • Maximize the throughput along Butterfield Road • Maximize the throughput along Cross Street • Accommodate the traffic at the critical intersection with a minimum of phase failures; and • Provide smooth flow along the arterial through other intersections.
8.2.4.4	8.2.4.4 Coordination and signal timing strategies
8.2.4.4.0-1	The signal timing strategies used by the system to accommodate this situation are: • At the critical intersection, select phase times that eliminate phase failures • At the critical intersection, select phase sequence that eliminates queue overflow in left turn bays • At the non-critical intersections on both arterials, provide sufficient time to serve all turning and side street traffic without phase failures • At the non-critical intersections, provide green on the arterial road phases in a manner that minimizes the stops for through traffic along the arterial.
8.4	**Moderate balanced flows**
8.4.1	**Arterial road with irregular spacing**
8.4.1.1	**Road network**
8.4.1.1.0-1	This project corridor includes nine (9) traffic signals and one railroad crossing, spanning through the Village of Libertyville, Village of Vernon Hills, and the Village of Mundelein. The traffic signals are interconnected with fiber optic communications and operate in a coordinated manner with a 140 second cycle length during the AM and PM peak periods and a 100 second cycle length during the midday peak. Most intersections are eight-phase intersections with protected or protected/permitted left turns on all approaches. The

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	remaining intersections provide access to local businesses and residential areas. Those intersections have protected left turns on Butterfield Road and permissive left turns on the side streets. Butterfield Road is a four lane divided minor arterial with a 40 mph posted speed limit. The average annual daily traffic (AADT) on Butterfield Road ranges from 17,900 vehicles per day (vpd) at the IL 137/Peterson Road intersection to 21,100 vehicle per day near the IL 176 intersection.
8.4.1.2	**Traffic conditions**
8.4.1.2.0-1	During business hours traffic is uncongested and the flows along Butterfield Road are similar in both directions. There is enough side street and turning movement traffic that most signal phases are called every cycle. The left turn volumes are sufficiently high that they need protected turn phases to provide sufficiently capacity and prevent phase failures.
8.4.1.3	**Operational objectives**
8.4.1.3.0-1	The operational objectives for this condition are to: • Smooth the flow of traffic along coordinated routes during nonpeak periods; • Maximize the throughput of traffic along coordinated routes during peak periods; • Equitably serve adjacent land uses during nonpeak periods; and • Manage queues, to prevent excessive queuing from reducing efficiency.
8.4.1.4	**Coordination and signal timing strategies**
8.4.1.4.0-1	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 of 80 seconds. 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

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	• At the specified intersection, select phase times that will accommodate frequent use of all pedestrian phases. • At other intersections, select phase times that will accommodate occasional use of pedestrian phases.
8.4.1.5	**Summary of Operation**
8.4.1.5.0-1	The critical intersection will determine the minimum cycle length that can be used for the entire group. This cycle length will accommodate all phases and all pedestrian movements. It 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 pedestrians and vehicles, and all spare time will 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 on Butterfield Road.
8.6	**Demand affecting event**
8.6.1	**High travel day (e.g., Mothers' Day, Super Bowl)**
8.6.1.0-1	During periods of major activity within or close to the ASCT's area of operation, the traffic characteristics are often similar to the 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.
8.7	**Capacity affecting event**

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8.7.1	**Weather event**
8.7.1.0-1	Adverse weather can often lead to disruptions in traffic capacity; flooding and wind-blown tree branches can block lanes or entire roadways and rain and ice can reduce speeds, leading to lower throughput and higher variability of traffic. As traffic volumes and speeds decrease, the system could adjust cycle and phase lengths to provide more time for vehicles to make their way through intersections in the corridor. The system will recognize the effects of a weather event and modify the signal operation to react to the changed traffic conditions in an efficient manner.
8.7.2	**Incident within the system (construction, maintenance, fire)**
8.7.2.0-1	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. In such a situation, 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. 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.

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8.8	**Fault Conditions**
8.8.1	**Communications Fault Condition**
8.8.1-1	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**
8.8.2.0-1	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, minimum, 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 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**
8.9.3	8.9.3 Bus Signal Priority
8.9.3.1	8.9.3.1 EXAMPLE BUS PRIORITY SCENARIO
8.9.3.1.0-1	Bus priority will be provided at each intersection on a bus route. The input requesting priority will come from the centralized priority system. The system will have the capability to extend the existing green if that will serve the bus, introduce an early green by

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	shortening or skipping other phases, or run a phase called exclusively by the bus. The decision to provide priority will be determined within the local controller, based on user-definable and settable rules. These rules will include such items as: length of time or number of cycles since last priority was provided, and priority level if there are competing requests. The bus system has its own logic to determine whether a priority request for an approaching bus will be transmitted to the signal controller, based on such parameters as schedule adherence, route number, in-service or out-of-service and passenger loading. This logic will not reside within the adaptive system.
8.9.4	**Emergency Vehicle Preemption**
8.9.4.0-1	When an intersection responds to an EV 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**
8.10.0-1	The system will recognize the increasing traffic as patrons arrive for the event and adopt an appropriate mode of operation. During the 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.
8.11	**Pedestrians**
8.11.0-1	Pedestrian crossing times must be accommodated. At locations with wide pedestrian crosswalks and a history of conflicts between turning vehicles and pedestrians, the pedestrian walk is displayed some seconds before the compatible vehicle green. At crosswalks with high pedestrian volumes, a pedestrian recall is used during the periods when the pedestrian volumes are high. Pedestrian recall is used for pedestrian phases that are adjacent to the coordinated movements. During periods when pedestrian volumes are high and queuing of the conflicting right turn movement becomes unacceptable, the vehicles are directed elsewhere by prohibiting the movement (such as by operating a No Right Turn

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	sign). 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**
8.12.0-1	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.