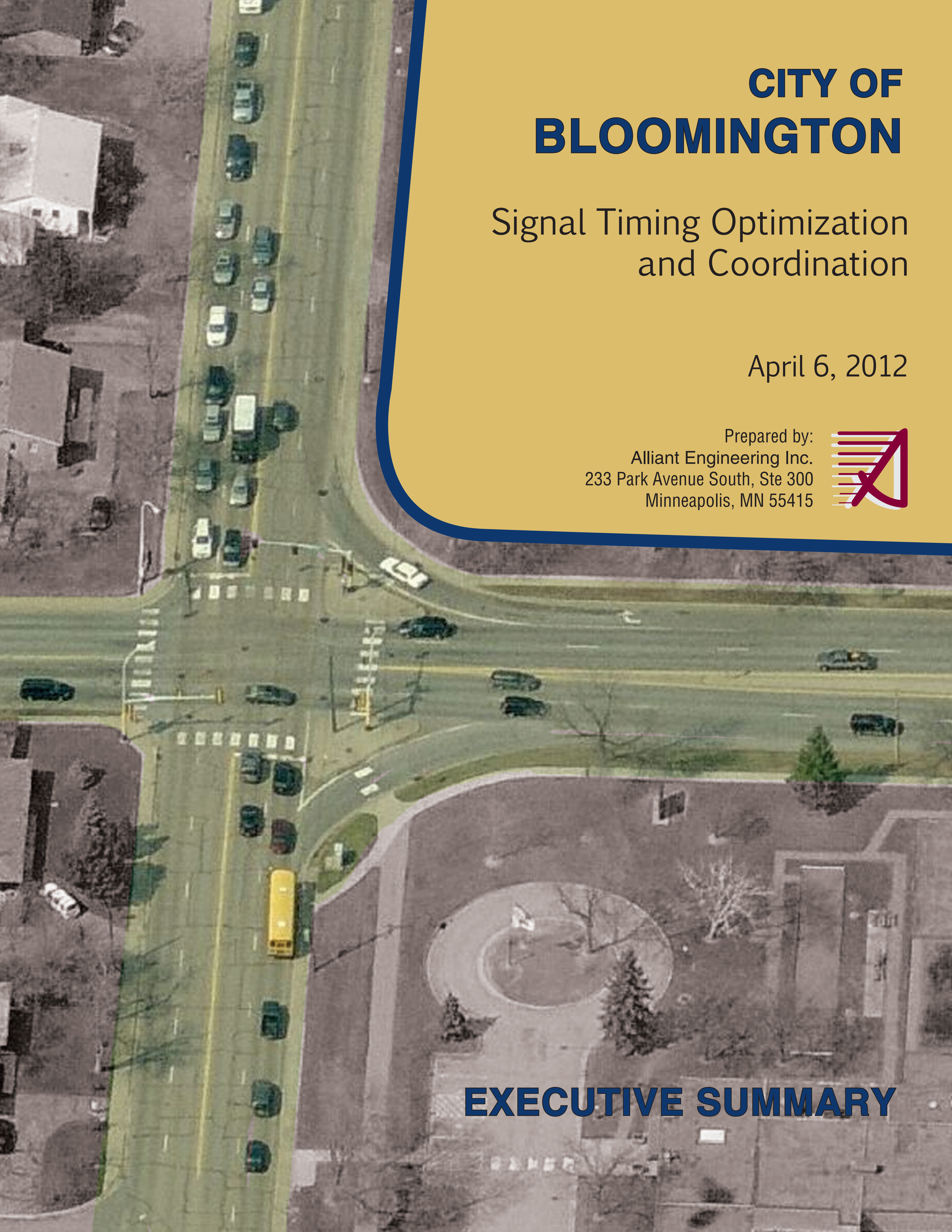

CITY OF BLOOMINGTON

Signal Timing Optimization and Coordination

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EXECUTIVE SUMMARY

Executive Summary

There are 149 traffic signals within the City of Bloomington. Many of these signals are operated by either Hennepin County or Minnesota Department of Transportation (Mn/DOT). The City of Bloomington operates 63 of these signals, including seven owned by the Metropolitan Airports Commission. The City has identified a need to improve the intersection signal operation efficiency and to determine the necessary actions required to implement optimized signal coordination where appropriate.

The City of Bloomington received federal money awarded through the Energy Efficiency and Conservation Block Grant Program (EECBG) as part of the American Recovery and Reinvestment Act of 2009. The Bloomington Signal Timing Optimization and Coordination Project allocated a portion of the project budget towards hardware, controller and communication system investment, which would allow for any signal coordination plans to be implemented. Additional funding for communications equipment and infrastructure was dedicated by the City in order to implement coordinated timing plans in Bloomington's South Loop District.

Project Description and Purpose

The Signal Timing Optimization and Coordination Project included evaluating 61 signalized intersections (including City of Bloomington, Hennepin County and Mn/DOT operated traffic signals). The primary goal of the Signal Timing Optimization and Coordination Project is to reduce average fuel consumption and emissions by improving traffic mobility, decreasing travel times, traffic delays and number of vehicle stops at signalized intersections. The Signal Timing Optimization and Coordination Project consisted of the following major components:

- Collecting traffic data (traffic volume counts and travel time studies).
- Conducting a roadway and signal system inventory and evaluating the existing quality of traffic flow.
- Conducting a signal system hardware and communication components assessment.
- Conducting a coordination feasibility study to determine coordinated zones, operation strategies, communication needs and agency maintenance and operation responsibility (referred to in the following document as indexes).
- Developing a traffic model to support preparing the new signal system timing coordination plans for each corridor.
- Installing new traffic signal controller equipment and communication devices to extent the project budget allows.
- Implementing the new timing plans to the street and fine-tuning them to real traffic conditions to the extent the project budget allows.
- Conducting a "before" and "after" analysis and documenting the project benefits.
- Conducting a comprehensive evaluation of each index and providing the City of Bloomington with low cost intersection improvements to further maximize operational efficiencies.

Elements of Project

An evaluation of the existing condition was completed. Key components of the existing conditions include collection of intersection and traffic volume characteristics, signal timing characteristics, development and calibration of the traffic model and collection/evaluation of current measures of effectiveness. The Synchro7.0 and SimTraffic7.0 models developed in evaluation of the existing conditions were used to conduct the coordination feasibility analysis and to create optimized signal timing plans. A key component of the Signal Timing Optimization and Coordination Project included conducting an existing signal system inventory and preparing a plan denoting the signal equipment and communication upgrades needed to allow for the implementation of traffic signal coordination.

As part of this project, optimized coordinated timing plans were implemented in the Normandale Lakes District, East Bush Lake Road and the Mall of America area. In addition, optimized signal timing parameters were developed for approximately 21 non-coordinated (isolated operation) traffic signals throughout the city. After implementation of the timing plans, Alliant Engineering and Bloomington staff conducted field reviews and fine-tuned the signal coordination plans. A benefit/cost analysis was also completed to evaluate the overall cost-effectiveness of the implemented signal timing plans.

The purpose of this document is to summarize the project process and present the conclusions of the Signal Timing Optimization and Coordination Project as discussed in the following sections:

- Introduction (Section 1.0)
- Existing Conditions (Section 2.0)
- Traffic Signal Assessment (Section 3.0)
- Signal Timing Optimization (Section 4.0)
- Project Benefit Analysis (Section 5.0)
- Potential Improvement Measures (Section 6.0)

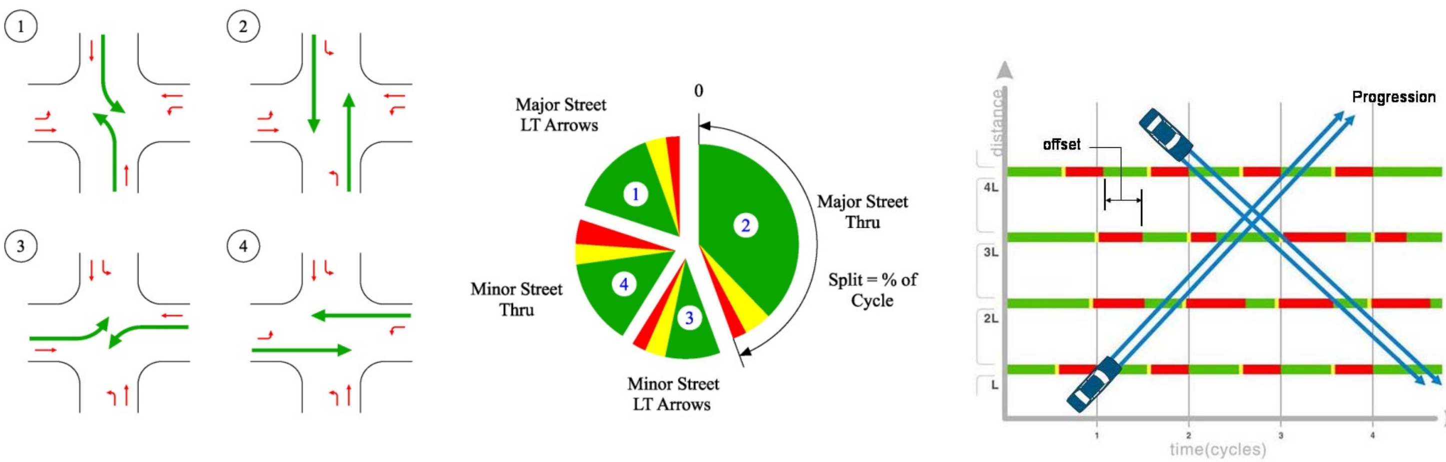
Signal Coordination

Signal coordination is the process to synchronize the start of the “green light” along the major roadway (e.g., northbound/southbound Normandale Boulevard), so that vehicles can travel through a group of signals with minimal or no stopping. There are three key timing parameters to make signal coordination work and are noticeable to the driver. These include the “cycle length”, intersection “offset,” or progression, and the individual traffic movement “green + yellow + red” phase (referred to as a movement “split”).

The cycle length is the total time to complete one sequence of all movements around an intersection. As shown in Figure ES-1, one cycle length is the total time required to complete Interval 1 through Interval 4. The cycle length is the most important parameter. In order for signal coordination to work, all intersections along the arterial must have the same cycle length (or be a multiple of each other). Choosing the optimum cycle length for a system of several intersections is challenging and often requires the use of a traffic modeling software to help balance coordinated traffic flow on the major roadway and minimizing delay on the minor street.

The individual movement (e.g., left turn arrow at Normandale Boulevard/94th Street) split is the sum of the "green time + yellow interval + red clearance interval). The movement split represents a percentage of the total cycle length. The movement splits are timed to clear all waiting motorists on a typical day. However, the total amount of split is constrained by the cycle length and other conflicting movements; therefore need to be balanced by the proportion of traffic volume at the intersection.

The offset, also illustrated in Figure ES-1, is the time between the start of the "green light" at one intersection and the start of "green light" at another intersection. The offset defines the movement of traffic along the arterial, also referred to as "progression." The offset is very important to observe and fine-tune in the field to real traffic speeds and conditions to help reduce stops and slowing.



Cycle Length **Movement Split** **Offset (Progression)**

Figure ES - 1. Key Signal Coordination Parameters

Traffic Signal Assessment

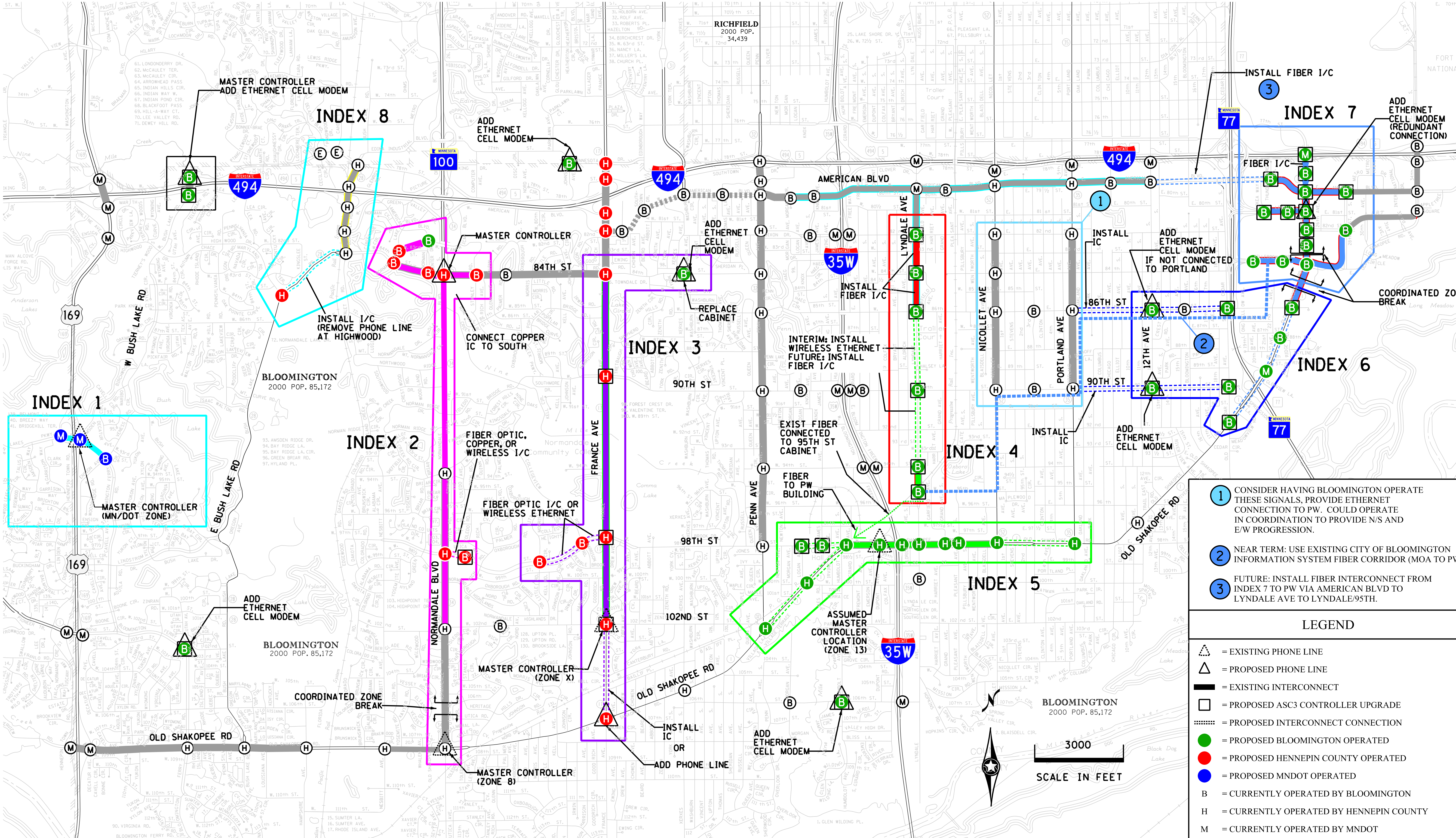
Signal coordination requires synchronized time clocks, communication between intersections and the appropriate infrastructure/hardware to allow the timing plans to efficiently operate. A system-wide planning level analysis was completed to inventory the existing equipment, infrastructure, hardware, and communication devices. To help the City of Bloomington determine the signal equipment needs, a coordination feasibility assessment was also completed. Many scenarios were evaluated to determine the overall most efficient operation for each intersection. The analysis also determined where coordinated zone breaks should be and identified intersections where a jurisdictional change in signal operation responsibility might be advantageous. The analysis identified nine distinct coordination indices. In the following, coordinated traffic signal groupings throughout the city are referred to as an index (e.g., Normandale Lakes District is Index 2 and Mall of America is Index 7). Results of the analysis were used to develop a signal upgrade plan and to begin prioritizing implementation of the plan. In addition, the analysis identified inter-jurisdictional priorities related to maintenance and operations. Key components of the signal plan are illustrated in Figure ES-2.

Through the EECBG, a portion of the Signal Timing Optimization and Coordination Project budget was allocated to implementing components of the signal plan. Preliminary equipment cost and operation user cost benefit estimates were developed to help prioritize implementation of optimized timing under this contract. Based upon the equipment cost, project budget, user benefits and ability to implement within the project timeframe, the signal equipment and communication implementation plan was prioritized. Index 2, 7 and 8 were implemented under the EECBG.

Project Benefit

The primary goal of signal timing is to respond to the demands of all types of motor vehicles, bicycles and pedestrians in an optimum or balanced manner. Although efficient signal coordination will achieve significant benefits, there are some impacts. Traffic flow and delays must be balanced throughout the system; therefore, trade-offs are always required. The biggest impact or trade-off with signal coordination projects is the lower volume cross-street movements could experience a slight increase in wait time. This occurs because:

- **Signal coordination requires that each intersection have the same cycle length or be multiples of the same cycle length.** Typically, there are a few critical intersections that require a particular cycle length to accommodate the traffic and pedestrian demands, while others within the system must then be compatible to allow coordination. This can at times result in a longer wait at certain locations, than would be otherwise expected.
- **A primary goal of signal coordination is to efficiently move the majority vehicles through the system with the fewest stops and reduced travel time.** It would be ideal if every vehicle entering the system could proceed through the system without stopping. This is not possible. Therefore, in traffic signal coordination, the majority rules and the busiest traffic movements are given precedence over the smaller traffic movements. This means that side street traffic often experiences a slightly longer wait time. However, once on the main street, motorists should generally experience better flowing traffic conditions.



Bloomington Signal Timing Optimization and Coordination Project

Figure ES-2

Traffic Signal Upgrade Plan

Alliant Engineering

All things considered, coordinated signal timing is one of the most cost-effective ways to improve traffic flow. This is done by:

- Improving traffic flow through a group or series of traffic signals.
- Reducing the overall delay time at an intersection (Note: does not always equal to an individual motorist's wait time).
- Accommodating for changes in traffic characteristics due to growth or new developments.
- Reducing motorist frustration and wear and tear on vehicles by reducing stops and delay.
- Improving safety by reducing the potential for rear-end crashes.
- Reducing response time for bus service and emergency vehicles.
- Postponing the need for costly road construction by improving traffic flow on the existing facility.

The key is to balance the positive benefits of signal coordination against the impacts. Once the benefits are outweighed, then signal coordination is no longer warranted.

A signal coordination benefit analysis was completed for the Signal Timing Optimization and Coordination Project. The following documents the benefit of the coordination timing plans implemented under the EECBG as part of the Signal Timing Optimization and Coordination Project. A detailed project benefit analysis was completed for only Index 2, Index 7 and Index 8, since these were the highest priority signal upgrades that occurred under the EECBG budget. A benefit/cost analysis was completed to establish the annual economic savings. Typical measures of effectiveness (MOE) used in estimating the benefit of signal optimization projects include approach vehicle delay, vehicle stops and fuel consumption. Table ES-1 illustrates the overall daily and annual "before" and "after" network MOE comparison and percent improvement.

Table ES - 1. Measures of Effectiveness – Network Performance Comparison

Index 2 - Total Network (Daily Summary)

MOE	Weekday				Annual Reduction
	Before	After	Net Reduction	Percent Improvement	
Stops (no. of veh)	173,073	149,534	**23,539**	**13.6%**	**5,908,164**
Delay (hr)	3,168	2,783	**385**	**12.1%**	**96,526**
Fuel Consumption (gal)	6,086	5,811	**275**	**4.5%**	**69,050**

Index 7 - Total Network (Daily Summary)

MOE	Weekday				Saturday/Sunday				Annual Reduction
	Before	After	Net Reduction	Percent Improvement	Before	After	Net Reduction	Percent Improvement	
Stops (no. of veh)	84,796	74,941	**9,855**	**11.6%**	139,847	130,282	**9,565**	**6.8%**	**3,563,952**
Delay (hr)	739	738	**1**	**0.1%**	1,781	1,639	**142**	**8.0%**	**16,417**
Fuel Consumption (gal)	2,290	2,237	**53**	**2.3%**	4,483	4,248	**236**	**5.3%**	**40,062**

Index 8 - Total Network (Daily Summary)

MOE	Weekday				Annual Reduction
	Before	After	Net Reduction	Percent Improvement	
Stops (no. of veh)	24,724	23,019	**1,705**	**6.9%**	**427,955**
Delay (hr)	266	265	**1**	**0.3%**	**194**
Fuel Consumption (gal)	647	633	**14**	**2.2%**	**3,508**

Based on the results, the total estimated annual benefit realized with the implementation of optimized signal coordination plans is estimated at approximately 2.7 million dollars, which includes an estimated annual savings of 112,600 gallons of gasoline. The benefit/cost ratio is computed based on the comparison between the annual net benefit and the total project cost. The estimated total project cost was $214,000 ($200,000 EECBG and $14,000 of city funds) and includes consulting fees, traffic signal assessment study and implementation of signal equipment infrastructure. Of the $214,000, approximately $111,000 is specific to the labor and equipment infrastructure costs required to implement signal coordination within Index 2, Index 7 and Index 8.Tactics operating system software is excluded from the benefit/cost analysis. Table ES-2 documents the estimated benefit/cost ratio under the EECBG contract.

Table ES - 2. Project Benefit to Cost Ratio

Index	Number of Intersections	Equpment Cost ($)	Labor Cost ($)	Cost / Zone ($)	Benefit ($)	Benefit-Cost Ratio
INDEX 2	9	$ 18,300.00	$ 15,561.31	$33,861	$2,004,294	**59**
INDEX 7	10	$ 55,239.00	$ 17,290.35	$72,529	$652,763	**9**
INDEX 8	3	$ -	$ 5,187.10	$5,187	$33,625	**6**
Total Project Implemented Under EECBG	**22**	**$ 73,539.00**	**$38,038.76**	**$111,578**	**$2,690,682**	**24**

As shown, the Signal Timing Optimization and Coordination Project experienced a benefit/cost ratio of approximately 24:1 when considering only one year of benefit and the upfront signal equipment infrastructure investment.

Potential Improvement Measures

As part of the Signal Timing Optimization and Coordination Project an operation review of each of the project intersections was completed. During the field implementation and signal timing review process, low cost signal operation and geometric improvements that enhance intersection efficiency were identified for future review and/or possible future implementation.

Table ES-3 documents potential signal operation and geometric improvement measures for the key project intersections.

Table ES - 3. Intersection Improvement Measures

	Int. ID	Intersection	Responsible Agency	Traffic Management	Operation Improvement (s)
Index 0	28	Minnesota Drive and Johnson Avenue	Bloomington		Re-stripe Westbound Approach to provide 1-LT, 1-TH, 1-RT Modify Signal Phasing to include: Phase 2 and 6 (EB/WB) Permissive, Phase 7 (SB LT) Prot/Perm, Phase 4 (SB) and Phase 8 (NB). Standard Ring/Barrier Configuration. Operate Phase 4 and 7 on Min Recall
	29	Bloomington Ferry Rd and Ensign Avenue	Bloomington		Convert Phase 1 and Phase 5 (EB/WB) left turns to Protected/Permissive Operation
	30	Bloomington Ferry Rd and 102nd Avenue	Bloomington		
	31	106th Street and Humboldt Avenue	Bloomington		Omit Phase 2 (EB/WB Arrows)
	32	Bush Lake Rd and 78th Street	Bloomington		Convert Phase 1 (WB) left turns to Protected/Permissive Operation
	33	Bush Lake Rd and Marth Rd	Bloomington		Repair or install Phase 4 stop bar loop detection, operate on lock and remove MAX Initial timing.
Index 2	6	American Boulevard and Norman Center Drive	Bloomington	See Future Signal Plan	
	7	Normandale Lake Boulevard and 83rd Street	Bloomington		
	8	84th Street and Normandale Lake Boulevard	Bloomington		
	9	84th Street and Norman Center Drive	Bloomington		
	10	CSAH 34 and 84th Street	Hennepin County		Consider long term intersection geometric/capacity needs (future intersection study)
	11	84th Street and Stanley Avenue	Bloomington		
	14	98th Street and Toledo Avenue	Bloomington		Convert EB/WB left turns to protected/permissive operation.
	72	CSAH 34 and Old Shakopee Rd	Hennepin County		
	70	CSAH 34 and 94th Street	Hennepin County		Convert EB/WB left turns to protected/permissive operation. Lengthen SB Left Turn Lane
	52	CSAH 34 and 98th Street	Hennepin County		Convert EB/WB left turns to protected/permissive operation. Lengthen SB Left Turn Lane
	71	CSAH 34 and 102nd Street	Hennepin County		Construct exclusive WB right turn lane
Index 3	15	98th Street and Little Avenue	Bloomington	See Future Signal Plan	
	16	98th Street and Collegeview Rd	Bloomington		Convert Phase 1 and Phase 5 (EB/WB) left turns to Protected/Permissive Operation Convert Phase 3 and Phase 4 (NB/SB) to Phase 4 and Phase 8 Permissive Only Operation
	17	CSAH 17 and 98th Street	Hennepin County		Install Stop Bar Loop Detection or Video Detection Convert Phase 3 and Phase 7 (EB/WB) left turns to Protected/Permissive Operation
	18	CSAH 17 and 102nd Street	Hennepin County		
	19	CSAH 1 and CSAH 17	Hennepin County		
	23	84th Street and Xerxes Avenue	Bloomington		Replace Cabinet and Control Equipment; Or Remove Signal and Install a Permanent Pedestrian Only Signal
	36	CSAH 17 AND 90th Street	Hennepin County		Convert Phase 3 and Phase 7 (EB/WB) left turns to Protected/Permissive Operation

Table ES - 3. Intersection Improvement Measures Cont'd

	Int. ID	Intersection	Responsible Agency	Traffic Management	Operation Improvement (s)
	1	Lyndale Avenue and Lyndale Circle	Bloomington		Convert Phase 1 and Phase 5 (NB/SB) left turns to Protected/Permissive Operation
	2	Lyndale Avenue and 86th Street	Bloomington		Convert Phase 1, 3, 5 and Phase 7 (NB/EB/SB/WB) left turns to Protected/Permissive Operation
Index 4	3	Lyndale Avenue and 90th Street	Bloomington	See Future Signal Plan	Convert Phase 1, 3, 5 and Phase 7 (NB/EB/SB/WB) left turns to Protected/Permissive Operation
	4	Lyndale Avenue and 94th Street	Bloomington		Convert Phase 1 and Phase 5 (NB/SB) left turns to Protected/Permissive Operation
	5	Lyndale Avenue and 95th Street	Bloomington		Convert Phase 1 and Phase 5 (NB/SB) left turns to Protected/Permissive Operation
	12	98th Street and Logan Avenue	Bloomington		
Index 5	13	98th Street and James Avenue	Bloomington	See Future Signal Plan	Convert Phase 1 and 5 (EB/WB) left turns to Permissive Only or Protected/Permissive Operation; Convert NB/SB to Phase 4 and 8 Permissive Only Operation Upgrade Controller to ASC3 and Program Leading Pedestrian Interval (Phase 4 and Phase 8)
	20	CSAH 1 and CSAH 32	Hennepin County		
	21	CSAH 1 and Logan Avenue	Hennepin County		
	35	CSAH 1 and CSAH 35	Hennepin County		
	22	CSAH 1 and Old Cedar Avenue	Bloomington		Split SB loop detectors. (abandon SB right turn lane detectors or install 12s delay)
	24	Old Cedar Avenue and 86th Street	Bloomington		Convert Phase 1 and Phase 5 (EB/WB) left turns to Protected/Permissive Operation Split Phase 8 loop detection (Left lane use 3s delay, Right lane use 8s delay) Restripe the NB approach to include 1-Left turn only lane, 1-shared throught/right turn lane
Index 6	25	Old Cedar Avenue and 90th Street	Bloomington	See Future Signal Plan	Install secondary EB Left Lane detector (set 5 feet behind walk). Operate Left lane with 3s delay and Right Lane with 12s delay
	26	86th Street and 12th Avenue	Bloomington		
	27	90th Street and 12th Avenue	Bloomington		Split the NB/SB detectors. Operate stop bar only. Program 3s delay on Left Lane and 12s delay on RL
	43	CSAH 1 and 86th Street	Bloomington		
	49	CSAH 1 at TH 77 N. Ramp	Mn/DOT		
	37	American Boulevard and Thunderbird Avenue	Bloomington		
	38	American Boulevard and 28th Avenue	Bloomington		Convert to 8 phase operation (long term). Short term, convert NB/SB to permissive only, block off inside left turn lane (WB) and convert EB/WB to protected/permissive
	39	CSAH 1 and American Boulevard	Bloomington	1. Develop specific timing plans that correspond with each pre-defined stage of MOA parking access closure. 2. Develop coordination / communication protocal with MOA to correlate timing plan change with access closure plan.	
	40	CSAH 1 and Lindau Lane	Bloomington		
Index 7	41	CSAH 1 and 82nd Street	Bloomington		Install stop bar loop detection (Phase 8) remove from detector lock operation.
	42	CSAH 1 and MOA Transit Station	Bloomington		
	44	Lindau Lane and Ikea Way	Bloomington		Install advance loop detector for NB left turn lane (Phase 3)
	45	Lindau Lane and 22nd Avenue	Bloomington		
	46	79th Street and 24th Avenue	Bloomington		Remove Signal
	47	494 and 24th Avenue (SinglePoint)	Bloomington		
Index 8	34	CSAH 28 and Highwood Drive	Hennepin County		