RSG INC.
TRANSPORTATION

MEMORANDUM

To: Alan Hanscom, Doug King
From: R. Chamberlin
Subject: Final NH 120 Coordinated Signal Timings
Date: 4 October 2011
Cc: Peter Crouch, Bill Lambert, John Butler, David Stiger

This memorandum summarizes the final coordinated timing plans for the NH 120 corridor. The plans were first implemented on Thursday, September 8. Traffic was subsequently monitored on several occasions during both the AM and PM peak periods. Adjustments to splits (green time allocation) and offsets were made. The final timing plans are provided in this memorandum. Findings are offered as well.

NH 120 Corridor

Resource Systems Group conducted AM and PM peak period turning movement counts on Wednesday, 18 May 2011 from 6:30 – 9:30 AM and from 2:00-6:00 PM at four intersections:

- NH 120/Etna Road
- NH 120/Heater Road
- NH 120/I-89 Exit 18 Northbound Ramps
- NH 120/I-89 Exit 18 Southbound Ramps

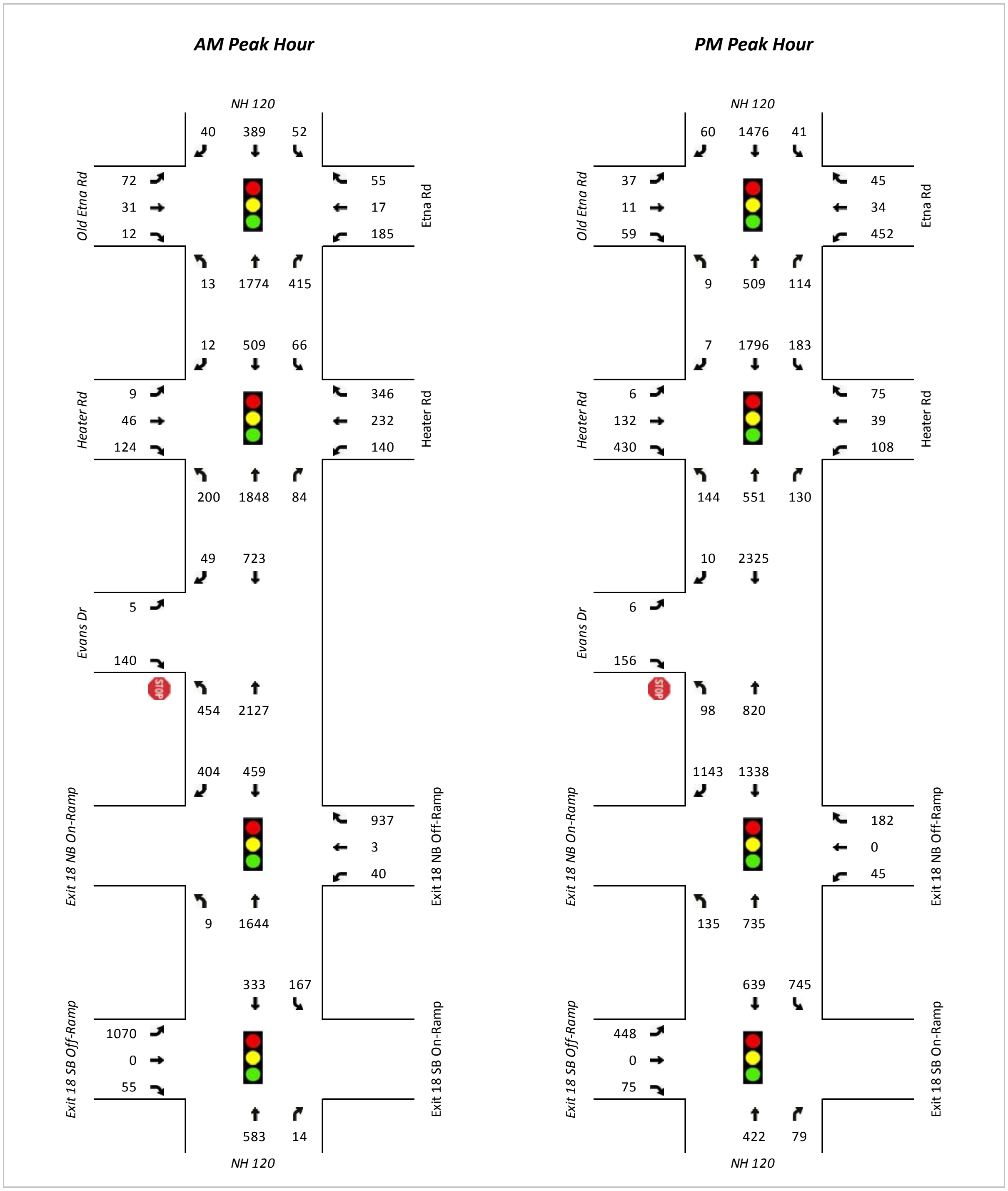
In addition to the intersection turning movement counts, automatic traffic recorders were installed from Tuesday, 17 May 2011 through Wednesday, 25 May 2011 at the following three locations:

- Evans Drive west of NH 120
- I-89 Exit 18 Northbound Off-Ramp
- I-89 Exit 18 Southbound Off-Ramp

Figure 1 presents the balanced turning movement data from the AM peak hour (7:15-8:15 AM) and the PM peak hour (4:30-5:30 PM).

Prior to the implementation of the new coordinated timing plans, there were chronic queue spillbacks onto I-89 during the morning commute. The central objective of the coordinated plan was to mitigate the queue spillback problem onto the I-89 mainline and, where possible, create smoother, platooned traffic movement in the peak direction of travel.

Figure 1: Balanced and Adjusted Peak Hour Turning Movement Count Volumes



Optimized Signal Timings

Signal timings were assessed using the Synchro and SimTraffic (v7) software package. HCM delays were analyzed using the Synchro program and queue results were observed from detailed simulations using the SimTraffic program.[1]

As the principle goal for this signal optimization is to reduce the potential for queue spillback onto the travelled portion of I-89, we have optimized timing plans to reduce queues on the I-89 Exit 18 Northbound and Southbound Off-Ramps. Additionally, signal timings were optimized in coordination with care given to obtaining offsets that facilitate traffic flow progression north on NH 120 during the AM peak and south on NH 120 during the PM peak. AM timing plans were initially programmed with an operating window of 6:45-9:00, which was reduced to 6:45-8:30 during monitoring. The PM timing plans were initially programmed with an operating window of 16:00-18:00, which was subsequently reduced to 16:00-17:45.

NH 120/Heater Road

Implementing the optimized signal timing plans included making geometric and signalization changes at the NH 120/Heater Road intersection. This intersection now operates under a split phasing configuration for the minor-leg movements on Heater Road and a reconfiguration of lane striping at this intersection that accommodates a shared left-through movement for the center westbound approach lane. The geometric and phasing changes have enabled the use of a right turn overlap phase for both the eastbound and westbound approaches which overlap with mainline left turn signaling. Right turn arrows have been installed for this purpose.

Table 1: Final Timing Parameters, NH120/Heater Road

Timing Parameters for Free Operation

Movement	NBL	SBT	EB	WB	SBL	NBT	Ped
Phase	1	2	3	4	5	6	9
Min Green	5	8	5	5	5	8	30
Max Green	14	44	15	12	20	44	30
Veh Ext	2.0	3.0	2.5	2.5	2.0	3.0	-
Yellow	4	4	4	4	4	4	4
All Red	2	2	2	2	2	2	2

Schedule

Day	Begin	End	Plan	Coord Phase	Cycle Length	Offset
Saturday-Sunday	0:00	24:00:00	free operation			
M-F	0:00	6:45	free operation			
M-F	6:45	8:30	Plan 1	6	110	0
M-F	16:00	17:45	Plan 2	2	120	0
M-F	17:45	0:00	free operation			

Coordination Data

	Movement	NBL	SBT	EB	WB	SBL	NBT	Ped
	Phase	1	2	3	4	5	6	9
Plan 1	Split	21	31	11	17	11	41	30
Plan 1	Primary Force Off	na	na	na	na	na	na	na
Plan 1	Vehicle Yield Point	na	na	na	na	na	na	na
	Phase	1	2	3	4	5	6	9
Plan 2	Split	18	42	14	16	30	30	30
Plan 2	Primary Force Off	na	na	na	na	na	na	na
Plan 2	Vehicle Yield Point	na	na	na	na	na	na	na

Coord Reference Begin of Coord Phase Green

[1] For this analysis simulation results represent the average of 10 individual model runs.

This intersection is the master intersection for the corridor and maintains a hardwire signal clock with the I-89 Southbound and Northbound ramps. This intersection is also the only one in the corridor with pedestrian signals. The pedestrian time (walk + flashing don't walk + ped clearance) is included within the overall cycle length to ensure that the system stays within coordination whenever a pedestrian call is made and served. It is worth noting that a pedestrian call at this intersection during coordinated operation can have system-wide effects. Pedestrian calls during peak periods can occur as frequently as once every 4 cycles and have been more commonly observed during the PM period. The 30-seconds for the entire pedestrian phase (walk + flashing don't walk + clearance) is allocated to the coordinated phase in cycles when no pedestrian calls are placed. Generally peak period volumes in the corridor warrant the significant extra time allocated to the coordinated phases.

NH 120/I-89 Northbound

Queuing spillback onto I-89 at this location has been significantly mitigated with the new timing plans. Operations are extremely sensitive to the allocation of green time, particularly during the critical 7:30-7:45 time period.

To help smooth traffic flow from the ramp onto NH 120, the offset between the ramp(s) and Heater Road are changed at 7:15 in anticipation of higher traffic flows. Switching offsets is a coarse way of approximating dynamic offset adjustments. As traffic volumes increase after 7:15, and queues build on northbound NH 120 at Heater Road, the offset is increased allowing the queue on NH 120 at Heater Road to advance before the northbound offramp is discharged.

There tends to be imbalanced lane utilization for traffic exiting the ramp, with strong preference for the curbside lane. This tends to create long spillbacks extending along NH120 from Heater Road to the Northbound offramp. The interior right turn lane from the exit ramp is less utilized and runs more freely.

Table 2 provides the final timing plans for this intersection.

Table 2: Final Timing Parameters, NH120/I-89 Northbound

Timing Parameters for Free Operation

Movement	NBL	SBT	WB (I-89 ramp)	NBT
Phase	1	2	4	6
Min Green	5	8	5	8
Max Green	20	60	20	60
Veh Ext	2.2	3.0	2.5	3.0
Yellow	4	4	4	4
All Red	2	2	2	2

Schedule

Day	Begin	End	Plan	Coord Phase	Cycle Length	Offset
Saturday-Sunday	0:00	24:00:00	free operation			
M-F	0:00	6:45	free operation			
M-F	6:45	7:15	Plan 1	6	110	38
M-F	7:15	8:30	Plan 2	6	110	54
M-F	16:00	17:45	Plan 3	2	120	5
M-F	17:45	0:00	free operation			

Coordination Data

	Movement	NBL	SBT	WB (I-89 ramp)	NBT
	Phase	1	2	4	6
Plan 1	Split	16	48	46	64
Plan 1	Primary Force Off	na	na	na	na
Plan 1	Vehicle Yield Point	na	na	na	na
	Phase	1	2	4	6
Plan 2	Split	16	48	46	64
Plan 2	Primary Force Off	na	na	na	na
Plan 2	Vehicle Yield Point	na	na	na	na
	Phase	1	2	4	6
Plan 3	Split	30	69	21	99
Plan 3	Primary Force Off	na	na	na	na
Plan 3	Vehicle Yield Point	na	na	na	na

Coord Reference Begin of Coord Phase Green

NH 120/I-89 Southbound

The new timing plans at this intersection have significantly reduced queuing on the ramp approach. More queuing has been experienced on the northbound NH120 approach as a result. For this reason, a second AM timing plan was programmed to initiate at 7:15 which shifts 4 seconds of green time from the ramp to the northbound approach. This has created a better balance in queuing: keeping queues off the I-89 mainline while minimizing queues for the northbound approach.

This intersection was programmed using the traditional specification of force offs and yield points. The reason for this was to improve efficiency during the PM peak hour. The Naztec v14 controller does not allow the designation of a minor phase (e.g. phase 5, the southbound left) as the coordinated phase. At this intersection for the PM peak period, the southbound left has the highest volume and could be designated as the coordinated phase. However, to work around the limitations of the controller, phase 2 is designated as the coordinated phase, which automatically ties phase 6 into coordination. In order to allow phase 6 to gap and yield to phase 5, a specific early yield point (12 seconds for phase 5) was programmed.

Table 3 shows the final timing plans for this intersection.

Table 3: Final Timing Parameters, NH120/I-89 Southbound

Timing Parameters for Free Operation

Movement	SBT	SBL	NBT	EB (I-89 ramp)
Phase	2	5	6	8
Min Green	6	5	6	5
Max Green	45	40	45	40
Veh Ext	2.8	2.5	2.8	2.7
Yellow	4	4	4	4
All Red	2	2	2	2

Schedule

Day	Begin	End	Plan	Coord Phase	Cycle Length	Offset
Saturday-Sunday	0:00	24:00:00	free operation			
M-F	0:00	6:45	free operation			
M-F	6:45	7:15	Plan 1	8	110	53
M-F	7:15	8:30	Plan 2	8	110	66
M-F	16:00	17:45	Plan 3	2	120	91
M-F	17:45	0:00	free operation			

Coordination Data

	Movement	SBT	SBL	NBT	EB (I-89 ramp)
	Phase	2	5	6	8
Plan 1	Split	51	16	35	59
Plan 1	Primary Force Off	103	103	87	52
Plan 1	Vehicle Yield Point	52	58	52	64
	Phase	2	5	6	8
Plan 2	Split	55	16	39	55
Plan 2	Primary Force Off	103	103	87	48
Plan 2	Vehicle Yield Point	48	54	48	60
	Phase	2	5	6	8
Plan 3	Split	85	16	55	35
Plan 3	Primary Force Off	78	78	23	113
Plan 3	Vehicle Yield Point	85	12	85	78

Coord Reference Begin of Coord Phase Green

NH 120/Etna Road

This intersection operates under time-based coordination with the other three. The time clock was synchronized twice during monitoring and has been observed to drift several seconds each week. For this reason, the offsets will not be well tuned to the system unless the clock is synchronized.

During the AM peak period, finely tuned offsets at this location are very worthwhile. Due to high northbound volume, shockwave effects can be observed when the advancing queue from NH120/Heater Road meets the end of the northbound queue at Etna Road and must come to a stop. This shockwave propagates in the southerly direction. There are limits to addressing this problem without the addition of a system detector that would enable dynamic offset adjustments based on the state of the northbound queue.

Table 4 shows the final timing plans for this intersection.

Table 4: Final Timing Parameters, NH120/Etna Road

Timing Parameters for Free Operation

Movement	NBL	SBT	EB	WB	SBL	NBT
Phase	1	2	3	4	5	6
Min Green	5	10	5	5	5	10
Max Green	15	50	20	40	15	50
Veh Ext	2.2	3.0	2.3	2.3	2.2	3.0
Yellow	4	4	4	4	4	4
All Red	2	2	2	2	2	2

Schedule

Day	Begin	End	Action		Coordinated Phase	Cycle Length	Offset
Saturday-Sunday	0:00	24:00:00	54	free operation			na
M-F	0:00	6:45	54	free operation			na
M-F	6:45	7:15	1	Split 1	6	110	20
M-F	7:15	7:55	2	Split 1	6	110	105
M-F	7:55	8:30	3	Split 1	6	110	0
M-F	16:00	17:45	4	Split 2	2	120	60
M-F	17:45	0:00	54	free operation			na

Coordination Data

	Movement	NBL	SBT	EB	WB	SBL	NBT
	Phase	1	2	3	4	5	6
Split 1	Split	16	60	17	17	16	60
	Primary Force Off	na	na	na	na	na	na
	Vehicle Yield Point	na	na	na	na	na	na
	Phase	1	2	4	6	6	6
Split 2	Split	16	58	16	30	16	58
	Primary Force Off	na	na	na	na	na	na
	Vehicle Yield Point	na	na	na	na	na	na

Coord Reference   Begin of Coord Phase Green

Findings

1. The corridor operates near- or over-capacity weekdays from 7:25-7:50, when the most significant queuing occurs. The revised coordinated timing plans have minimized queuing on the I-89 ramps. Queuing has increased at other locations associated with uncoordinated movements, specifically:
    a. NH 120 Northbound at the I-89 SB ramps (phase 6). To attenuate queues for this approach, a second Split plan was programmed at this intersection beginning at 7:15. This plan transfers 5 seconds of green time from the coordinated phase 8 (SB off ramp) to the NB NH 120 phase 6.
    b. Heater Road Westbound (phase 4). Queues on this approach average 10-20 vehicles. On average it takes a vehicle 2 cycles to proceed through the intersection. Queues on this approach are much less than projected by the Synchro analysis, however.
2. Due to the near overcapacity conditions, small changes in behavior or capacity can have large repercussions. For example, inclement weather causing more conservative driving can lead to building queues with each successive cycle. Any vehicle crashes that occur during the peak periods will have major impacts on overall traffic flow. Incident responders – fire, ambulance, and police – should be trained to clear incidents along NH 120 during peak periods as quickly as possible. Rapid incident clearance has become standard operating procedure in other urban areas.
3. Due to the near overcapacity conditions, minor changes in time can noticeably improve efficiency. For example, vehicle extensions have been reduced for all minor movements. This allows the intersections to shift phases more rapidly, which is particularly important during saturated conditions.

    One improvement that we recommend for the entire corridor is the adjustment of yellow (yellow change) and all red intervals (red clearance) times to reflect the state of the practice as indicated in FHWA's Signal Timing Manual (June, 2008). Using the equation recommended by this resource (based on research by Kell and Fullerton), the following Yellow Change and Red Clearance intervals could be applied:

Intersection	**Approach**			
NH 120/Etna	EB	WB	NB	SB
Yellow Change	2.8	2.8	3.9	3.9
Red Clearance	3.0	2.6	1.8	1.6

Intersection	**Approach**			
NH 120/Heater	EB	WB	NB	SB
Yellow Change	2.8	2.8	3.9	3.9
Red Clearance	3.7	3.9	1.9	2.0

Intersection	**Approach**			
NH 120/I89 NB	EB	WB	NB	SB
Yellow Change	na	2.8	3.9	3.9
Red Clearance	na	2.6	1.3	1.3

Intersection	**Approach**			
NH 120/I89 SB	EB	WB	NB	SB
Yellow Change	2.8	na	3.9	3.9
Red Clearance	3.0	na	1.4	1.5

The calculations of these intervals depend on several factors, including: driver reaction time, deceleration rate, vehicle length, intersection width, and 85th percentile speed. Note that the intervals would in most cases increase for protected left turns which have significantly lower operating speeds.

We think adjusting the Yellow Change and Red Clearance intervals as described above will have a noticeable impact on efficiency in the corridor.

4. Clock synchronization at Etna Road could be achieved with additional hardware that can re-set the clock periodically to synchronize it with the master intersection at Heater Road. The precise hardware additions that would be necessary have not been researched for this memorandum.

5. Offsets in the corridor are critical for optimal operation of the coordinated system. Each intersection in the corridor could benefit from a more advanced signal timing system that allowed dynamic offset adjustments based on the state of queuing. In the currently implemented plan we have tried to account for the observed surges in traffic that occur every weekday morning by programming in a different set of offsets at 7:15.

   This is particularly important at Etna Road where shockwave behavior is observed from time to time. Offset adjustments could be effected for the northbound approach to Etna Road with the installation of system detectors placed approximately 200-400 feet away from the stop bar and associated programming of the controller. Further research into the capabilities of the Naztec v61.2 controller would be necessary to establish a full configuration of this system.