Lincoln Square Traffic Signal Improvements Evaluation

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COPY: Rich Benevento, Tighe & Bond

DATE: April 10, 2024

The City of Worcester has retained Tighe & Bond to conduct Follow-On Services to their Citywide Traffic Signal Inventory and Evaluation, focused on the Lincoln Square intersections. Additional services include identifying and evaluating existing traffic signal phasing, timing, and operational issues at the two Lincoln Square intersections: Belmont Street (Route 9) at Highland Street (Route 9)/Lincoln Street/Major Taylor Boulevard; and Highland Street (Route 9) at Grove Street and Main Street. Field observations, discussion with a traffic signal equipment vendor familiar with the City and the intersections, research, and the development of improvements/recommendations are included as part of the follow-on services.

Existing Conditions

Key Intersections

Lincoln Square, shown in Figure 1, is comprised of two closely spaced intersections just north of Worcester's downtown center: Belmont Street (Route 9) at Highland Street (Route 9)/Lincoln Street/Major Taylor Boulevard; and Highland Street (Route 9) at Grove Street and Main Street. Together these intersections serve six approaches and carry a heavily trafficked Route 9 through the intersections. Belmont Street, Highland Street, Major Taylor Boulevard, and Lincoln Street form the four-legged eastern intersection, while Highland Street, Main Street, and Grove Street form the four-legged western intersection. The two intersections are offset by a 100-foot segment of Highland Street. Both intersections operate under traffic signal control, with a full complement of traffic signals at each of the closely spaced intersections. A single traffic signal controller operates both intersections with a series of phases and overlaps to direct traffic from all approaches through the intersections.

At the eastern intersection, Belmont Street comprises the east leg, Highland Street the west leg, Major Taylor Boulevard the south leg, and Lincoln Street the north leg of the intersection. All four legs are median-divided with raised concrete medians. Route 9 is carried along Belmont Street and Highland Street, with both roadways classified as an urban principal arterial. Belmont Street provides two travel lanes westbound, widening at the intersection to provide a dedicated left-turn lane for turns to Major Taylor Boulevard southbound and a channelized right-turn lane under yield control for turns to Lincoln Street northbound. Belmont Street eastbound provides three travel lanes departing the intersection, with the right-most lane becoming a right-turn only lane further east for the on-ramp to I-290 westbound. Lincoln Street provides three travel lanes southbound in advance of the intersection with the left-most lane becoming a dedicated left-turn lane for turns to Belmont Street eastbound. The left-lane widens at the intersection to provide a second dedicated left-turn lane southbound, with the right two lanes for through and right-turning traffic.

LINCOLN SQUARE TRAFFIC SIGNAL IMPROVEMENTS
WORCESTER, MA

LOCATION MAP

DATE:	03/28/2024
SCALE:	1" = 100'
FIGURE:	1

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Plotted On: Mar 29, 2024 - 4:21pm By: JCurewitz
Tighe & Bond: I:\WW\W1951 Worcester\1065 - City-Wide Traffic Signal Inventory\Drawings\Figures\Figure 1 - Location Map.dwg

Lincoln Street northbound provides three travel lanes departing the intersection, with the left two lanes destined for left turns to Salisbury Street, while the right lane continuing as Lincoln Street northbound. Major Taylor Boulevard provides three travel lanes northbound, widening at the intersection to provide a dedicated left-turn lane for turns to Highland Street westbound. Southbound, Major Taylor Boulevard provides three departure lanes. Lincoln Street and Major Taylor Boulevard are both functionally classified as urban principal arterials.

At the western intersection, Highland Street comprises the east and west legs, Main Street the south leg, and Grove Street the north leg of the intersection. Both Main Street and Grove Street are median divided at the intersection with raised concrete splitter islands and sidewalks. Route 9 is carried along Highland Street and functionally classified as an urban principal arterial. The Highland Street west leg provides two travel lanes in each direction with an eastbound channelized right-turn lane for turns to Main Street southbound, while eastbound left-turns to Grove Street are restricted. Grove Street provides a single travel lane southbound in advance of the intersection, widening to provide a second travel lane at the intersection. A shared left/through and through/right-turn lane comprise the two approach lanes, with both lanes allowed to go through the intersection to Main Street southbound. Grove Street northbound provides a single departure lane for westbound right turns from Highland Street and northbound through traffic from Main Street. As mentioned previously, eastbound left-turns are restricted from Grove Street. Main Street provides a single travel lane northbound, widening at the intersection to provide a dedicated U-turn Lane to reverse direction on Main Street prior to the intersection with Highland Street. Southbound, Main Street provides two departure lanes. Grove Street and Main Street are both functionally classified as urban minor arterials. A tunnel underpass provides a connection from Salisbury Street to Main Street, independent of the signalized intersection; this tunnel is currently closed to traffic.

In between the eastern and western intersections is a short 100-foot median-divided segment of Highland Street connecting both intersections. Westbound provides a shared left/through and through/right-turn lane for left turns to Main Street and right turns to Grove Street. Eastbound provides a four-lane approach with two dedicated left-turn lanes to Lincoln Street northbound and two through lanes eastbound, with right-turns accommodated through a shared lane.

Lane extension lines are provided for several turning movements at both intersections. At the eastern intersection, the eastbound, northbound, and southbound left-turn lanes all provide lane extension markings as well as the eastbound through movement. The eastbound left-turn extension markings direct the two left turn lanes into the left lane and middle lane northbound on Lincoln Street. For vehicles destined to continue on Lincoln Street northbound, they must change lanes to enter the right-most lane to complete this movement otherwise they will funnel into the turn for Salisbury Street, approximately 500 feet north of the intersection. The eastbound through lane extension markings direct the two through lanes into the middle lane and right lane eastbound on Belmont Street. For vehicles in the right lane looking to continue along Belmont Street eastbound, they must change lanes to enter the middle lane to complete this movement otherwise they will funnel into the right-turn only lane to I-290 westbound, approximately 350 feet east of the intersection. The northbound left-turn extension markings direct the left turn into the left lane on Highland Street, while the southbound left-turn extension markings direct the two left turn lanes into the left lane and middle lane eastbound on Belmont Street.

At the western intersection, the eastbound through movement provides lane extension markings connecting the lane line separating the two-lane approach to the lane line separating the two left-turn and two through lanes. This lane extension creates a lane trap for the eastbound left-lane approaching the eastern intersection as the current markings force the

left lane into the left-turn lanes as opposed to the through lanes. This results in a majority of the eastbound traffic queuing in the right lane on the approach to the Lincoln Square intersections to avoid this trap. Vehicles that are unaware of this condition or do not want to wait multiple signal cycles to traverse the intersection will changes lanes within the eastern intersection to avoid this trap, sometimes resulting in near miss collisions with vehicles in the right lane.

Sidewalks are provided along both sides of all roadways within the Lincoln Square intersections. Crosswalks are provided across all four legs of the eastern intersection and across all legs of the western intersection, except for the east leg. Pedestrian pushbuttons, signal heads, phasing, and curb ramps, with detectable warning panels, are provided for all crosswalks.

Traffic Signal Phasing

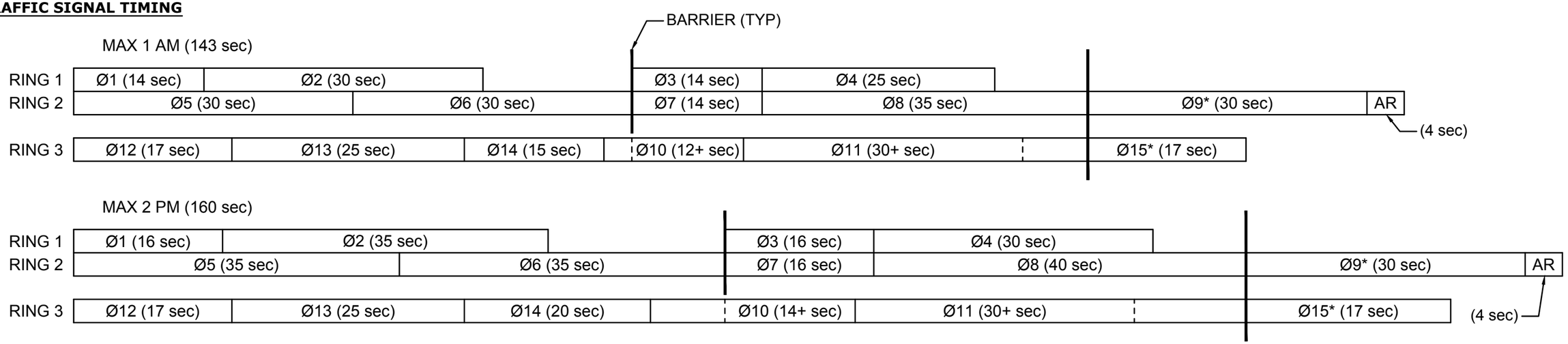
Traffic signal phasing features fifteen individual phases (thirteen vehicle phases and two pedestrian phases) at the two intersections:

- Phase 1: Major Taylor Boulevard NB Left-turn
- Phase 2: Lincoln Street SB Through/Right-turn
- Phase 3: Highland Street EB Left-turn (eastern intersection)
- Phase 4: Belmont Street WB Through
- Phase 5: Lincoln Street SB Left-turn
- Phase 6: Major Taylor Boulevard NB Through/Right-turn
- Phase 7: Belmont Street WB Left-turn
- Phase 8: Highland Street EB Through/Right-turn (eastern intersection)
- Phase 9: Exclusive Pedestrian Phase (eastern intersection)
- Phase 10: Highland Street WB Left-turn/Through (western intersection)
- Phase 11: Highland Street EB/WB Through (western intersection)
- Phase 12: Highland Street WB Left-turn/Through overlap (western intersection)
- Phase 13: Main Street NB
- Phase 14: Grove Stret SB
- Phase 15: Exclusive Pedestrian Phase (western intersection)

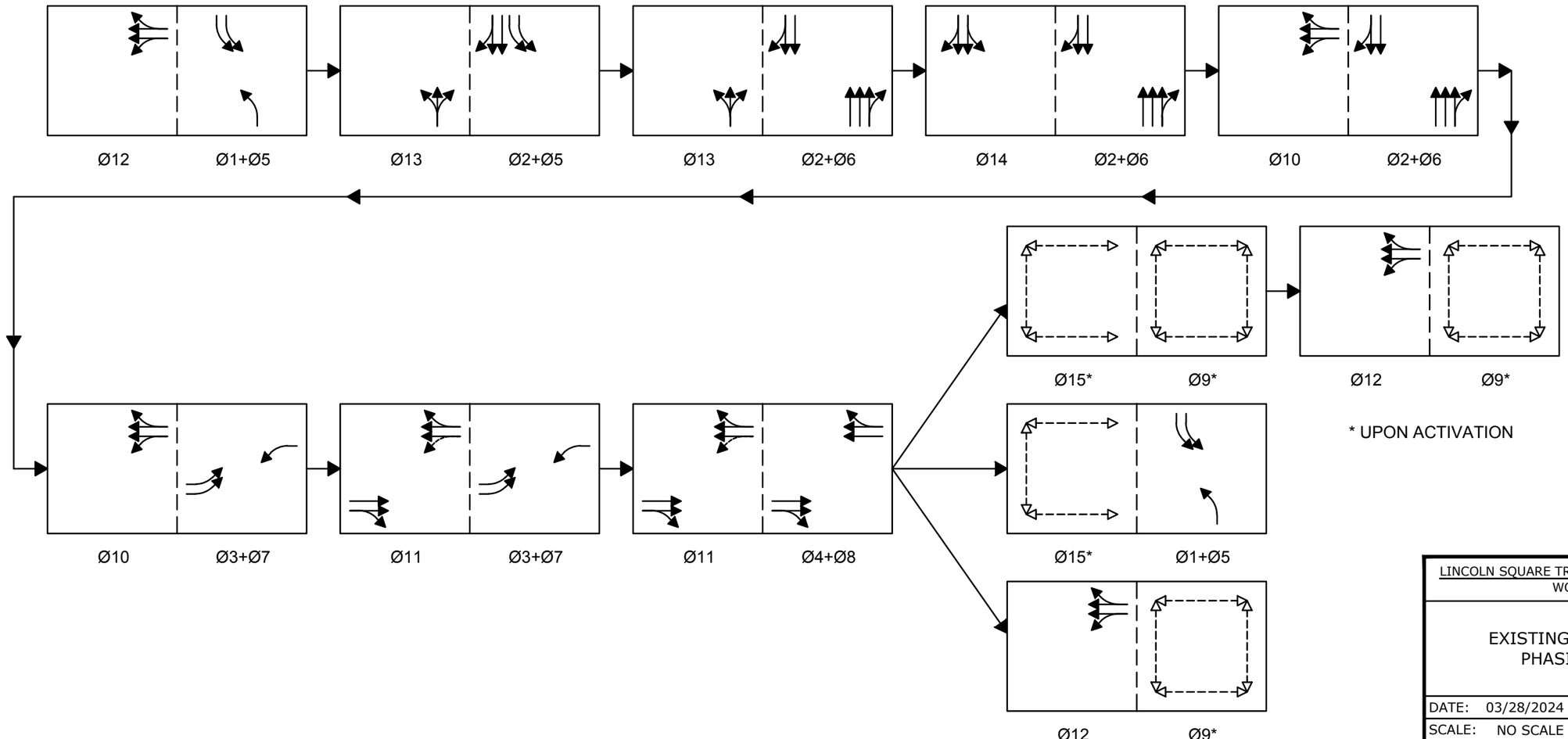
The intersection phasing features three ring operation with Ring 1 & 2 for the eastern intersection and Ring 3 for the western intersection. Two time-of-day plans are in use at the intersection, with Max 2 operating from 3PM-6PM and Max 1 operating all other times. Video detection has been installed at the intersection and appears to be working; however, recalls for all signal phases have been set to MAX recall, resulting in the intersections running pretimed. This results in several movements with unused green time, while other phases would benefit from additional green time. The existing traffic signal phasing along with signal timings are shown in Figure 2.

As seen in Figure 2, Max 1 features a 143 second cycle length, while Max 2 features a 160 second cycle length. These longer cycle lengths, while necessary at complex intersections such as this, can cause longer delays, queues and blocking of approaches at critical times due to phase interactions.

TRAFFIC SIGNAL TIMING



TRAFFIC SIGNAL PHASING



* UPON ACTIVATION

LINCOLN SQUARE TRAFFIC SIGNAL IMPROVEMENTS
WORCESTER, MA

EXISTING TRAFFIC SIGNAL
PHASING & TIMING

DATE:	03/28/2024
SCALE:	NO SCALE
FIGURE:	2

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Background Information/History

As part of the follow-on services, a discussion took place with Ocean State Signal, a traffic signal vendor familiar with the equipment and phasing at the intersections. Included in the discussion was a background on the history of the intersection, the equipment upgrades, and issues that have been noted at both Lincoln Square intersections.

Key Background Information

- Recent intersection equipment upgrades included:
  - New 16-channel traffic signal cabinet from prior existing 12-channel cabinet
  - New Iteris Vantage NEXT video detection equipment for all approaches
- The currently installed traffic signal cabinet and controller was bench tested with MIN recalls for only a few phases, not MAX recalls for every approach as exists currently in the field.
- The MAX recalls were believed to be programmed as an interim solution to the cycle failure that was experienced at least once a week that would put the intersection into flashing operation. The intersections have been operating this way for at least nine months.
- The intersection operates with three rings: Rings 1 & 2 for the eastern intersection and Ring 3 for the western intersection.
- Main Street (Phase 13) and Grove Street (Phase 14) phases are only compatible with Phases 2 (Lincoln Street SB) and 6 (Major Taylor Boulevard NB) and would require recalls for those phases to ensure that the controller calls Phases 13 and 14.
- The detection for Main Street (Phase 13) and Grove Street (Phase 14) place calls for Phases 2 (Lincoln Street SB) and 6 (Major Taylor Boulevard NB).

Field Observations

Field observations of the intersections were conducted as part of the citywide traffic signal inventory on Friday, July 14, 2023, as part of operational observations for the citywide inventory on Wednesday, September 20, 2024, and specifically to support follow-on services on Tuesday, March 19, 2024, from 7:00 AM to 9:00 AM and from 4:00 PM to 6:00 PM and again on Thursday, March 21, 2024, from 4:00 PM to 6:00 PM to capture commuter peak periods. Observations are summarized by peak period as well as general observations below:

General Observations

- Emergency pre-emption is not working at these intersections; cards are pulled out. Given the significant amount of emergency vehicles and the proximity of UMass Memorial Medical Center's Memorial Campus, the intersections would benefit from pre-emption as emergency vehicles struggle to get through intersections, especially Main Street northbound due to blocking vehicles.
- No trailing green/clearance phase exists for Highland Street between intersections to help clear out this middle segment.
- A lane trap exists for Highland Street eastbound through traffic as it turns into a left-turn lane at the eastern intersection.
- Main Street northbound has a 4-section (R, Y, G, GL) signal head, but GL indication does not illuminate even though this approach has split phasing, where this configuration would be appropriate. Grove Street southbound has the same signal head and phasing with GL illuminating. Indication could be burnt-out or not working.

AM Peak

- Not many vehicles use inside left-turn lane EB at Lincoln.
- EB queues extend back to Harvard Street, primarily in the right lane.

- WB left-turn vehicles destined for Main Street SB cannot make the turn due to EB through vehicles blocking intersection.
- WB queues extend back to I-290 on-ramp intersection. (possibly beyond but visibility was blocked by hill)
- Due to Mass College of Pharmacy and Health located between Main Street and Major Taylor Boulevard, pedestrian phase comes on almost every cycle at both intersections between 8 and 9 AM with students arriving.

PM Peak

- Highland Street EB left-turn queues back to Harvard Street (approx. 700 feet) and has no release until EB receives the green.
- Highland Street EB segment between intersections always blocks Main Street and does not allow any vehicles to exit.
- WB left-turn vehicles destined for Main Street SB cannot make turn due to EB through vehicles blocking intersection. This movement queues back to and into Lincoln St intersection.
- WB queues extend back to I-290 on-ramp intersection. (possibly beyond but visibility was blocked by hill)
- EB queues extend back to Harvard Street, primarily in the right lane.

Existing Deficiencies

A summary of existing deficiencies found at the intersections is compiled below. These deficiencies range from minor maintenance repairs to intermediate phasing changes to mid-term geometric improvements.

- Emergency pre-emption cards are pulled out in the traffic signal cabinet and pre-emption is not working at the intersections. Equipment and hardware appear to be installed and ready for use but are currently non-operational.
- Given the close proximity of intersections and the existing phasing, no trailing green or clearance phase is provided for eastbound vehicles. Both eastbound sets of signal turn red at the same time resulting in vehicles getting trapped in between intersections.
- A lane trap exists for the eastbound left through lane as it turns into the left-turn lane at the eastern intersection. This alignment funnels traffic in the left lane into the dedicated left-turn only lanes, without prior advanced warning.
- Main Street northbound has a 4-section (R, Y, G, GL) signal head, but GL indication does not illuminate even though its split-phased. Indication could be burnt-out or not working.
- Queued eastbound vehicles at the western intersection block the intersection for northbound and southbound traffic as well as westbound left-turning traffic.
- Intersections appear to have working vehicle detection (video detection) but are set to MAX recall for all vehicle phases.
- Given the MAX recall at the intersections, green times for Main Street (Phase 13) and Grove Street (Phase 14) under Max 1 and Lincoln Street southbound (Phase 2) and Major Taylor Boulevard (Phase 6) under Max 2 would benefit from minor interim timing adjustments to better balance timings at the intersection.

Recommended Improvements

Based upon the background information/history, field observations, and the existing deficiencies identified at the Lincoln Square intersections, recommended improvements have been developed. These improvements have been prioritized based upon improved safety and operations and are recommended to be implemented one at a time to allow trial period testing to determine effectiveness and troubleshoot additional adjustments which may be needed following implementation.

Improvement 1: Emergency Pre-emption

This improvement recommends turning on pre-emption at the intersections. Given the proximity of the intersections to the nearby hospital facilities and the significant number of emergency vehicles accessing the intersections, this added level of priority will help emergency vehicles navigate the intersection, clear blocked traffic, and improve response times. Existing emergency pre-emption equipment should be turned on, tested for correct operation, with any issues diagnosed and repaired to proper working order. Figure 3 depicts the emergency pre-emption phasing and priority that should be implemented at the intersections. This improvement would require the services of the City's traffic signal maintenance contractor to implement.

Improvement 2: Implement Phasing and Timing Changes

This improvement recommends implementing two phasing changes to the existing traffic signal phasing: the addition of an eastbound clearance phase at the eastern intersection (Phase 16); and converting the Highland Street eastbound left-turn (Phase 3) at the western intersection from a leading phase to a lagging phase. These changes in phasing would help to clear out the Highland Street eastbound segment between intersections and reduce the eastbound blocking that occurs at the western intersection. This would also help provide storage for vehicles exiting Main Street and Grove Street heading eastbound.

In addition, minor timing adjustments to the Max 1 and Max 2 green times are recommended. Under Max 1, it is recommended to reduce the Main Steet (Phase 13) maximum green time from 25 seconds to 20 seconds and increase the Grove Street (Phase 14) maximum green time from 15 seconds to 20 seconds. Under Max 2, it is recommended to reduce both the Lincoln Street southbound (Phase 2) and the Major Taylor Boulevard (Phase 6) northbound maximum green times from 35 seconds to 30 seconds.

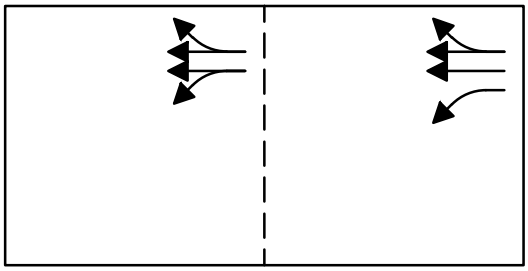
Figure 4 details the changes in phasing and timing (in red) as described above. These improvements would require the services of the City's traffic signal maintenance contract to implement.

Improvement 3: Implement Vehicle Detection

This improvement recommends removing MAX recalls for all vehicles phases and allowing video detection to operate at the intersection. The first task of this improvement would be to test existing video detection for correct operation, with any issues diagnosed and repaired to proper working order. From there it is recommended that the removal of MAX recalls is done in a staged approach to test for operation and diagnose any issues that arise during the process. The rollout of these changes would be as follows:

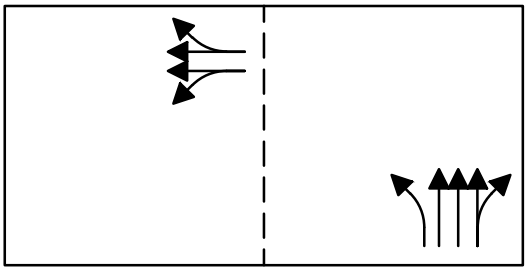
- Stage 1: Change recall setting for Phases 1, 3, 5, and 7 from MAX to NONE and allow operation for approximately one week to ensure stable operations.

R1



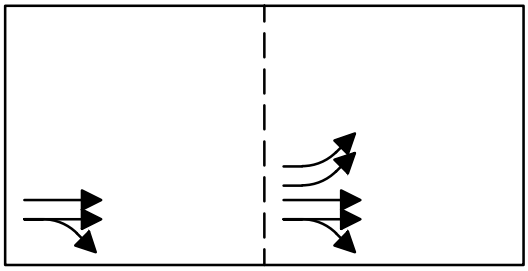
Ø12 Ø4+Ø7

R4



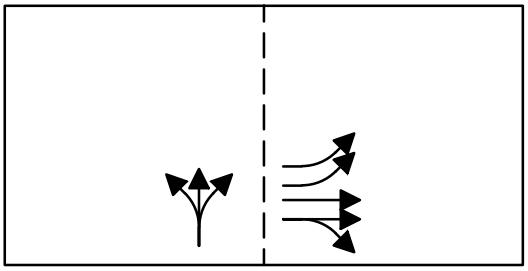
Ø12 Ø1+Ø6

R2



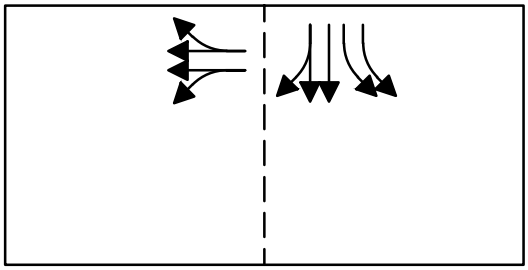
Ø11 Ø3+Ø8

R5



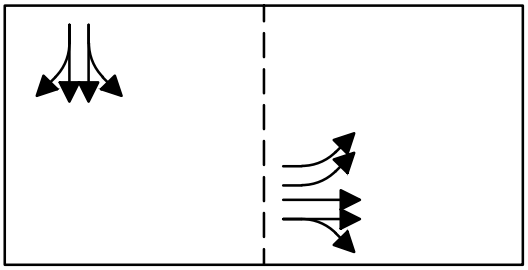
Ø13 Ø3+Ø8

R3



Ø12 Ø2+Ø5

R6



Ø14 Ø3+Ø8

PRE-EMPTION PHASING & PRIORITY

RECEIVER AND PRIORITY	PRE-EMPT PHASE ASSIGNMENT	MOVEMENT	VEHICLE PHASE ASSIGNMENT
R1	1	WB	Ø4,7,12
R2	2	EB	Ø3,8,11
R3	3	SB	Ø2,5,12
R4	4	NB	Ø1,6,12
R5	5	NB	Ø3,8,13
R6	6	SB	Ø3,8,14

LINCOLN SQUARE TRAFFIC SIGNAL IMPROVEMENTS
WORCESTR, MA

EMERGENCY PRE-EMPTION PHASING

DATE: 03/28/2024
SCALE: NO SCALE
FIGURE: 3

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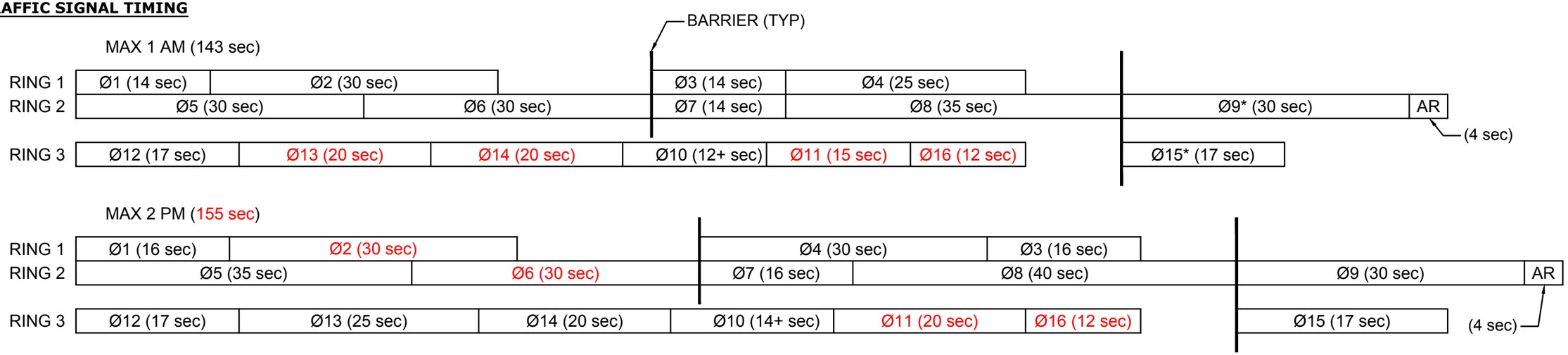
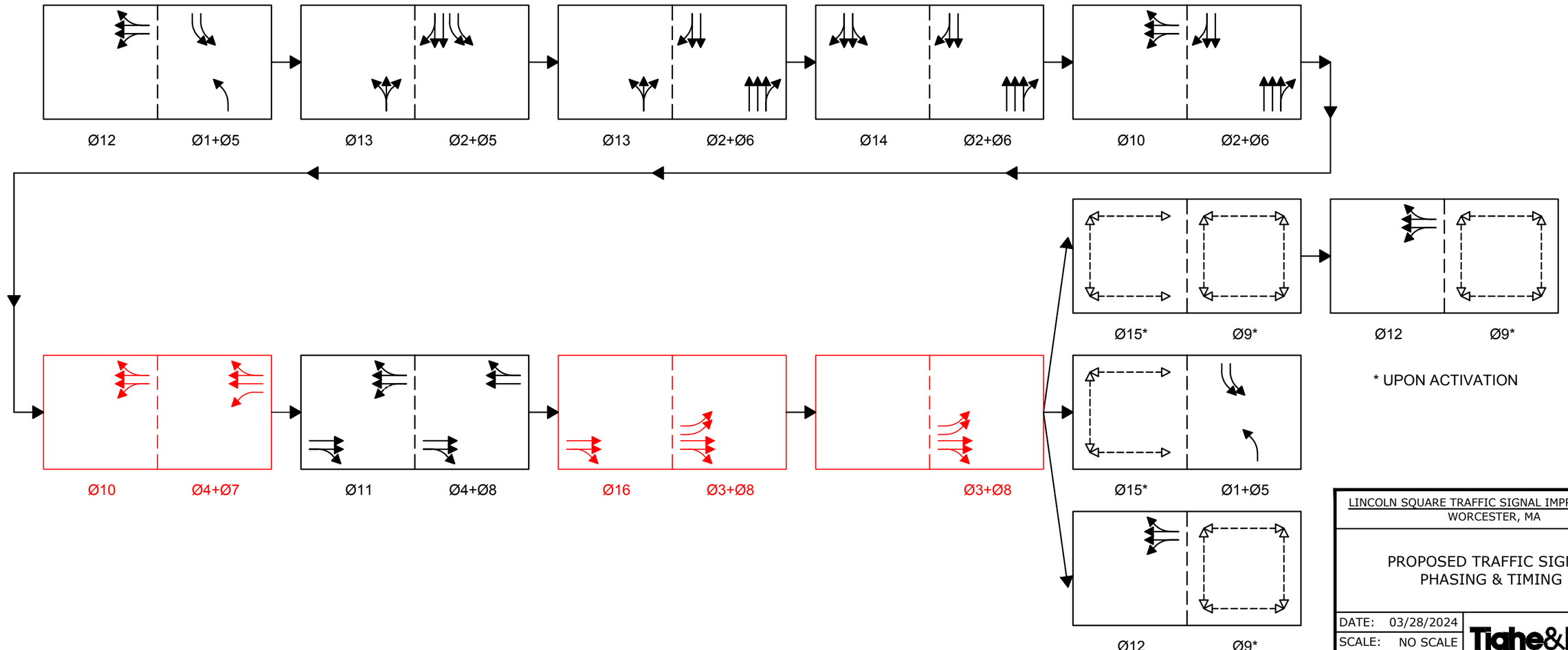
TRAFFIC SIGNAL TIMING



TRAFFIC SIGNAL PHASING



* UPON ACTIVATION

LINCOLN SQUARE TRAFFIC SIGNAL IMPROVEMENTS
WORCESTER, MA

PROPOSED TRAFFIC SIGNAL
PHASING & TIMING

DATE: 03/28/2024
SCALE: NO SCALE
FIGURE: 4

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- Stage 2: Change recall setting for Phases 11, 13, and 14 from MAX to NONE and allow operation for approximately one week to ensure stable operations.
- Stage 3: Change recall settings for Phases 2, 4, 6, 8, and 12 from MAX to MIN and allow operation for approximately one week to ensure stable operations.

Upon implementation of each stage, a trial/testing period should take place to diagnose any issues that arise. Supplemental intersection observations are recommended after each stage to ensure proper operations.

Improvement 4: Comprehensive Improvement Study

Once Improvements 1 through 3 have been implemented, Improvement 4 would be to conduct a Comprehensive Improvement Study including data collection, traffic analysis, and recommendations for further timing and phasing adjustments at the intersections. With the changes completed under Improvements 1 through 3, this study would help to reassess the operations at the intersections to ensure that green time is properly allocated to each approach. The study would also look at collision history, identify any additional safety issues, and recommend improvements based upon the findings.

Improvement 5: Eastbound Geometric Changes

This improvement recommends geometric changes to the raised islands on the south side of Highland Street to allow alternation to the eastbound lane extension line at the western intersection. The existing extension line connects the lane line separating the two-lane approach to the lane line separating the two left-turn and two through lanes. This lane extension creates a lane trap for the eastbound left through lane approaching the eastern intersection as the current markings force the left lane into the left-turn lanes as opposed to the through lanes. This improvement would maintain the beginning connection point of the extension line, while shifting the downstream connection point to the lane line between the two through lanes. This change would allow vehicles to utilize both eastbound travel lanes in advance of the intersection without encountering a lane trap. Modification to the lane extension line to maintain alignment with the through lanes without the need for geometric changes was evaluated but would result in substandard lane widths and an increased risk of sideswipe crashes along the approach. Modification to the lane extension line would allow both left-turning vehicles and through vehicles to utilize the eastbound left lane without a lane trap and would balance distribution of through vehicles between the two eastbound through lanes. This would help reduce the existing queuing that extends back to Harvard Street in both peak periods.

As part of this improvement, geometric changes would be needed to shift the existing curbline on the south side of Highland Street to allow for proper lane widths before the extension line is shifted further to the right. With the shift in the curb line, existing signal equipment, including the mast arm, may need to be relocated. Given the proximity of the Main Street tunnel, this signal equipment relocation could present additional challenges beyond geometric concerns and would need to be further investigated prior to implementation.