PHASE 4 TRAFFIC SIGNAL SYSTEM OPTIMIZATION

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GREEN LIGHT LINCOLN™

IT'S GO TIME

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EXECUTIVE SUMMARY

This report documents the results of traffic engineering work completed for the Green Light Lincoln – Phase 4 Traffic Signal System Optimization project. Phase 4 builds upon work completed in Phases 1, 2, and 3 which included over 320 traffic signals. Phase 4 updated timings at 69 additional traffic signals and incorporated 13 intersections from previous phases for signal timing plan development and corridor performance review. The following areas were studied and evaluated for improved safety and traffic flow:

- Corridors (40 traffic signals)
  - S. 14th Street – Old Cheney Road to Pine Lake Road (FHU)
  - 33rd Street – D Street to Huntington Avenue (HDR)
  - N. 56th Street – O Street to Fremont Street (FHU)
  - N. 66th Street / N. Cotner Boulevard – O Street to Adams Street (FHU)
  - Sun Valley Boulevard – West O Street to Cornhusker Highway (HDR)
  - W. Cornhusker Highway – NW 12th Street & Adams Street to N 11th Street (HDR)
- Various additional intersections and pedestrian signals (42 traffic signals)

The primary objective of the project was to prepare and implement optimized traffic signal timing plans, bringing these locations to current City standards, and to quantify the resulting changes in traffic operations. These timing plans were developed based on a data collection effort, industry research, field observations, operational / safety review, and detailed traffic engineering which included utilizing computerized software models (Synchro, SimTraffic, and Tru-Traffic). Study corridors and intersections were evaluated for many variables to bring the timing plans into conformance with current best practices including proper time-of-day schedule, appropriate left-turn phasing type, cycle length, phase splits, and vehicle and pedestrian clearance intervals. The optimized traffic signal timing plans were developed based on turning movement count data collected before the COVID-19 pandemic began impacting traffic. The timings were then implemented and fine-tuned under COVID-19 traffic volumes in the fall of 2020.

The new timing plans were then implemented with the help of City of Lincoln Traffic Engineering staff and fine-tuned in the field over the course of several weeks to achieve optimal results. To confirm and quantify these results, performance measures were documented in the form of travel time studies which occurred both before and after the signal timing implementation and field fine-tuning tasks. Reductions in delay and fuel from Green Light Lincoln – Phase 4 are estimated to save Lincoln motorists over 61,900 hours of delay and $1.4 million in time and fuel costs per year. These benefits are the direct result of improved traffic signal timings and equipment upgrades which achieved decreased travel time among users and vehicle fuel consumption savings.

It is recommended to continue retiming efforts throughout the city and retime corridors approximately every three to five years to further save Lincoln motorists time and money. Phase 4 of Green Light Lincoln produced a calculated benefit-to-cost ratio of 13:1 over the next five-year time frame.

The report that follows documents in detail the Phase 4 Traffic Signal System Optimization objectives, processes, results, and benefits.

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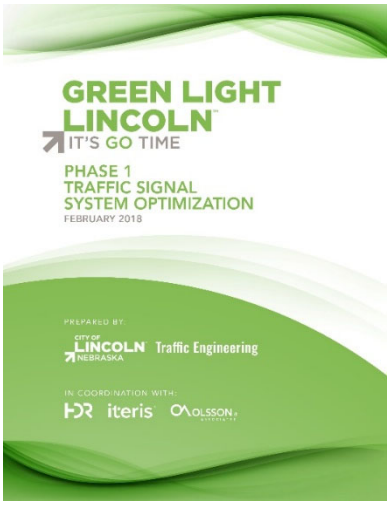
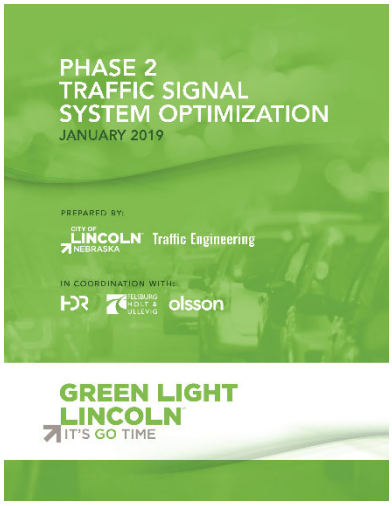
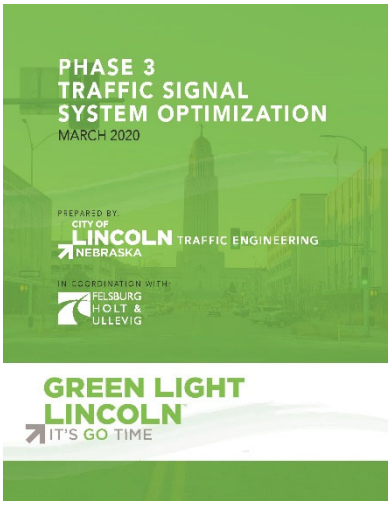
1.0 INTRODUCTION

This traffic signal system optimization project (Green Light Lincoln – Phase 4) is a continuation of collaborative efforts from City of Lincoln Traffic Engineering, City leaders, contractors, and consultants to improve travel in the City of Lincoln. The Green Light Lincoln initiative originated from a recommendation of the City of Lincoln's *Traffic Management Master Plan* (TMMP); a document that has provided insight on the status of citywide traffic systems to City leaders and has also set the vision for the future of traffic engineering in Lincoln. Several key components of the TMMP, including this project, are being addressed under the Green Light Lincoln initiative.

Green Light Lincoln – Phases 1, 2, and 3 were successful endeavors, retiming over 320 traffic signals on or adjacent to 26 corridors and in the downtown grid system. The total documented reductions in travel delay and fuel consumption for the first three phases were estimated to save Lincoln motorists over 1,153,000 hours of delay and $22.3 million in time and fuel costs per year. Phase 4 builds upon this success, addressing 6 additional corridors, 69 new traffic signals and incorporating 13 intersections from previous phases for timing plan development and performance review, to further improve mobility and safety for Lincoln motorists.

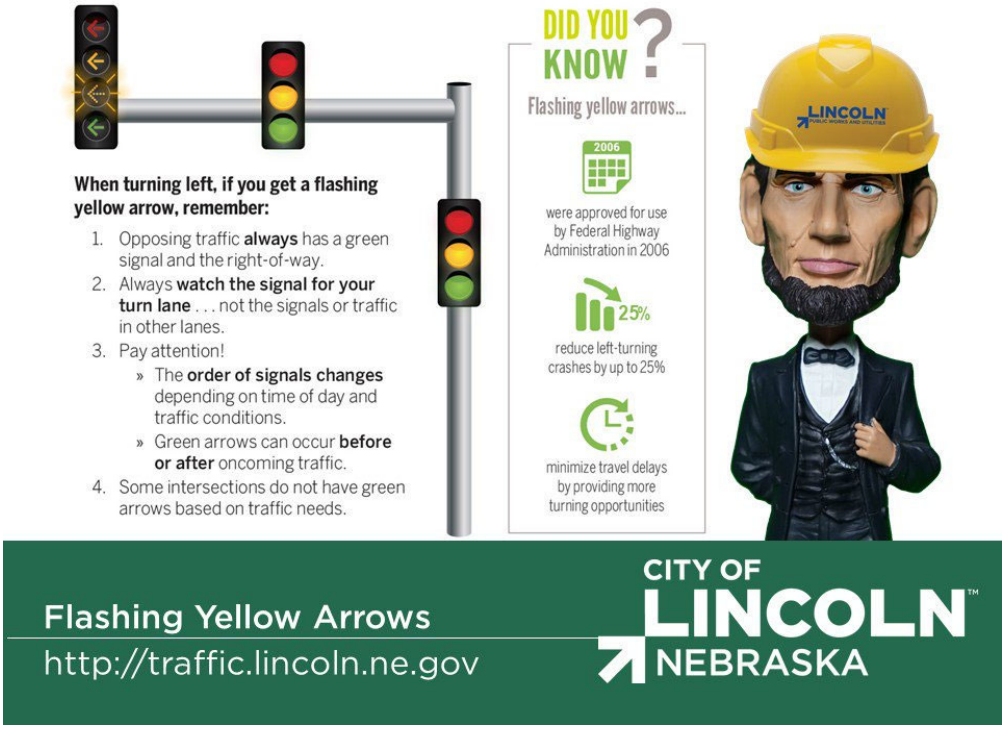






The overall purpose of this project was to prepare and implement optimized traffic signal timing plans for the corridors and intersections, bringing these locations to current City standards, and to quantify and document the changes in traffic operations resulting from signal equipment upgrades and signal timing changes with "before" and "after" performance measures.

City forces and private contractors upgraded traffic signal controller cabinets, and fixed faulty detection in preparation for new signal timing plans. They also installed new signal heads, improved signal displays, and installed Flashing Yellow Arrow (FYA) indications to achieve uniformity across the city. Their collective efforts paved the way for the signal timing implementation portion of this project. An infographic from the City's website describing FYA operation is included on the following page.



For this phase, two consultant teams were tasked with signal timing changes and performance measure documentation: Felsburg Holt & Ullevig / Iteris (FHU) and HDR. Consultant teams were assigned the following corridors and intersections (consultant listed in parenthesis):

- S. 14th Street – Old Cheney Road to Pine Lake Road (FHU)
- 33rd Street – D Street to Huntington Avenue (HDR)
- N. 56th Street – O Street to Fremont Street (FHU)
- N. 66th Street / N. Cotner Boulevard – O Street to Adams Street (FHU)
- Sun Valley Boulevard – West O Street to Cornhusker Highway (HDR)
- W. Cornhusker Highway – NW 12th Street & Adams Street to N 11th Street (HDR)
- Various additional intersections and pedestrian signals were assigned to both FHU and HDR

Figure 1 provides a map of the streets retimed as part of each phase of Green Light Lincoln. **Figure 2** provides a map of the Phase 4 study area. A complete list of Phase 4 intersections is provided in **Appendix A**.

The following standalone documents were prepared as part of Phase 4:

- Traffic Signal Warrants Review Memos
- ITE Clearance Interval Review Memo

Figure 1: Network Map by Phase

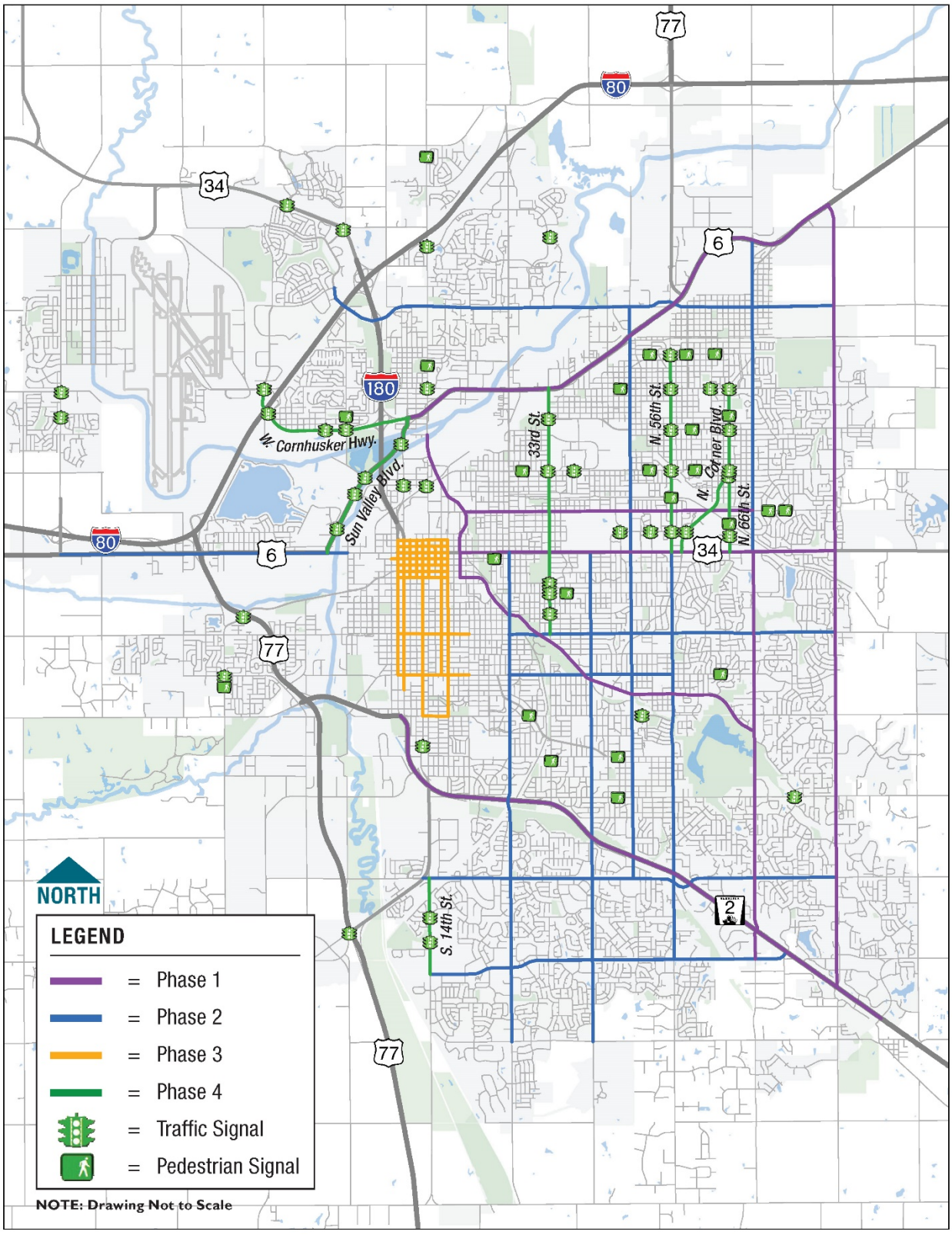
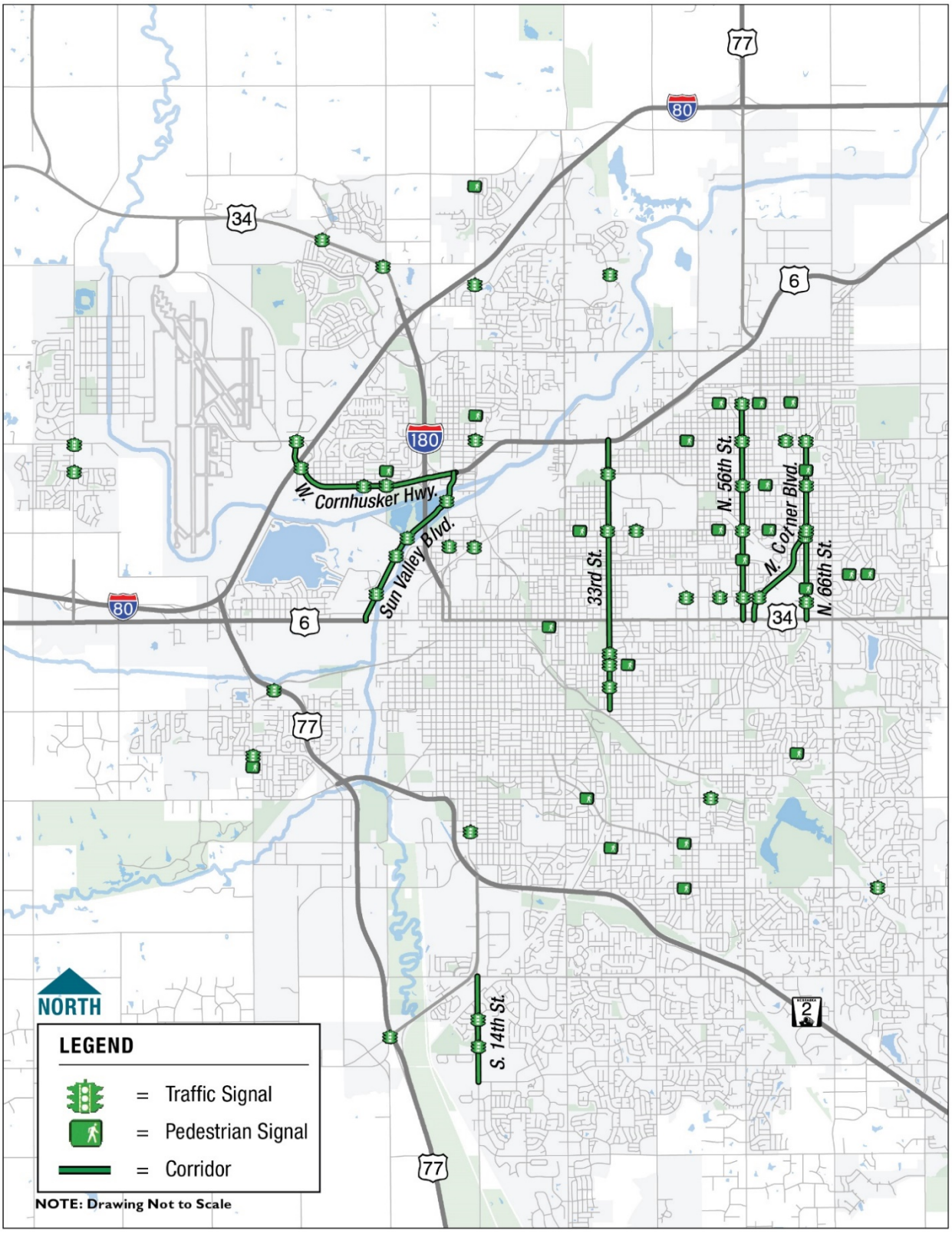


Figure 2: Phase 4 Intersection Map



2.0 Data Collection

Data collection and review efforts were completed for each study intersection. These efforts were dual-purposed. First, the characteristics and documentation necessary to perform calculations and support the development of new timing plans were catalogued. Second, a baseline to compare operations for updated conditions was established.

2.1 City Provided Information

The City of Lincoln provided the following:

- City of Lincoln *Traffic Signal Timing Guidelines v2.0*
- City of Lincoln *2019 Lincoln Crash Data Analysis*
- Existing timing plans via ATMS software (ACTRA and Centracs)
- Synchro files
- Intersection Turning Movement Volumes (TMVs)
- 24-hour Traffic Volumes
- Pedestrian crossing distances (crosswalk lengths)
- Vehicle crossing distance (near to far side of intersection)

2.2 Consultant Collected Information

Consultants collected the following for each intersection:

- Intersection lane configuration / utilization
- Pedestrian crossing distances (crosswalk lengths) at locations not provided by the City
- Vehicle crossing distance (near to far side of intersection)
- Posted speed limits
- Distance between signalized intersections
- Intersection approach grades
- Turn restrictions
- Turn lane storage lengths
- Push button documentation
- Location of mast arm ends
- Intersection approach photographs
- Field observations of traffic operations
- Sight distance restrictions
- Deficient signal equipment
- Existing timing plans via Direct Connection

2.3 Network Description

Detailed field notes were prepared for each intersection and corridor on the Phase 4 network. The network locations were visited to observe and document roadway characteristics and traffic operations. Desktop reviews were also conducted to bring all the information together and to provide a comprehensive analysis of the overall network. Characteristics of each study area are provided below.

S. 14th Street

The S. 14th Street corridor includes four traffic signals from Pine Lake Road to Old Cheney Road. The corridor is oriented in a north/south direction and is approximately 1.25 miles long with an average 24-hour volume of 22,500 vehicles.

S. 14th Street has a four-lane divided cross-section with raised median and auxiliary turn lanes at intersections. The posted speed limit along the corridor is 45 mph. The land use along S. 14th Street is a mix of residential and commercial/retail. Commercial and retail development are located near the intersections with Pine Lake Road and Old Cheney Road. Major generators along S. 14th Street include Lincoln Southwest High School, the YMCA, and Fiserv.

33rd Street

The 33rd Street corridor includes seven traffic signals from D Street to Huntington Avenue. The corridor is oriented in a north/south direction and is approximately 2.5 miles long with an average 24-hour volume of 11,000 vehicles.

33rd Street has a three-lane cross-section with a center turn lane for the entirety of the corridor except approximately 300 feet on either side of the Vine Street intersection where it is four lanes with a raised median.

The posted speed limit on 33rd Street is 35 mph. The land use along 33rd Street is mostly residential with commercial areas around major intersections. The University of Nebraska-Lincoln East Campus is located immediately east of the 33rd Street & Holdrege Street intersection. Hartley Elementary School is located in the southeast corner of 33rd Street & Vine Street.

N. 56th Street

The N. 56th Street corridor includes nine traffic signals from O Street to Fremont Street, including the intersection of N. Cotner Boulevard & O Street as the starting point for northbound travel. The corridor is oriented in a north/south direction and is approximately 2.5 miles long with an average 24-hour volume ranging from 15,000 vehicles near O Street to 10,000 vehicles near Fremont Street.

N. 56th Street has a three-lane divided cross-section with center turn lane. The posted speed limit along the corridor is 35 mph. The land use along S. 56th Street is a mix of residential and commercial/retail. Commercial and retail development is located near the intersections with O Street, R Street, and Holdrege Street. The corridor is also influenced by trip generators such as Trinity Lutheran School, Nebraska Wesleyan University, and Veyance Technologies.

N. 66th Street / N. Cotner Boulevard

The N. 66th Street / N. Cotner Boulevard corridor includes nine traffic signals from O Street to Adams Street. The N. 66th Street corridor is oriented in a north/south direction and is approximately 2.0 miles long with an average 24-hour volume of 11,000 vehicles.

N. 66th Street has a mix of the following cross-sections (listed south to north along the corridor):

- O Street to Q Street – Four-lane divided with raised median and auxiliary turn lanes
- Q Street to X Street – Five-lane with center turn lane
- X Street to Starr Street – Three-lane with center turn lane

N. Cotner Boulevard has a mix of the following cross-sections (listed south to north along the corridor):

- Starr Street to Aylesworth Avenue – Three-lane with center turn lane
- Aylesworth Avenue to Garland Street – Two-lane divided with raised median
- Garland Street to Adams Street – Three-lane with center turn lane

The posted speed limit along N. 66th Street is 35 mph from O Street to Starr Street. The posted speed limit along N. Cotner Boulevard is 30 mph from Starr Street to Walker Avenue and 35 mph from Walker Avenue to Adams Street.

The land use along both N. 66th Street and N. Cotner Boulevard is a mix of residential and commercial/retail. Commercial and retail development is located near the Gateway Mall between O Street and Vine Street, and in the Bethany area between Dudley Street and Walker Avenue. The corridor is also influenced by trip generators such as Robin Mickle Middle School and Lincoln Northeast High School.

Sun Valley Boulevard

The Sun Valley Boulevard corridor includes seven traffic signals from West O Street to Cornhusker Highway. The corridor is oriented in a north/south direction and is approximately 2.0 miles long with an average 24-hour volume of 12,900 vehicles.

Sun Valley Boulevard has primarily a two-lane cross-section with left and right turn lanes near each intersection. The posted speed limit on Sun Valley Boulevard is 45 mph from West O Street to north of the intersection of 10th Street / 11th Street & Sun Valley Boulevard, and 35 mph north to the intersection with Cornhusker Highway. The Sun Valley corridor is primarily surrounded by commercial and recreational areas with the Haymarket Park Stadium, Bowlin Stadium, and John Breslow Ice Hockey Center all located off of Line Drive.

W. Cornhusker Highway

The W. Cornhusker Highway corridor includes five traffic signals from NW 12th Street & Adams Street to Cornhusker Highway & N. 11th Street (Cornhusker Highway & N. 11th Street is also part of the Sun Valley Boulevard corridor). The corridor is approximately 2.1 miles long with an average 24-hour volume of 19,100 vehicles.

This portion of Cornhusker Highway has four lanes with a raised median and left-turn lanes at all intersections. The posted speed limit on Cornhusker Highway is 45 mph. The land use around this corridor is a mix of residential, commercial, and industrial. Lincoln Airport is located near the northwest end of the corridor with direct access off the west leg of the NW 12th Street & Adams Street intersection.

Additional Intersections

In addition to the traffic signals along the project corridors, 42 traffic signals at other intersections and pedestrian crossings were included. Each of these signals are listed below.

- **NW 48th Street & W. Adams Street** – NW 48th Street & W. Adams Street is a four-leg intersection surrounded by Airport Authority land on the northeast corner, commercial property on the southeast corner, and residential land use to the west.
- **NW 48th Street & W. Huntington Avenue** – NW 48th Street & W. Huntington Avenue is a four-leg intersection surrounded by residential land use except for commercial property on the northeast corner.
- **N. 33rd Street & Northstar HS / N. 33rd Circle** – N. 33rd Street & Northstar HS / N. 33rd Circle is a four-leg intersection in northeast Lincoln. Both N. 33rd Street and Northstar HS Drive have four-lane divided cross-sections with auxiliary turn lanes. The intersection provides access to Lincoln Northstar High School.
- **Touzalin Avenue & Fremont Street** – Touzalin Avenue & Fremont Street is a four-leg intersection surrounded by commercial land use on each corner within a generally residential area.
- **N. 63rd Street & Adams Street** – N. 63rd Street & Adams Street is a four-leg intersection surrounded by Northeast United Church of Christ on the northwest corner, Lincoln Northeast High School on the southwest corner, and residential land use to the east.
- **N. Cotner Boulevard & Vine Street** – N. Cotner Boulevard & Vine Street is a four-leg intersection surrounded by a mix of commercial and residential land uses. It was retimed as part of Phase 1 of the Green Light Lincoln initiative as part of the Vine Street corridor and is now cross-coordinated along Cotner Boulevard.
- **N. 46th Street & R Street** – N. 46th Street & R Street is a four-leg intersection surrounded mostly by commercial business.
- **N. 52nd Street & R Street** – N. 52nd Street & R Street is a three-leg intersection with an entrance to Colonial Chapel Funeral Home on the fourth approach. It is surrounded by a mix of commercial and residential land uses.
- **N. Cotner Boulevard & R Street** – N. Cotner Boulevard & R Street is a four-leg intersection surrounded by a mix of commercial and residential land uses.
- **S. Coddington Street & W. South Street** – S. Coddington Street & W. South Street is a four-leg intersection surrounded mostly by residential land uses with Roper Elementary School southwest of the intersection.

- **US Highway 77 & Rosa Parks Way** – US Highway 77 & Rosa Parks Way is a single-point urban interchange surrounded by BNSF Hobson Yard to the north and residential land uses to the south with minimal access near the interchange.
- **US Highway 77 & W. Denton Road-Warlick Boulevard** – US Highway 77 & W. Denton Road-Warlick Boulevard is a four-leg intersection with an offset northbound right-turn lane starting approximately 2,000 feet south of the intersection surrounded by farmland and developing rural residential land to the west and Wilderness Park to the east.

- **Lucile Drive & Pioneers Boulevard** – Lucile Drive & Pioneers Boulevard is a four-leg intersection surrounded mostly by commercial business.
- **Dairy Store Drive & Holdrege Street** – Dairy Store Drive & Holdrege Street is a three-leg intersection adjacent to the University of Nebraska-Lincoln East Campus.
- **Fallbrook Boulevard & US Highway 34** – Fallbrook Boulevard & US Highway 34 is a three-leg intersection surrounded by a mix of commercial and residential land uses and serving commuter/regional trips on US Highway 34.
- **W. Fletcher Avenue & US Highway 34** – W. Fletcher Avenue & US Highway 34 is a four-leg intersection surrounded by a mix of commercial and residential land uses and serving commuter/regional trips on US Highway 34.
- **N. 10th Street & Charleston Street** – N. 10th Street & Charleston Street is a four-leg intersection surrounded mostly by residential land uses.

- **N. 14th Street & Salt Creek Roadway** – N. 14th Street & Salt Creek Roadway is a three-leg intersection adjacent to the University of Nebraska main campus.
- **N. 14th Street & Fletcher Avenue / Turtle Creek Road** – N. 14th Street & Fletcher Avenue / Turtle Creek Road is a four-leg intersection surrounded mostly by residential land uses.
- **N. 14th Street & Adams Street** – N. 14th Street & Adams Street is a four-leg intersection surrounded mostly by residential land uses.
- **S. 13th Street & Arapahoe Street** – S. 13th Street & Arapahoe Street is a four-leg intersection surrounded by a mix of commercial and residential land uses.
- **S. 51st Street & Van Dorn Street** – S. 51st Street & Van Dorn Street is a four-leg intersection surrounded by a mix of commercial and residential land uses.
- **Pedestrian Signal: S. Coddington Avenue & W. Jean Avenue –** This pedestrian signal crosses S. Coddington Avenue at Roper Elementary School just north of W. Jean Avenue.
- **Pedestrian Signal: N. 46th Street & Adams Street** – This pedestrian signal crosses Adams Street at Huntington Elementary School just east of N. 46th Street.
- **Pedestrian Signal: N. 51st Street & Holdrege Street** – This pedestrian signal crosses Holdrege Street just east of N. 51st Street. It is situated approximately a quarter mile north of Riley Elementary School.
- **Pedestrian Signal: N. 52nd Street & Fremont Street** – This pedestrian signal crosses Fremont Street just west of N. 52nd Street. It is situated approximately an eighth mile south of Dawes Middle School.
- **Pedestrian Signal: N. 60th Street & Leighton Avenue** – This pedestrian signal crosses Leighton Avenue between two offset legs of 60th Street. It is situated approximately a third mile north of Brownell Elementary School and a third mile southwest of Lincoln Northeast High School.
- **Pedestrian Signal: N. 61st Street & Holdrege Street** – This pedestrian signal crosses Holdrege Street just west of N. 61st Street. It is situated approximately an eighth mile south of Brownell Elementary School.

- **Pedestrian Signal: N. 64th Street & Fremont Street** – This pedestrian signal crosses Fremont Street just west of N. 64th Street. It is situated approximately an eighth mile north of Pershing Elementary School.
- **Pedestrian Signal: N. 73rd Street & Vine Street** – This pedestrian signal crosses Vine Street at Meadow Lane Elementary School just west of N. 73rd Street.
- **Pedestrian Signal: Colony Lane & Vine Street** – This pedestrian signal crosses Vine Street at St. John's Catholic School just west of Colony Lane. It is situated approximately an eighth mile east of Meadow Lane Elementary School.
- **Pedestrian Signal: South Street at Broadmoore Drive** – This pedestrian signal crosses South Street on the west leg of the intersection with Broadmoore Drive.
- **Pedestrian Signal: Holdrege Street at Clinton Elementary** – This pedestrian signal is immediately south of Clinton Elementary School and crosses Holdrege Street.
- **Pedestrian Signal: N Street at Elliott Elementary** – This pedestrian signal crosses N Street at Elliott Elementary School just west of S. 25th Street.

- **Pedestrian Signal: N. 14th Street at Belmont Elementary** – This pedestrian signal crosses N. 14th Street at Belmont Elementary School.
- **Pedestrian Signal: N. 14th Street at Kooser Elementary** – This pedestrian signal crosses N. 14th Street at Kooser Elementary School.
- **Pedestrian Signal: N. 1st Street North of W. Dawes Avenue** – This pedestrian signal crosses N. 1st Street between W. Dawes Avenue and Nance Avenue.
- **Pedestrian Signal: S. 33rd Street at Rousseau Elementary** – This pedestrian signal crosses S. 33rd Street at Rousseau Elementary School.
- **Pedestrian Signal: Sheridan Boulevard at Van Dorn Street** – This pedestrian signal crosses Sheridan Boulevard on the north leg of the intersection with Van Dorn Street.
- **Pedestrian Signal: Calvert Street / Sheridan Boulevard at S. 46th Street** – This pedestrian signal crosses Calvert Street / Sheridan Boulevard just west of the intersection with S. 46th Street. It is located in central Lincoln just north of Calvert Elementary School.
- **Pedestrian Signal: Pioneers Boulevard at S. 46th Street** – This pedestrian signal crosses Pioneers Boulevard just west of S. 46th Street. It is situated approximately a quarter mile south of Calvert Elementary School and north of Pound Middle School.
- **Pedestrian Signal: Randolph Street East of S. 36th Street** – This pedestrian signal crosses Randolph Street just east of S. 36th Street. It is just south of St Teresa's School and about a quarter mile north of Randolph Elementary School.

3.0 Traffic Signal System Optimization

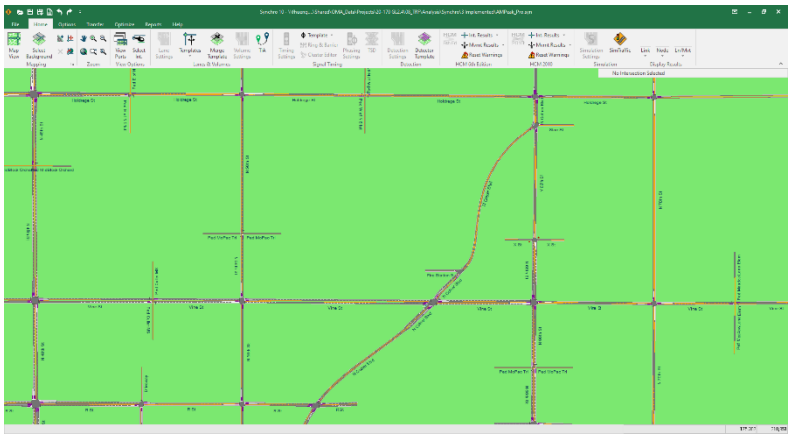
Study locations were reviewed and evaluated for potential infrastructure improvements to be considered on this project or through future work. Optimized timings were then developed for four time periods:

- Morning (AM) peak period
- Midday (MD) period
- Afternoon (PM) peak period
- Off-peak (OP) period

3.1 Synchro Network Development

Base Synchro models developed by the City of Lincoln for the AM, MD, and PM peak periods were provided to the Consultants. These base Synchro models included changes that had been incorporated as part of Phases 1, 2, and 3 of the Green Light Lincoln initiative. The Synchro models were reviewed by the Consultants to verify the accuracy of lane configurations, speed limits, turn restrictions, volume, and timing information utilizing the data provided by the City of Lincoln and collected in-field by the Consultants. Proposed changes were submitted to the City of Lincoln based on the review of intersection configuration data, count data, and timing permits.

The City of Lincoln incorporated the proposed changes for Phase 4 into the Synchro models. The MD Synchro model was then used by the Consultants as a base network to create the OP Synchro model for each of the study corridors. The City of Lincoln did not have turning movement volumes available for the OP hours at all study intersections. Consistent with past phases of Green Light Lincoln, a factor of 0.4 was applied to the MD volumes to generate OP volumes based on review of 24-hour counts at spot locations around the City. In general, the OP timing plans were primarily developed based on the intersection minimum cycle length requirements, as the OP timing plans are utilized during the low-volume hours (late-night/early-morning).



3.2 Operational Analysis

Prior to signal timing development, a review of operations was conducted to identify spot improvements at study intersections to be implemented with the new signal timings or considered for future implementation. The following sections provide a summary of the evaluation of operational characteristics for the study intersections along the project corridors. The operational analysis included review of movements that would benefit from the addition of exclusive turn lanes, review of left-turn storage bay lengths and vehicle queues, left-turn phasing analysis including the use of FYA indications, and operational deficiencies noted during field review.

3.2.1 Auxiliary Lanes

A cursory review of the provided Synchro files was performed to note left-turn and right-turn movements where operations could be improved with the addition of an exclusive turn lane. Movements that were identified as benefiting from an exclusive turn lane are listed below. These additional lanes should be considered during the planning of future improvements.

- N. 63rd Street & Adams Street Eastbound Right Turn – The movement exceeds 200 vph during the AM peak hour. Right turns are currently served with a shared through/right turn lane. This movement would benefit from adding an exclusive right turn lane. The addition of the lane may be complicated by existing utilities.
- N. 1st Street & Cornhusker Highway Southbound Left Turn Lane – The movement exceeds 300 vph during the AM peak hour. Left turns are currently served with two lanes, one of which is a shared through/left turn lane, resulting in split-phase operations at the signal. This movement and the overall intersection would benefit from adding a southbound approach lane to create two dedicated southbound left turn lanes. A signal replacement project is programmed for this intersection that may address this heavy volume movement.

During field observations, locations where turn bay length is not sufficient to store queued vehicles during peak volume times of the day were noted. To extend the storage at most of these locations would require right-of-way acquisition or significant impacts to adjacent features. One location was identified as having additional median length available upstream of the turn lane that could be used to extend the turn lane and reduce queues that spill into the adjacent lane:

- US Highway 77 & W. Denton Road-Warlick Boulevard; SB Left-turn

The City of Lincoln should consider extending the turn bay storage length at this location as part of future intersection improvement projects to prevent queue spillback into the adjacent through lane. These improvements would achieve safety and operational benefits.

3.2.2 Left-Turn Phasing

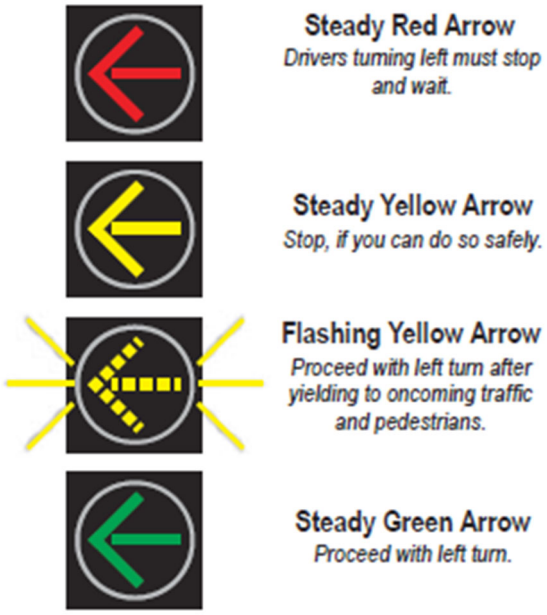
An analysis of left-turn phasing was conducted to determine the least restrictive level of control that could be used to operate left-turn movements efficiently and safely. This analysis was conducted based on the guidance provided in the City of Lincoln *Traffic Signal Timing Guidelines*. The results of the analysis were used to generate initial left-turn phasing that was implemented with the new signal timings. The implemented left-turn phasing was reviewed in the field and further adjusted as necessary.

3.2.3 Flashing Yellow Arrow (FYA) Analysis

The City of Lincoln is in the process of implementing FYA signal heads for left-turn movements throughout the city, where appropriate. Benefits of the FYA signal heads include:

- To enhance safety at intersections
- Flexibility to use any type of left-turn operation (i.e., permissive, protected/permissive, protected) to improve overall traffic flow
- Provides an exclusive signal indication to left-turning motorists
- The ability to operate signals with lead/lag left-turn phasing without the safety concern of a yellow trap

In the past, the City of Lincoln had predominantly used dog-house (five-section) or three-section signal heads for left-turn movements. Dog-house signal heads were installed on the lane line between the exclusive left-turn lane and the adjacent through lane. Guidance in the Manual on Uniform Traffic Control Device (MUTCD) suggests that FYA signal heads should be installed over the center of the left-turn lane. Based on this criteria, field reviews were conducted at each intersection approach and noted the length of the mast arm.



The FYA analysis was done independently of the left-turn operation analysis to assess if the existing mast arms could accommodate the installation of FYA signal heads. In some instances, the FYA analysis indicated that some approaches are suitable for FYA while the operational analysis determined that the movement should operate as protected only. Ultimately, the results of the left-turn operation analysis determined the operation of the left-turns at an intersection approach and the FYA analysis determined which approaches could have FYA signal heads installed.

3.2.4 Field Observations

Consultant staff were in the field on multiple occasions during this project. Those occasions included field review and inventory of study intersections, to conduct travel time studies, and as part of the implementation of the new timings. Additional operational notes from time in the field are noted below.

- The intersection of Touzalin Avenue & Fremont Street incorporates a wide boulevard type section on Touzalin Avenue and operates with split phasing due to its geometry. This leads to inefficient operations that could be improved with a smaller footprint or conversion to a roundabout.

- Eastbound left-turns and U-turns are not prohibited at the intersection of N. 52nd Street & R Street. While these movements do not occur often, they do limit the phase sequencing options for the intersection. This limitation can reduce the efficiency of the intersection operations.
- Parking is not restricted on the northbound approach of the intersection of N. 56th Street & R Street. This can create a sight distance issue and reduce operational efficiency. The City was made aware of this after field data collection was complete and has already addressed the situation.
- Parking is not restricted along the southbound lane of N. 66th Street between N. Cotner Boulevard-Starr Street and Dudley Street. This can create a sight distance issue and reduce operational efficiency. The City was made aware of this after field data collection was complete and has already addressed the situation.
- 33rd Street – Dense residential driveway spacing throughout the corridor and implications with garbage and mail trucks.
- 33rd Street – A pedestrian rapid flashing beacon located at the Mopac Trail north of X Street gets frequent use, resulting in variable speeds along the corridor.
- 33rd Street & O Street – Southbound traffic occasionally experiences long queues and cycle failures during the peak periods.
- Cornhusker Highway & N. 11th Street – Intersection timings during the PM peak period are regularly out of coordination and may be related to a recent controller upgrade and unique signal phasing at the intersection. The City is currently monitoring this location for further adjustment to timings in the new controller.
- Cornhusker Highway & NW 12th Street / I-80 EB Ramps – Railroad preemption for signal due to tracks crossing southwest leg of intersection.
- Cornhusker Highway & NW 12th Street / I-80 EB Ramps – Pavement over railroad tracks on southwest leg of intersection is in poor condition. This results in slow moving vehicles over the crossing, limiting the amount of traffic served during its dedicated signal phase.
- Cornhusker Highway & N. 1st Street – Pedestrian trail crosses east leg of intersection and has moderate pedestrian and bicycle volumes. Crossing distance requires long northbound green time to accommodate.
- Sun Valley Boulevard & N. 10th Street / N. 11th Street – Vehicles on westbound approach to signal stopped short of the loop detector and their signal phase was skipped.
- N. 14th Street at Belmont Elementary – Combination of school drop-offs and pedestrian crossing actuation resulted in roughly two blocks of traffic queued during the AM peak.
- N. 14th Street & Adams Street – Northbound traffic queued near the westbound Cornhusker Highway on-ramp (roughly 900 feet) during the peak 15 minutes of the afternoon.
- S. 51st Street & Van Dorn Street – There is a right-in, right-out driveway access approximately 100 feet west of the S. 51st Street & Van Dorn Street signal. This driveway access serves a commercial area that is also served by the signalized, full access intersection.

3.3 Intersection Crash Analysis

The City of Lincoln conducts periodic crash studies of intersections with high crash rates to identify potential safety improvements. As part of this project, the City of Lincoln *2019 Lincoln Crash Data Analysis* was reviewed for recommendations specific to project intersections. No project intersections for Phase 4 were included in the report.

3.4 Traffic Signal Timing Development

Traffic signal timing development was completed through multiple steps. This process included calculation or determination of intersection basic timing parameters (minimum green, yellow change, red clearance, walk, flashing don't walk, and vehicle recall), cycle lengths, splits, and offsets. Timings were then refined in the field based on observations of traffic operations. A brief overview on how these parameters were developed and modified is described in the following sections.

3.4.1 Basic Signal Timing Parameters

Basic timing parameters of minimum green, yellow change, red clearance, walk, flashing don't walk, and vehicle recall were evaluated based on information in the City of Lincoln *Traffic Signal Timing Guidelines*. Data collected from the intersection inventory and aerial photography were used to calculate these parameter values. Calculated values reflect current industry practices which are based on new research that is intended to improve the safety of intersection operations. The initial intersection calculation file for each intersection was submitted to the City of Lincoln for their review and approved prior to the development of optimized timing plans. The approved timing parameters were then coded into Synchro by the Consultants for use in creating the new timing plans. Final intersection basic signal timing parameters were submitted to the City of Lincoln with the final project deliverables.

3.4.2 Cycle Length

An optimum cycle length provides sufficient green time to efficiently serve all movements at an intersection while providing efficient flow of traffic along a corridor from one intersection to the next. Long cycle lengths generally accommodate efficient flow of traffic (progression), however, they generally cause greater delays for pedestrians and the minor street approaches. Short cycle lengths sometimes work well to reduce delay for pedestrians and minor street approaches, however, the progression along the corridor can be easily disrupted. An optimum cycle length balances these two considerations of delay and progression. Additionally, it is important to consider how selection of a cycle length at an intersection affects operations at adjacent intersections. System-wide coordination would be accomplished by using complementary cycle lengths throughout the system or grouping of intersections. The optimum cycle length is the merging of the following factors:

- System-wide coordination
- Proximity of study corridors to other major corridors in the system
- Intersection vehicular demand (through and turning movements)
- Minimum cycle length
- Pedestrian and bicyclist volumes
- Overall intersection delay and level of service
- Intersection approach/movement delays
- Progression

Various cycle lengths were considered and evaluated against the items listed above with consideration given to performance of existing cycle lengths. The selection of a standard cycle length for all the project corridors allows the potential for cross coordination of corridors that intersect each other. Ultimately, the cycle lengths selected for Phase 1 and 2 of Green Light Lincoln Traffic Signal Optimization project were also selected for the Phase 4 corridors due to the number of shared intersections with Phases 1 and 2. To reduce delay for minor street approaches, half cycle lengths were considered at intersections where traffic volumes were light enough to maintain efficient progression with a shorter cycle length.

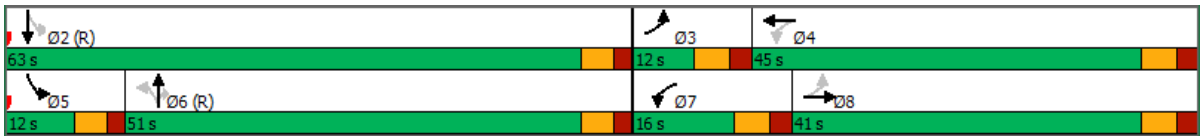
The existing cycle lengths varied within time-of-day plans but were generally similar to those ultimately selected for implementation. For the AM and PM peak periods, 120 seconds was selected for the cycle length. The MD period traffic volumes are less than the AM and PM peak hours, and thus a lower cycle length of 100 seconds was selected. The OP cycle length of 70 seconds was selected to keep the side street delay low during the late-night/early-morning hours when traffic volumes are lower. For the Sun Valley Boulevard corridor, it was decided to keep some intersections similar to existing operations of running "free," meaning there is no set cycle length, due to relatively low volume and for flexibility with events at adjacent facilities.

Several additional intersections were included with Phase 4. These are intersections not located on one of the listed study corridors. Many of these are isolated intersections. An intersection is considered isolated if there are not any nearby signals with which to establish coordinated progression timing plans. However, some of the additional intersections are coordinated with nearby signals during certain times of day. Additional intersections with coordinated timing plans include:

- N. 14th Street & Salt Creek Roadway – coordinated with Antelope Valley Parkway
- S. 13th Street & Arapahoe Street – coordinated along S. 13th Street
- NW 48th Street & W. Adams Street and NW 48th Street & W. Huntington Avenue – coordinated together
- N. 52nd Street & R Street – coordinated along R Street
- N. 63rd Street & Adams Street – coordinated with N. 66th Street
- N. Cotner Boulevard & R Street – coordinated along R Street
- Pedestrian Signal East of S. 36th Street & Randolph Street – coordinated along Randolph Street
- Touzalin Avenue & Fremont Street – coordinated with N. 56th Street
- US Highway 34 & W. Fletcher Avenue and US Highway 34 & Fallbrook Drive – coordinated together

3.4.3 Splits and Offsets

Synchro software was used to develop the initial proposed timing plans. Intersection splits and offsets were determined after model development and selection of proposed cycle lengths. Synchro provided initial splits and offsets for each intersection through its optimization function. From these initial values, a review of each intersection's splits was conducted to make the most efficient use of the overall cycle length. Changes were made as necessary to satisfy system standards, lower intersection/movement delay and improve coordination along the corridors.



Intersection offsets were determined using a combination of Synchro and Tru-Traffic software. Coordination along the corridors was based on directional traffic flow trends by time-of-day with progression favored in the direction of travel having notably higher traffic volumes. In cases where traffic volumes were similar, the offsets were set to maximize traffic flow in both directions. Proposed timing plans were submitted to the City of Lincoln for review, discussion, revision, and approval prior to implementation.

3.4.4 Time-of-Day Schedule

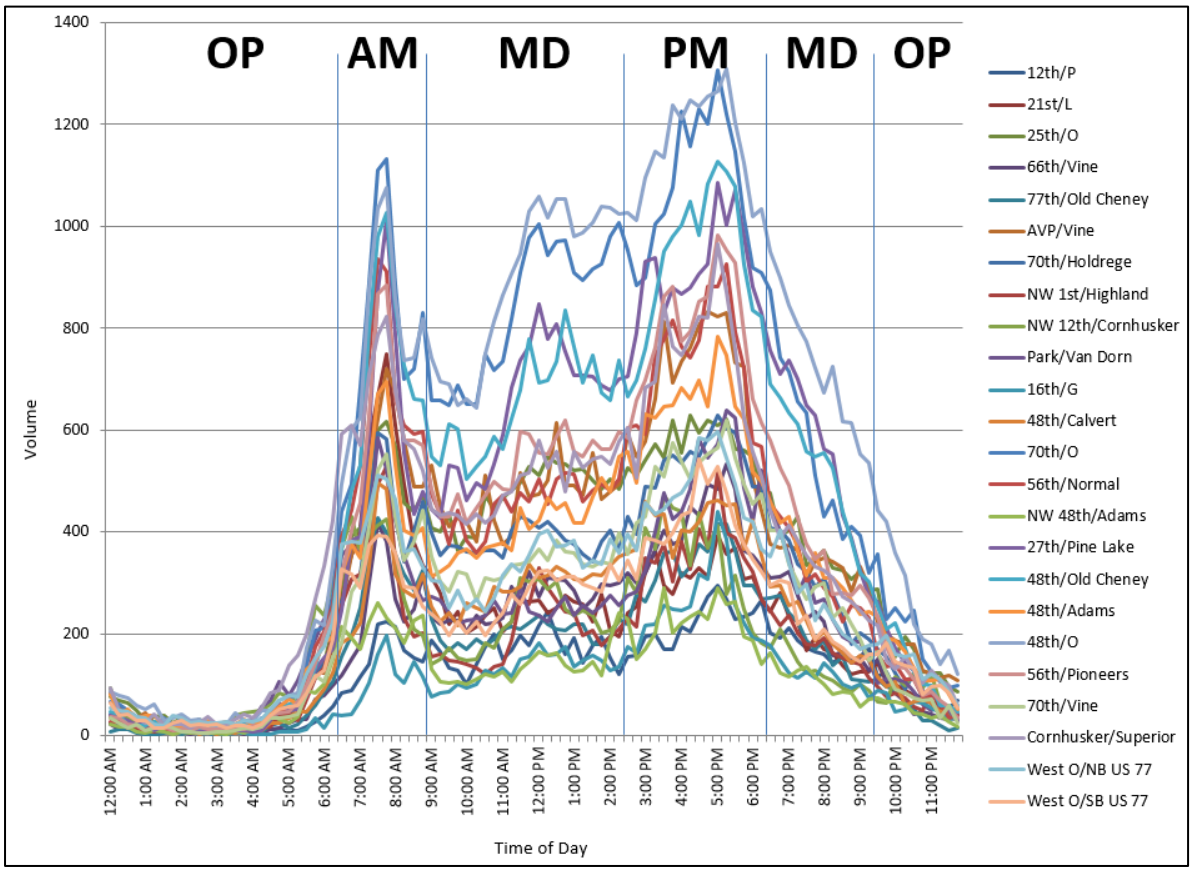
A schedule was developed to operate the proposed timing plans based on patterns from 24-hour volumes throughout the city. **Figure 3** provides a graphical illustration of 24-hour volume data, which shows the variation in traffic volumes throughout the day that was used as the basis for developing the time-of-day schedule. The spikes seen in the AM and PM peak periods of the graph are typical of weekday traffic, as commuters are traveling to and from work.

During these AM and PM peak periods, longer cycle lengths than those during the remainder of the day are typically needed to serve the increase in vehicle demand. To accommodate cross-coordination along intersecting corridors, a common time-of-day plan was selected for all study corridors. However, certain intersections were set to run "free" instead of coordinated operation during certain times of day to maximize efficiency. **Table 1** illustrates the implemented time-of-day schedule.

Table 1: Time-of-Day Schedule

Days	Timing Plan	Time-of-Day
Weekday	AM	6:30 AM – 9:00 AM
	MD	9:00 AM – 2:30 PM 6:30 PM – 9:30 PM
	PM	2:30 PM – 6:30 PM
	OP	9:30 PM – 6:30 AM
Weekend	MD	6:30 AM – 9:30 PM
	OP	9:30 PM – 6:30 AM

Figure 3: Weekday 24-Hour Count Data Graph



3.4.5 Implementation and Field Fine-Tuning

Implementation and field fine-tuning was conducted jointly by Consultant and City staff. This iterative process was conducted over several weeks allowing sufficient time to be dedicated to each corridor. The initial implementation and fine-tuning was completed in fall 2020. Fine-tuning continued in the weeks following the initial implementation to address operational deficiencies that were noted during monitoring of the new timings' operations and based on citizen comments.

Fine-tuning was conducted to further improve operations throughout the system. Movements found needing more time were addressed based on the tradeoff between improving the movement operations and the impact to the overall coordination along the corridor. Offsets were adjusted along the corridors to improve progression based on field observations. In addition to the initial field observations, additional changes were made based on citizen comments received along the project corridors. Any revisions made during the fine-tuning process were recorded and revised in the Synchro and Tru-Traffic files. Final Synchro and Tru-Traffic files were submitted to the City of Lincoln with the final project deliverables.

4.0 Corridor Performance Evaluation

The study corridors were evaluated to determine the effectiveness of the retiming effort. The corridor evaluations consisted of comparing performance measures from "Before" and "After" studies conducted before and after implementation of new signal timings. This chapter provides details on the methodology used to evaluate corridor performance and the results of those evaluations.

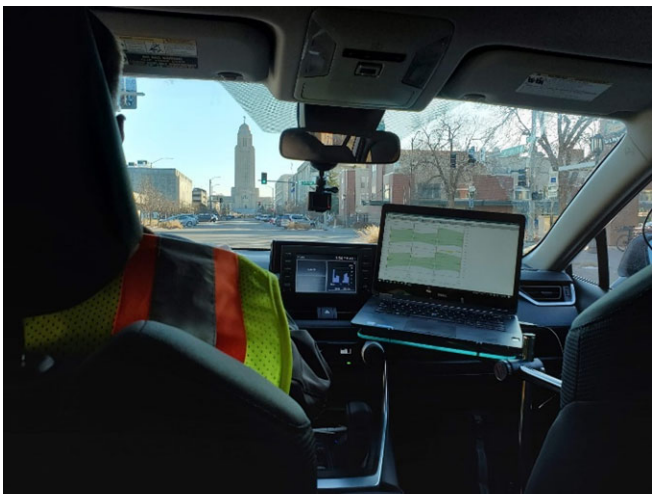
4.1 Performance Evaluation Data

Travel time study data were used to calculate a variety of performance measures. Corridor performance results were based on data from "Before" and "After" travel time studies conducted for each study corridor. The corridor travel time studies occurred during multiple periods throughout the day for "Before" and "After" conditions of implementing the new signal timing plans. The periods for the travel time studies were:

- AM peak period – 7:00 AM – 8:30 AM (Weekday) – All study corridors
- Mid-morning (MM) period – 9:00 AM – 10:30 AM (Weekday) – All study corridors
- MD peak period – 11:30 AM – 1:00 PM (Weekday) – All study corridors
- Mid-afternoon (MA) period – 2:30 PM – 4:00 PM (Weekday) – All study corridors
- PM peak period – 4:00 PM – 6:00 PM (Weekday) – All study corridors
- Weekend MD period – Varied by corridor
    - Saturday – 11:00 AM – 3:00 PM – S. 14th Street, N. 56th Street, N. 66th Street / N. Cotner Boulevard, W. Cornhusker Highway, and Sun Valley Boulevard
    - Sunday – 11:00 AM – 3:00 PM – 33rd Street

The "Before" travel time studies were conducted in September 2020 prior to implementation of new signal timings. The "After" travel time studies were conducted in October/November 2020 after implementation and fine-tuning of new signal timings.

The travel time studies were conducted with a pilot vehicle traveling each study corridor for a minimum of five travel time runs for each time period of "Before" and "After" conditions. During these studies, travel time data was collected with Tru-Traffic software. Tru-Traffic, accompanied with a GPS device, is used to track a vehicle's position while it travels along a corridor. It records the position of the vehicle every second and uses that information, along with inputs on the locations of intersections, to calculate performance measures along the corridor.



4.2 Performance Measures

The following performance measures were identified to be reported for this project:

- **Travel Time** – The time to travel from one end of a study corridor to the other
- **Corridor Performance**
  - **Delay** – The amount of time corridor through traffic is slowed or stopped by traffic signals on a trip from one end of a study corridor to the other
  - **Stops** – The number stops experienced by through traffic on a study corridor on a trip from one end of a study corridor to the other
  - **Fuel Consumption** – The estimated amount of fuel consumed by through traffic on a trip from one end of a study corridor to the other
  - **Emissions** – The estimated emissions produced by through traffic on a trip from one end of a study corridor to the other

Performance measures were summarized for times of the day when travel time studies were completed. This means that benefits derived from the retiming effort are only reported for those hours during the day in which travel time studies were conducted. For the remaining hours of the day, it is expected that additional benefits are realized that are not reported in this study since travel studies were not collected during those times of day.

4.3 User Savings Analysis

The travel time performance measure was reported as the change in travel time between "Before" and "After" conditions by comparing the average time to travel from one end of a study corridor to the other end during the study periods. Travel time was extracted from the travel time run data in Tru-Traffic for each period of "Before" and "After" conditions. "Time" is of value to all people. A reduction in travel time, delay, and fuel consumption keep dollars in the pockets of motorists. These direct savings were tracked and quantified to determine community savings.

Corridor performance measures of delay, stops, fuel consumption, and emissions were calculated using output from Tru-Traffic travel time runs, year 2019 local demographics, and procedures outlined in the City of Lincoln *Traffic Signal Timing Guidelines v2.0*. Each of the corridor performance measures was reported as the change between "Before" and "After" conditions.

4.4 Summary of Performance Measures and User Savings

Results from the performance evaluation show that new signal timings along the six study corridors produced substantial benefits to the community. A summary of corridor-specific performance measures is provided below.

4.4.1 Travel Time Results

The average travel time change from "Before" to "After" conditions by time period are provided in **Table 2** for each study corridor. The travel times conducted after the new signal timings were implemented showed a decrease in travel times from the "Before" conditions for most corridor study periods. A total of 72 comparisons were made from "Before" to "After" conditions when considering two directions of travel, during six time periods, and for six corridors. Of the 72 travel time

comparisons, 55 showed a reduction in travel time when traveling from one end of the corridor to the other. It should be noted that most of the travel time comparisons that showed an increase in travel time with the new timings are relatively minor increases. These increases could be attributed to enhanced safety treatments through updated pedestrian and vehicle clearance times at intersections included with the new signal timings.

For those travel time comparisons that showed an increase in travel time, some reasons for an increase include (but are not limited to):

- A change in signal progression to improve flow and reduce travel time in one direction resulted in an increase to travel time in the opposing direction.
- Progression needs of a crossing arterial with higher traffic volumes result in added delay of a study corridor at the crossing intersection.
- Increased pedestrian crossing times resulting in more likelihood for signals operating out of coordination for a period of time.
- Increased vehicle yellow change and all red times at select intersections.
- Consistent time of day plans along a corridor that reduce the likelihood of random progression through signals.
- Day-to-day variation in traffic demand.
- Failed detection, resulting in a constant call on the cross-street, that was not yet fixed during the after runs but was functioning properly during the before runs.

More detailed travel time results, showing the total corridor travel times with the travel time savings, is provided in **Appendix C**.

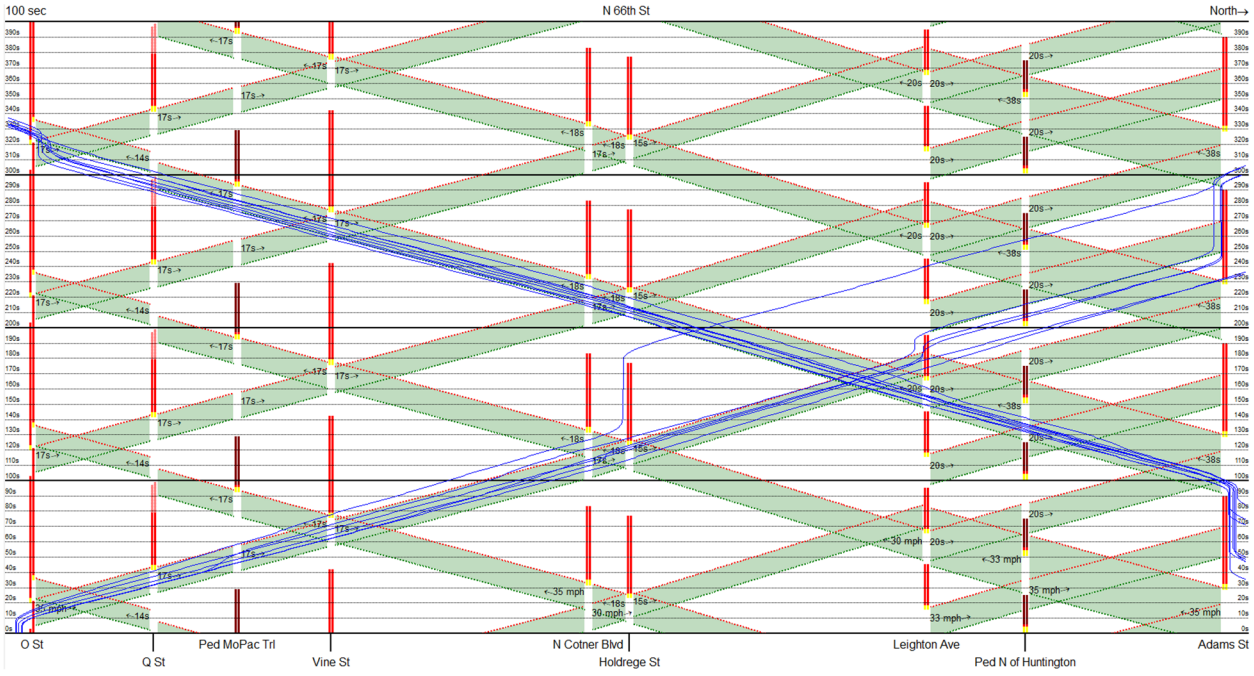


Table 2: Travel Time Comparison from "Before" to "After" Conditions

Corridor	Period	Travel Time Change (Min:Sec)[1]		
		NB/EB	SB/WB	Total
S. 14th Street (YMCA – Old Cheney Rd)	AM	0:36	-0:15	0:21
	MM	-0:09	-0:08	-0:17
	MD	-0:30	-0:23	-0:53
	MA	0:04	-0:08	-0:04
	PM	-0:32	-0:09	-0:41
	WE	-0:13	-0:01	-0:14
33rd Street (D Street – Huntington Avenue)	AM	-0:51	-0:57	-1:48
	MM	0:37	-0:22	0:15
	MD	0:54	-0:19	0:35
	MA	-0:22	-0:11	-0:33
	PM	-0:54	-1:03	-1:57
	WE	-1:03	-0:34	-1:37
N. 56th Street (O Street – Adams Street)	AM	-0:29	0:13	-0:16
	MM	-0:19	0:12	-0:07
	MD	-0:01	-0:03	-0:04
	MA	-1:24	-1:07	-2:31
	PM	-1:04	-1:02	-2:06
	WE	-0:39	-0:37	-1:16
N. 66th Street (O Street – Fremont Street)	AM	-0:08	-0:44	-0:52
	MM	-1:36	-1:33	-3:09
	MD	-0:52	-1:23	-2:15
	MA	-1:11	-1:35	-2:46
	PM	-0:57	-1:24	-2:21
	WE	-0:40	-1:38	-2:18
Sun Valley Boulevard (West O Street – Cornhusker Highway)	AM	0:36	-0:13	0:23
	MM	-0:07	0:09	0:02
	MD	-0:22	0:09	-0:13
	MA	-0:22	-0:26	-0:48
	PM	0:21	-0:11	0:10
	WE	0:23	0:14	0:37
W. Cornhusker Highway (NW 12th Street & Adams Street – N. 11th Street)	AM	-0:23	-0:10	-0:33
	MM	-0:33	-0:38	-1:11
	MD	-0:09	-0:36	-0:45
	MA	0:19	0:30	0:49
	PM	0:14	0:10	0:24
	WE	0:04	-0:44	-0:40

[1] Negative time values represent a decrease in travel time during the "After" condition as compared to the "Before" condition; Positive time values represent an increase in travel time during the "After" condition.

4.4.2 Corridor Performance Results

The total benefits to corridor performance from "Before" to "After" conditions are summarized in **Table 3**. The corridor performance results show sizable reductions for motorist delay, fuel consumption, stops, and emissions. The reductions to delay and fuel are estimated to save Lincoln motorists over 61,900 hours of delay and $1.4 million in user (time and fuel) costs per year. More detailed corridor performance measures, including a breakdown by study time period, are provided in **Appendix D**. It should be noted that the 42 additional intersections were not included in these results; there is likely some unquantified performance improvement for those locations as well.

Table 3: Corridor Performance Results

Corridor	Annual Savings (From "Before" to "After" Conditions)				
	Delay (Veh-Hours)	Fuel (Gallons)	Stops (Veh-Stops)	Emissions (Kilograms)	User Savings[1] ($)
S. 14th Street (YMCA – Old Cheney Road)	10,500	17,700	875,100	1,800	$229,400
33rd Street (D Street – Huntington Avenue)	11,200	15,000	889,600	1,500	$237,200
N. 56th Street (O Street – Fremont Street)	13,300	21,100	1,224,700	2,100	$289,100
N. 66th Street (O Street – Adams Street)	21,200	28,900	2,091,000	2,900	$447,900
Sun Valley Boulevard (West O Street – Cornhusker Highway)	1,200	6,700	695,400	700	$36,900
W. Cornhusker Highway (NW 12th Street & Adams Street – N. 11th Street)	4,500	14,800	913,500	1,500	$117,600
TOTALS	61,900	104,200	6,689,300	10,500	$1,358,100

[1] Savings based on reductions in delay, fuel, and local demographic information.

4.5 Study Benefit-to-Cost

A benefit-to-cost analysis was completed for the overall study area to understand the return benefit based on City investment. The annual benefit of the project is estimated to be $1.4 million, as shown in **Table 3**. The costs for the project are outlined below:

- Consultant services = $ 330,000
- Equipment & contractor services = $ 200,000
- Total = $ 530,000

The Federal Highway Administration (FHWA) recommends that signal timings be updated every three to five years. Based on the FHWA's recommendation, the quantified benefits are assumed to be realized each year for the next five years. The benefits over five years are expected to be $6.8 million.

The benefit-to-cost ratio is calculated to be 13:1. This shows a significant return on investment through delay and fuel savings to Lincoln motorists. Additionally, the reduction to stops and emissions (which were not monetized), provide a benefit to the air quality in Lincoln. Reduction in stops is expected to provide added safety benefits by reducing crashes (also not monetized). Moreover, these savings are only inclusive for the portion of the day for which travel time data was collected. As a result, benefits are being experienced during other hours of the day and thus, the benefit-to-cost ratio is much greater than 13:1.

5.0 SUMMARY/CONCLUSION

The overall purpose of this project was to prepare and implement optimized traffic signal timing plans in Lincoln and to quantify the changes in traffic operations resulting from signal equipment upgrades and signal timing changes with "before" and "after" performance measures. Data analysis and travel time studies conducted after the new signal timings were implemented showed a decrease in travel times from the "before" conditions. Additionally, updates to pedestrian and vehicle clearance times at study intersections enhance safety at these locations.

The reductions to delay incurred and fuel consumed are estimated to save Lincoln motorists over 61,900 hours of delay and 104,200 gallons of fuel per year, equating to $1.4 million annual user savings. The benefit-to-cost ratio over a five-year period (recommended period between retiming efforts) is 13:1. These savings are only inclusive of travel time and fuel consumption, safety and emissions benefits were not monetized.

A summary of benefits and costs for Phases 1, 2, 3 and 4 of the Traffic Signal System Optimization effort are shown in **Table 4**. Phase 4 resulted in similar benefit-to-cost ratio achieved with Phase 2. Phase 4 had a lower cost per signal when accounting for improvements/repairs to the intersections but also yielded less benefits due to the large number of isolated and additional intersections included with the project. Operational benefits were not quantified at the isolated or additional intersections; these represent the last of the remaining traffic signals in Lincoln to be brought to current City standards by the Green Light Lincoln initiative.

Table 4: Summary of Benefits and Costs for Phases 1, 2, 3 and 4

Variable	Phase 1	Phase 2	Phase 3	Phase 4	Total of Phases 1-4
Annual Delay Savings (Veh-Hours)	437,200	403,000	313,100	61,900	1,215,200
Annual Fuel Savings (Gallons)	575,000	538,700	77,900	104,200	1,295,800
Annual User Savings[1] ($)	$8,766,200	$8,859,600	$4,676,700	$1,358,100	$23,660,600
Project Cost	$2,325,100	$3,173,700	$850,000	$530,000	$6,878,800
Benefit-to-Cost Ratio[2]	19:1	14:1	28:1	13:1	17:1

[1] Savings based on reductions in delay, fuel, and local demographic information.

[2] Benefits calculated for five years based on FHWA recommendation for traffic signal retiming.

The next phase of Traffic Signal System Optimization (Phase 5) is slated for 2021 and will continue the effort to improve safety and mobility in Lincoln. It is recommended to continue retiming efforts throughout the city and retime corridors approximately every three to five years to further save Lincoln motorists time and money.

APPENDIX A

Intersection List

Study Corridors and Intersections (1 of 3)

S. 14th Street	33rd Street	N. 56th Street
S. 14th Street & Old Cheney Road[1]	N. 33rd St & Huntington Ave	N. 56th St & Fremont St
S. 14th Street & Brookridge Circle / S. 16th Street[1]	N. 33rd St & Holdrege St	N. 56th St & Adams St
S. 14th Street & Aberdeen Ave / Old Farm Road	S. 33rd St & Vine St[1]	N. 56th St & Leighton Ave
S. 14th Street & YMCA Drive	S. 33rd St & O St[1]	N. 56th St & Holdrege St
N. 66th Street / N. Cotner Blvd	S. 33rd St & J St	N. 56th St & MoPac Trail (Ped)
N. 66th St & N. Cotner Blvd / Adams St	S. 33rd St & Randolph St	N. 56th St & Vine St[1]
N. Cotner Blvd & Huntington Ave (Ped)	S. 33rd St & D St	N. 56th St & R St
N. Cotner Blvd & Leighton Ave	**Sun Valley Boulevard**	N. 56th St & O St[1]
N. Cotner Blvd & Holdrege St	Cornhusker Hwy & N. 11th St[1]	N. Cotner Blvd & O St[1]
N. 66th St & N. Cotner Blvd / Starr St	N. 11th St & Saunders Ave[1]	**W. Cornhusker Highway**
N. 66th St & Vine St[1]	Sun Valley Blvd & N. 10th St / N. 11th St	Cornhusker Hwy & N. 11th St[1]
N. 66th St & MoPac Trail (Ped)	Sun Valley Blvd & Charleston St	N. 1st St & W. Cornhusker Hwy / Cornhusker Hwy
N. 66th St & Q St	Sun Valley Blvd & Line Dr	NW 4th St & W. Cornhusker Hwy
N. 66th St & O St[1]	Sun Valley Blvd & Westgate Blvd	EB I-80 Ramps & W. Cornhusker Hwy / NW 12th St
	Sun Valley Blvd & West O St[1]	NW 12th St & W. Adams St

[1] Previous Phase Intersection

Study Corridors and Intersections (2 of 3)

Additional Intersections		
NW 48th St & W. Adams St	N. Cotner Blvd & R St	US Hwy 34 & W. Fletcher Ave
NW 48th St & W. Huntington Ave	S. Coddington Ave & W. South St	N. 10th St & Charleston St
N. 33rd St & Northstar HS / N. 33rd Cir	US Hwy 77 & Rosa Parks Way	N. 14th St & Salt Creek Rdwy
Touzalin Ave & Fremont St	US Hwy 77 & W. Denton Rd / Warlick Blvd	N. 14th St & Turtle Creek Rd / Fletcher Ave
N. 63rd St & Adams St	Lucile Dr & Pioneers Blvd	N. 14th St & Adams St
N. Cotner Blvd & Vine St[1]	Dairy Store Dr & Holdrege St	S. 13th St & Arapahoe St
N. 46th St & R St	US Hwy 34 & Fallbrook Dr	S. 51st St & Van Dorn St
N. 52nd St & R St		

[1] Previous Phase Intersection

Study Corridors and Intersections (3 of 3)

Additional Pedestrian Signals		
S. Coddington Ave & W. Jean Ave	N. 73rd St & Vine St	N. 1st St & N of W. Dawes
N. 46th St & Adams St	Colony Ln & Vine St	S. 33rd St & Rousseau Elem
N. 51st St & Holdrege St	Broadmoore & South St	Sheridan Blvd & Van Dorn St
N. 52nd St & Fremont St	Clinton Elem & Holdrege St	W of S. 46th St & Sheridan Blvd/Calvert
N. 60th St & Leighton Ave	Elliott Elem & N St	W of S. 46th St & Pioneers Blvd
N. 61st St & Holdrege St	N. 14th St & Belmont Elem	E of S. 36th St & Randolph St
N. 64th St & Fremont St	Kooser Elem (N of Julesburg on N. 14th St)	

APPENDIX B

Priority Corridor Travel Time Results

Travel Time Results 1 of 2

Corridor	Period	Travel Time (Min:Sec)						Travel Time Change (Min:Sec)[1]		
		"Before"			"After"					
		NB/EB	SB/WB	Total	NB/EB	SB/WB	Total	NB/EB	SB/WB	Total
S. 14th Street (YMCA – Old Cheney Rd)	AM	1:36	1:21	2:57	2:12	1:06	3:18	0:36	-0:15	0:21
	MM	1:34	1:14	2:48	1:25	1:06	2:31	-0:09	-0:08	-0:17
	MD	1:50	1:28	3:18	1:20	1:05	2:25	-0:30	-0:23	-0:53
	MA	1:59	1:16	3:15	2:03	1:07	3:10	0:04	-0:08	-0:04
	PM	3:23	2:03	5:26	2:51	1:55	4:46	-0:32	-0:09	-0:41
	SA	1:43	1:07	2:50	1:30	1:06	2:36	-0:13	-0:01	-0:14
33rd Street (D Street – Huntington Avenue)	AM	6:14	5:52	12:06	5:23	4:55	10:18	-0:51	-0:57	-1:48
	MM	5:18	6:14	11:32	5:55	5:52	11:47	0:37	-0:22	0:15
	MD	4:53	5:48	10:41	5:47	5:29	11:16	0:54	-0:19	0:35
	MA	7:22	5:55	13:17	7:00	5:44	12:44	-0:22	-0:11	-0:33
	PM	7:05	6:50	13:55	6:11	5:47	11:58	-0:54	-1:03	-1:57
	SU	6:16	6:17	12:33	5:13	5:43	10:56	-1:03	-0:34	-1:37
N. 56th Street (O Street – Adams Street)	AM	6:55	6:20	13:15	6:26	6:34	13:00	-0:29	0:13	-0:16
	MM	6:38	5:41	12:19	6:19	5:52	12:11	-0:19	0:12	-0:07
	MD	6:26	5:39	12:05	6:24	5:36	12:00	-0:01	-0:03	-0:04
	MA	6:58	8:08	15:06	5:33	7:01	12:34	-1:24	-1:07	-2:31
	PM	6:53	6:41	13:34	5:49	5:39	11:28	-1:04	-1:02	-2:06
	SA	6:47	6:06	12:53	6:08	5:29	11:37	-0:39	-0:37	-1:16
N. 66th Street (O Street – Fremont Street)	AM	5:12	5:42	10:54	5:04	4:58	10:02	-0:08	-0:44	-0:52
	MM	5:14	5:18	10:32	3:38	3:45	7:23	-1:36	-1:33	-3:09
	MD	5:16	5:12	10:28	4:24	3:50	8:14	-0:52	-1:23	-2:15
	MA	5:37	6:25	12:02	4:26	4:51	9:17	-1:11	-1:35	-2:46
	PM	5:33	6:09	11:42	4:36	4:45	9:21	-0:57	-1:24	-2:21
	SA	5:14	5:34	10:48	4:34	3:56	8:30	-0:40	-1:38	-2:18
W. Cornhusker Highway (NW 12th St & W. Adams Street – N. 11th Street)	AM	3:58	3:23	7:21	3:35	3:13	6:48	-0:23	-0:10	-0:33
	MM	3:31	3:38	7:09	2:58	3:00	5:58	-0:33	-0:38	-1:11
	MD	3:22	3:42	7:04	3:13	3:06	6:19	-0:09	-0:36	-0:45
	MA	3:29	3:25	6:54	3:48	3:55	7:43	0:19	0:30	0:49
	PM	3:34	3:40	7:14	3:48	3:50	7:38	0:14	0:10	0:24
	SA	3:03	3:46	6:49	3:07	3:02	6:09	0:04	-0:44	-0:40
Sun Valley Boulevard (West O Street – Cornhusker Highway)	AM	3:43	3:20	7:03	4:19	3:07	7:26	0:36	-0:13	0:23
	MM	3:52	3:25	7:17	3:45	3:34	7:19	-0:07	0:09	0:02
	MD	4:07	3:21	7:28	3:45	3:30	7:15	-0:22	0:09	-0:13
	MA	4:33	3:46	8:19	4:11	3:20	7:31	-0:22	-0:26	-0:48
	PM	4:15	3:29	7:44	4:36	3:18	7:54	0:21	-0:11	0:10
	SA	3:57	3:21	7:18	4:20	3:35	7:55	0:23	0:14	0:37

[1] Negative time values represent a decrease in travel time during the "After" condition; Positive time values represent an increase in travel time during the "After" condition.

APPENDIX C

Network Performance Measures

Travel Time Run System Evaluation

S 14th Street from Pine Lake Road to Old Cheney Road
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project - Phase 4
Project number: 700158

	Period	Delay Saved Veh-Hrs/Yr	Reduction Delay %	Stops Saved Veh-Stops/Yr	Reduction Stops %	Fuel Saved Gal/Yr	Reduction Fuel %	Carbon Monoxide Emissions Saved grams/Yr	Reduction Carbon Monoxide %	Nitrogen Oxides Emissions Saved grams/Yr	Reduction Nitrogen Oxides %	Volatile Oxygen Compounds Emissions Saved grams/Yr	Reduction Volatile Oxygen %
S 14th Street	AM	-509	-9%	103,476	21%	783	2%	55,825	2%	10,831	2%	12,943	2%
	MM	635	37%	83,249	53%	1,527	10%	105,047	10%	20,413	10%	24,312	10%
	MD	3,307	64%	364,524	72%	7,067	24%	494,995	24%	96,291	24%	114,702	24%
	MA	691	11%	-126,531	-48%	-1,351	-5%	-93,791	-5%	-18,261	-5%	-21,719	-5%
	PM	5,188	36%	326,228	36%	7,340	12%	516,752	13%	100,535	13%	119,769	13%
	WM	1,171	36%	124,176	48%	2,330	9%	163,363	9%	31,782	9%	37,856	9%
	Total	10,483	27%	875,121	31%	17,696	8%	1,242,192	8%	241,592	8%	287,863	8%

Delay Reduction Per Year (hours)	10,483
Value of Travel Time Savings ($/Hour) (Personal Travel)	$14.24
Value of Travel Time Savings ($/Hour) (Business Travel)	$28.48
Value of Travel Time Savings ($/Hour) (Truck Travel)	$31.52
Cost per Hour of Delay	$15.17
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$190,835**
Fuel Consumption Reduction per Year (Gallons)	17,696
Cost of Fuel per Gallon	$2.18
Cost Saving per Year for Fuel Consumption Reduction	**$38,578**
Total Savings per Year	**$229,412**

Note: Total savings reported represent annual savings during the periods of travel time run data collection only. Savings outside of the times of day for which travel time run data was collected are not reported and would be in addition to those reported.

Travel Time Run System Evaluation

33rd Street from D Street to Huntington Avenue
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project - Phase 4
Project number: 700158

	Period	Delay Saved Veh-Hrs/Yr	Reduction Delay %	Stops Saved Veh-Stops/Yr	Reduction Stops %	Fuel Saved Gal/Yr	Reduction Fuel %	Carbon Monoxide Emissions Saved grams/Yr	Reduction Carbon Monoxide %	Nitrogen Oxides Emissions Saved grams/Yr	Reduction Nitrogen Oxides %	Volatile Oxygen Compounds Emissions Saved grams/Yr	Reduction Volatile Oxygen %
33rd Street	AM	2,888	42%	208,678	37%	3,693	13%	257,354	13%	50,070	13%	59,687	13%
	MM	-522	-12%	-60,999	-23%	-977	-5%	-67,238	-5%	-13,042	-5%	-15,597	-5%
	MD	-878	-23%	40,140	12%	-266	-1%	-18,456	-1%	-3,570	-1%	-4,329	-1%
	MA	1,026	11%	127,273	19%	1,748	5%	121,434	5%	23,617	5%	28,155	5%
	PM	6,265	35%	351,940	29%	7,439	13%	516,480	13%	100,519	13%	119,661	13%
	SU	2,424	38%	222,560	46%	3,370	14%	234,749	14%	45,677	14%	54,413	14%
	Total	11,204	22%	889,592	25%	15,007	8%	1,044,322	8%	203,272	8%	241,989	8%

Delay Reduction Per Year (hours)	11,204
Value of Travel Time Savings ($/Hour) (Personal Travel)	$14.24
Value of Travel Time Savings ($/Hour) (Business Travel)	$28.48
Value of Travel Time Savings ($/Hour) (Truck Travel)	$31.52
Cost per Hour of Delay	$15.21
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$204,496**
Fuel Consumption Reduction per Year (Gallons)	15,007
Cost of Fuel per Gallon	$2.18
Cost Saving per Year for Fuel Consumption Reduction	**$32,714**
Total Savings per Year	**$237,210**

Note: Total savings reported represent annual savings during the periods of travel time run data collection only. Savings outside of the times of day for which travel time run data was collected are not reported and would be in addition to those reported.

Travel Time Run System Evaluation

N 56th Street from O Street to Fremont Street
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project - Phase 4
Project number: 700158

	Period	Delay Saved Veh-Hrs/Yr	Reduction Delay %	Stops Saved Veh-Stops/Yr	Reduction Stops %	Fuel Saved Gal/Yr	Reduction Fuel %	Carbon Monoxide Emissions Saved grams/Yr	Reduction Carbon Monoxide %	Nitrogen Oxides Emissions Saved grams/Yr	Reduction Nitrogen Oxides %	Volatile Oxygen Compounds Emissions Saved grams/Yr	Reduction Volatile Oxygen %
N 56th Street	AM	797	10%	31,063	5%	4,700	14%	329,058	14%	64,000	14%	76,227	14%
	MM	1,464	36%	55,315	19%	-306	-2%	-20,152	-2%	-3,919	-2%	-4,670	-2%
	MD	-106	-2%	49,444	11%	228	1%	17,545	1%	3,418	1%	4,063	1%
	MA	4,698	37%	394,435	35%	6,610	16%	460,963	16%	89,713	16%	106,847	16%
	PM	4,477	33%	441,955	31%	6,428	11%	452,358	12%	88,028	12%	104,858	12%
	WM	2,006	32%	252,512	38%	3,453	12%	242,653	12%	47,174	12%	56,243	12%
	Total	13,336	27%	1,224,724	26%	21,113	10%	1,482,424	10%	288,414	10%	343,569	10%

Delay Reduction Per Year (hours)	13,336
Value of Travel Time Savings ($/Hour) (Personal Travel)	$14.24
Value of Travel Time Savings ($/Hour) (Business Travel)	$28.48
Value of Travel Time Savings ($/Hour) (Truck Travel)	$31.52
Cost per Hour of Delay	$15.19
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$243,115**
Fuel Consumption Reduction per Year (Gallons)	21,113
Cost of Fuel per Gallon	$2.18
Cost Saving per Year for Fuel Consumption Reduction	**$46,027**
Total Savings per Year	**$289,142**

Note: Total savings reported represent annual savings during the periods of travel time run data collection only. Savings outside of the times of day for which travel time run data was collected are not reported and would be in addition to those reported.

Travel Time Run System Evaluation

N 66th Street from O Street to Adams Street
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project - Phase 4
Project number: 700158

	Period	Delay Saved Veh-Hrs/Yr	Reduction Delay %	Stops Saved Veh-Stops/Yr	Reduction Stops %	Fuel Saved Gal/Yr	Reduction Fuel %	Carbon Monoxide Emissions Saved grams/Yr	Reduction Carbon Monoxide %	Nitrogen Oxides Emissions Saved grams/Yr	Reduction Nitrogen Oxides %	Volatile Oxygen Compounds Emissions Saved grams/Yr	Reduction Volatile Oxygen %
N 66th Street	AM	2,193	40%	101,411	19%	2,054	8%	144,608	8%	28,114	8%	33,501	8%
	MM	2,837	97%	260,898	85%	3,975	27%	277,631	27%	54,036	27%	64,349	27%
	MD	3,084	73%	269,260	70%	4,259	21%	298,303	21%	58,049	21%	69,137	21%
	MA	4,176	53%	421,288	57%	5,710	19%	397,683	19%	77,381	19%	92,161	19%
	PM	5,368	51%	630,952	57%	7,476	16%	523,714	16%	101,850	16%	121,462	16%
	WM	3,557	62%	407,181	62%	5,408	22%	379,558	22%	73,882	22%	87,984	22%
	Total	21,215	59%	2,090,990	56%	28,882	18%	2,021,499	18%	393,311	18%	468,594	18%

Delay Reduction Per Year (hours)	21,215
Value of Travel Time Savings ($/Hour) (Personal Travel)	$14.24
Value of Travel Time Savings ($/Hour) (Business Travel)	$28.48
Value of Travel Time Savings ($/Hour) (Truck Travel)	$31.52
Cost per Hour of Delay	$15.12
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$384,896**
Fuel Consumption Reduction per Year (Gallons)	28,882
Cost of Fuel per Gallon	$2.18
Cost Saving per Year for Fuel Consumption Reduction	**$62,963**
Total Savings per Year	**$447,859**

Note: Total savings reported represent annual savings during the periods of travel time run data collection only. Savings outside of the times of day for which travel time run data was collected are not reported and would be in addition to those reported.

Travel Time Run System Evaluation

Sun Valley Blvd from West O St to Cornhusker Hwy
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project - Phase 4
Project number: 700158

	Period	Delay Saved Veh-Hrs/Yr	Reduction Delay %	Stops Saved Veh-Stops/Yr	Reduction Stops %	Fuel Saved Gal/Yr	Reduction Fuel %	Carbon Monoxide Emissions Saved grams/Yr	Reduction Carbon Monoxide %	Nitrogen Oxides Emissions Saved grams/Yr	Reduction Nitrogen Oxides %	Volatile Oxygen Compounds Emissions Saved grams/Yr	Reduction Volatile Oxygen %
Sun Valley Blvd	AM	-531	-29%	24,190	14%	-285	-1%	-19,951	-1%	-3,883	-1%	-4,631	-1%
	MM	-62	-3%	34,991	13%	113	1%	8,870	1%	1,766	1%	2,030	1%
	MD	-10	0%	16,499	5%	-150	-1%	-8,644	-1%	-1,691	-1%	-2,030	-1%
	MA	2,080	37%	212,783	42%	3,128	11%	221,174	11%	43,020	11%	51,264	11%
	PM	356	5%	433,320	54%	4,760	11%	333,859	11%	65,015	11%	77,380	11%
	SA	-638	-23%	-26,374	-11%	-915	-4%	-64,688	-5%	-12,605	-5%	-15,018	-5%
	Total	1,196	6%	695,409	29%	6,650	4%	470,619	4%	91,623	4%	108,995	4%

Delay Reduction Per Year (hours)	1,196
Value of Travel Time Savings ($/Hour) (Personal Travel)	$14.24
Value of Travel Time Savings ($/Hour) (Business Travel)	$28.48
Value of Travel Time Savings ($/Hour) (Truck Travel)	$31.52
Cost per Hour of Delay	$15.61
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$22,400**
Fuel Consumption Reduction per Year (Gallons)	6,650
Cost of Fuel per Gallon	$2.18
Cost Saving per Year for Fuel Consumption Reduction	**$14,497**
Total Savings per Year	**$36,896**

Note: Total savings reported represent annual savings during the periods of travel time run data collection only. Savings outside of the times of day for which travel time run data was collected are not reported and would be in addition to those reported.

Travel Time Run System Evaluation

Cornhusker from 11th Street to W Adams Street
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project - Phase 4
Project number: 700158

	Period	Delay Saved Veh-Hrs/Yr	Reduction Delay %	Stops Saved Veh-Stops/Yr	Reduction Stops %	Fuel Saved Gal/Yr	Reduction Fuel %	Carbon Monoxide Emissions Saved grams/Yr	Reduction Carbon Monoxide %	Nitrogen Oxides Emissions Saved grams/Yr	Reduction Nitrogen Oxides %	Volatile Oxygen Compounds Emissions Saved grams/Yr	Reduction Volatile Oxygen %
Cornhusker	AM	2,736	40%	138,065	23%	3,787	9%	263,932	9%	51,374	9%	61,132	9%
	MM	2,602	83%	309,952	80%	5,426	22%	376,694	22%	73,292	22%	87,284	22%
	MD	2,068	51%	280,770	63%	5,103	15%	354,549	15%	69,022	15%	82,182	15%
	MA	-2,861	-62%	-69,885	-20%	-2,502	-6%	-173,296	-6%	-33,710	-6%	-40,187	-6%
	PM	-1,848	-22%	-5,986	-1%	-1,521	-3%	-103,877	-2%	-20,216	-2%	-24,092	-2%
	SA	1,844	60%	260,541	87%	4,493	16%	312,998	16%	60,861	16%	72,509	16%
	Total	4,540	17%	913,456	34%	14,785	7%	1,031,001	7%	200,623	7%	238,828	7%

Delay Reduction Per Year (hours)	4,540
Value of Travel Time Savings ($/Hour) (Personal Travel)	$14.24
Value of Travel Time Savings ($/Hour) (Business Travel)	$28.48
Value of Travel Time Savings ($/Hour) (Truck Travel)	$31.52
Cost per Hour of Delay	$15.67
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$85,362**
Fuel Consumption Reduction per Year (Gallons)	14,785
Cost of Fuel per Gallon	$2.18
Cost Saving per Year for Fuel Consumption Reduction	**$32,231**
Total Savings per Year	**$117,593**

Note: Total savings reported represent annual savings during the periods of travel time run data collection only. Savings outside of the times of day for which travel time run data was collected are not reported and would be in addition to those reported.