GREEN LIGHT LINCOLN™

IT'S GO TIME

PHASE 1 TRAFFIC SIGNAL SYSTEM OPTIMIZATION

FEBRUARY 2018

PREPARED BY:

CITY OF LINCOLN™ NEBRASKA Traffic Engineering

IN COORDINATION WITH:

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EXECUTIVE SUMMARY

This report documents the results of traffic engineering work completed for the Green Light Lincoln – Phase 1 Traffic Signal System Optimization project. Over 120 intersections on or adjacent to nine major corridors were studied and evaluated for improved safety and traffic flow. Phase 1 corridors include:

- S. 70th Street
- S. 84th Street
- N. 84th Street
- Antelope Valley Parkway
- Capitol Parkway / Normal Boulevard
- Cornhusker Highway
- Nebraska Highway 2
- O Street
- Vine Street

The primary objective of the project was to prepare and implement optimized traffic signal timing plans along the study corridors 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 a computerized software model (Synchro). Study corridors / intersections were evaluated for many variables to bring the timing plans into conformance with current best practices including proper time-of-day schedule, desirable left-turn phasing type, cycle length, phase splits, clearance intervals, and pedestrian walk and don't walk times.

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 weeks to achieve the best results possible. 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. Based on the "Before" and "After" data summarized, reductions in delay and fuel are estimated to save Lincoln motorists over 437,000 hours of delay and $8.8 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. Additionally, the implementation of new timings also resulted in 41 countermeasures from the City of Lincoln *2012 Crash Study* being implemented, which is expected to provide additional safety benefits to motorists along these corridors.

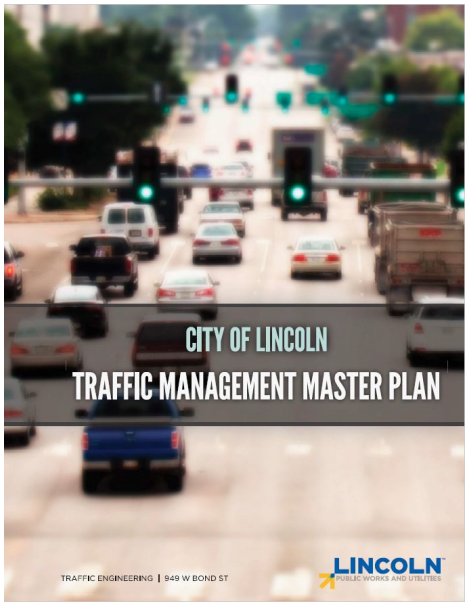
It is recommended to continue retiming efforts throughout the city and retime corridors no more than every five years to further save Lincoln motorists time and money. This project alone produced a calculated benefit-to-cost ratio of 19:1 over the next five-year time frame.

The report that follows documents in detail the Phase 1 Traffic Signal System Optimization objectives, processes, results, and benefits.

IT'S **GO** TIME.

1.0 INTRODUCTION

This traffic signal system optimization project 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. This focused effort will have realized positive impacts on motorists throughout the community.



Green Light Lincoln includes the following measurable benefits while also supporting other City initiatives:

CLEANER GREENER LINCOLN
MAYOR CHRIS BEUTLER
"OUR HOME, OUR FUTURE, OUR CHOICE"

The overall purpose of this project was to prepare and implement optimized traffic signal timing plans along nine signalized corridors, 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.

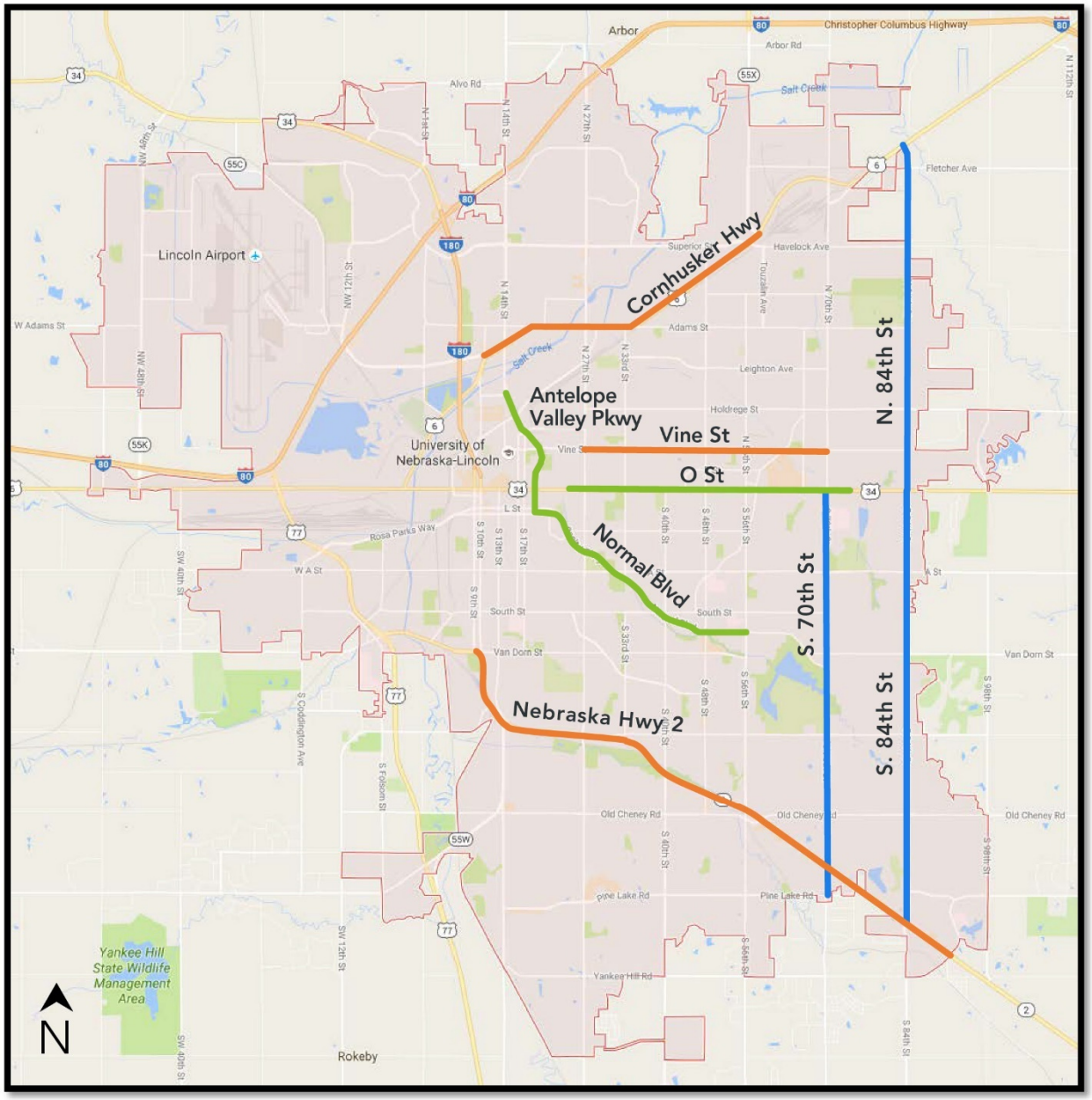
City forces and private contractors upgraded traffic signal controller cabinets, and fixed faulty detection in preparation for new signal timing plans. They also installed new signal heads, improved signal displays, and installed Flashing Yellow Arrow (FYA) indications to achieve uniformity across the city. Their collective efforts paved the way for the signal timing implementation portion of this project.

Three Consultants were tasked with signal timing changes and performance measure documentation and assigned the following corridors (Consultant listed in parenthesis):

- S. 70th Street – Pine Lake Road to O Street (Iteris)
- S. 84th Street – Nebraska Highway 2 to O Street (Iteris)
- N. 84th Street – O Street to Cornhusker Highway (Iteris)
- Antelope Valley Parkway – K Street to Military Road (Olsson Associates)
- Capitol Parkway / Normal Boulevard – Antelope Valley Parkway to S. 56th Street (Olsson Associates)
- Cornhusker Highway – N. 11th Street to N. 56th Street (HDR)
- Nebraska Highway 2 – Van Dorn Street to S. 91st Street (HDR)
- O Street – 25th Street to Skyway Road (Olsson Associates)
- Vine Street – N. 27th Street to N. 70th Street (HDR)

Figure 1 provides a map of the study corridors. A complete list of intersections per corridor is provided in **Appendix A**.

Figure 1: Study Corridors Map



Legend Olsson Associates HDR Iteris

2.0 Data Collection

Data collection and information review efforts were dual-purposed. First, it yielded the characteristics and documentation necessary to perform calculations and support the development of new timing plans. Second, it provided the means to compare operations from updated conditions to baseline conditions.

2.1 City Provided Information

The City of Lincoln provided the following:

- City of Lincoln *Traffic Signal Timing Guidelines*
- City of Lincoln *2012 Crash Study*
- Existing timing plans via ATMS software (ACTRA)
- Synchro files
- Intersection Turning Movement Volumes (TMVs)
- 24-hour Traffic Volumes

2.2 Consultant Collected Information

Consultants collected the following for each intersection:

- Intersection lane configuration / utilization
- Posted speed limits
- Pedestrian crossing distances (crosswalk lengths)
- Vehicle crossing distance (near to far side of intersection)
- Distance between signalized intersections
- Intersection approach grades (see image at right)
- Turn restrictions
- Turn lane storage lengths
- Push button documentation
- Location of mast arm ends
- Intersection approach photographs
- Field observations of traffic operations

2.3 Corridor Descriptions

Each corridor underwent detailed desktop reviews, field reviews at each intersection, and windshield reviews to observe and document corridor characteristics and operations. Characteristics of each study corridor are provided below.

S. 70th Street

The S. 70th Street corridor includes 15 signalized intersections from Pine Lake Road to O Street. The corridor is oriented in a north/south direction and is approximately 5.0 miles long with an average 24-hour volume of 26,800 vehicles. The cross-section for most of the corridor is a four-lane divided roadway, except between Normal Boulevard and South Street, which is a five-lane section with a two-way-left-turn-lane. The posted speed limit along the corridor is 40 mph north of Van Dorn Street and 45 mph south of Van Dorn Street. The land use along S. 70th Street is predominantly residential, with some commercial and retail buildings located on the corners of major intersection. The corridor also provides access to Lincoln East High School. The S. 70th Street corridor also included the adjacent signalized intersection at:

- Pioneers Boulevard & Pioneer Woods Drive / Stacy Lane

S. 84th Street

The S. 84th Street corridor includes 13 signalized intersections from Nebraska Highway 2 to O Street. The corridor is oriented in a north/south direction and is approximately 5.4 miles long with an average 24-hour volume of 23,300 vehicles. The cross-section for most of the corridor is a four-lane divided roadway, except between South Street and O Street, which is a five-lane section with a two-way-left-turn-lane. The posted speed limit along the corridor is 40 mph north of Van Dorn Street and 45 mph south of Van Dorn Street. The land use along S. 84th Street is predominantly residential, with some retail and commercial buildings on the corner of major intersections. The corridor provides access to Lincoln Christian School.

N. 84th Street

The N. 84th Street corridor includes 10 signalized intersections from O Street to Cornhusker Highway. The corridor is oriented in a north/south direction and is approximately 4.3 miles long with an average 24-hour volume of 26,300 vehicles. The cross-section for most of the corridor is a four-lane divided roadway, except between O Street and Vine Street, which is a five-lane section with a two-way-left-turn-lane. The posted speed limit along the corridor is 45 mph north of Vine Street and 40 mph south of Vine Street. The land use along N. 84th Street is rural in nature with new growth areas on the north end, and transitions to residential further south, with some retail and commercial buildings on the corners of major intersections. The corridor provides access to the Lancaster Event Center and Southeast Community College.

Antelope Valley Parkway

The Antelope Valley Parkway corridor includes 10 signalized intersections from K Street to Military Road. The corridor is oriented in a north/south direction and is approximately 1.8 miles long with an average 24-hour volume of 15,800 vehicles. The cross-section for most of the corridor is a six-lane divided roadway while narrowing to a four-lane divided section from approximately R Street to Vine Street. The posted speed limit along the corridor is 35 mph south of Vine Street and 40 mph north of Vine Street. The corridor serves as a boundary for the University of Nebraska – Lincoln campus and provides access to east downtown, the Bob Devaney Sports Center, and Nebraska Innovation Campus.

Capitol Parkway / Normal Boulevard

The Capitol Parkway / Normal Boulevard corridor includes 13 signalized intersections from Antelope Valley Parkway to S. 56th Street. The corridor is oriented in a northwest/southeast direction and is approximately 3.2 miles long with an average 24-hour volume of 25,400 vehicles. The corridor involves separate one-way streets (K Street and L Street) on the west end, becomes a four-lane divided boulevard (Capitol Parkway) to A Street, then transitions to a five-lane section, with a two-way left-turn lane, to S. 56th Street. The posted speed limit along the corridor is 35 mph west of S. 27th Street and 40 mph east of S. 27th Street. It is also reduced to 35 mph from S. 48th Street to S. 56th Street. Many land uses are included along the corridor; schools, parks, zoo, residential, and businesses. Capitol Parkway / Normal Boulevard provides access to downtown, the State Capitol, Lincoln High School, and Lincoln Children's Zoo. The Capitol Parkway / Normal Boulevard corridor also included the adjacent signalized intersections at:

- S. 27th Street & Randolph Street
- S. 27th Street & J Street
- S. 27th Street & M Street (signalized pedestrian crossing)
- S. 40th Street & South Street
- S. 33rd Street & A Street

Cornhusker Highway

The Cornhusker Highway corridor includes 10 signalized study intersections from N. 11th Street to N. 56th Street. The corridor is oriented in a northeast/southwest direction and is approximately 3.9 miles long with an average 24-hour volume of 25,200 vehicles. The cross-section for most of the corridor is a four-lane divided roadway, except between N. 20th Street and N. 29th Street, which is a six-lane divided section. The posted speed limit along the corridor is 45 mph. The land use along Cornhusker Highway is mostly commercial and light industrial with some access to residential areas. The west boundary of the corridor is approximately one-quarter mile from I-180. Between N. 33rd Street and N. 56th Street, Cornhusker Highway parallels the BNSF Railway railroad tracks. The corridor provides access to I-180 and N. 56th Street. The Cornhusker Highway corridor also included the adjacent signalized intersection at:

- N. 11th Street & Saunders Avenue

Nebraska Highway 2

The Nebraska Highway 2 corridor includes 16 signalized study intersections from Van Dorn Street to S. 91st Street. The corridor is oriented in a southeast/northwest direction and is approximately 7.4 miles long with an average 24-hour volume of 26,300 vehicles. The cross-section for most of the corridor is a four-lane divided roadway. The posted speed limit on the study corridor transitions from 35 mph to 45 mph between Van Dorn Street and Pioneers Boulevard, is 45 mph between Pioneers Boulevard and Old Cheney Road, and is 55 mph east of Old Cheney Road. The land use along Nebraska Highway 2 is mostly commercial with access to residential areas. Nebraska Highway 2 also parallels railroad tracks from Pioneers Boulevard to S. 56th Street. The Nebraska Highway 2 corridor also included the adjacent signalized intersections at:

- S. 27th Street & Woods Boulevard
- S. 33rd Street & Pioneers Boulevard
- S. 56th Street & Shady Creek Drive
- S. 56th Street & Old Cheney Road
- Vandervoort Drive & Old Cheney Road

O Street

The O Street corridor includes 15 signalized intersections from 25th Street to Skyway Road. The corridor is oriented in an east/west direction and is approximately 3.6 miles long with an average 24-hour volume of 32,600 vehicles. The cross-section for the corridor is a four-lane divided roadway from 25th Street to 46th Street and Wedgewood Drive to Skyway Road. From 46th Street to Wedgewood Drive, it widens to a six-lane divided section. The posted speed limit along the corridor is generally 40 mph except west of 27th Street (35 mph) and east of Wedgewood Drive (45 mph). Land use along O Street is predominantly commercial/ retail. The corridor provides access to downtown and Gateway Mall. The O Street corridor also included the adjacent signalized intersections at:

- N. 27th Street & P Street
- N. 48th Street & Target Drive
- N. 48th Street & R Street

Vine Street

The Vine Street corridor includes 10 signalized study intersections from N. 27th Street to N. 70th Street. The corridor is oriented in an east/west direction and is approximately 3.0 miles long with an average 24-hour volume of 15,400 vehicles. The cross-section between N. 27th Street and N. Cotner Boulevard is a four-lane section. East of N. Cotner Boulevard, the cross-section changes to a three-lane section with a two-way left-turn lane. The posted speed limit along the corridor is 35 mph. The land use along Vine Street is predominately residential with commercial near the N. 27th Street and N. 48th Street intersections. The corridor also provides access to UNL and Gateway Mall.

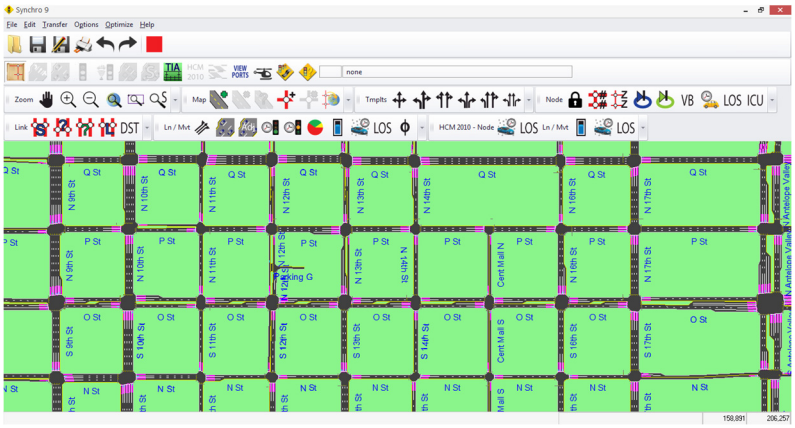
3.0 Traffic Signal System Optimization

This section discusses the development of optimized traffic signal timing plans and associated tasks for the project corridors. Specifically, existing timings were reviewed and included in the existing conditions Synchro model, then the project team developed optimized timings for each corridor by conducting analyses of the cycle length, phasing, and timing parameters described below. Optimized timings were developed for four time periods, which are:

- 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. 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 into the Synchro models and returned to the Consultants updated Synchro models for the AM, MD, and PM peak hours. 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. A factor to apply to MD volumes to generate OP volumes for use in developing OP signal timings was developed from 24-hour volumes at spot locations around the city. This resulted in a factor of 0.4 applied to the MD volumes to develop OP volumes. 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 Additional 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 and having available right-of-way to accommodate the additional turn lane are shown in **Table 1**. These additional lanes should be considered during the planning of future improvements. The locations noted with an asterisk (*) in the "Additional Lane" column of **Table 1** require only pavement marking modifications. The remaining locations would require new pavement. There are several specific locations (listed in **Table 1**) where the addition of a right-turn lane would achieve operational benefits. As a general recommendation; exclusive right-turn lanes should be considered at every intersection approach along arterial streets to reduce the potential for rear-end collisions caused by turning traffic from the through travel lane.

Table 1: Additional Auxiliary Lanes

Intersection	Additional Lane	Justification
S. 70th St & Pioneers Blvd	SB Left*	Movement exceeds 300 vehicles per hour (vph); continue to monitor while delaying installation to avoid going to protected only operations.
S. 70th St & Old Cheney Rd	EB Left*	Movement exceeds 300 vph; continue to monitor while delaying installation to avoid going to protected only operations.
S. 84th St & A Street	NB Left	Movement exceeds 300 vph.
S. 84th St & Pioneers Blvd	EB Left*	Movement exceeds 300 vph; continue to monitor while delaying installation to avoid going to protected only operations.
S. 84th St & Old Cheney Rd	SB Left*	Movement exceeds 300 vph; continue to monitor while delaying installation to avoid going to protected only operations.
Capitol Pkwy & S. 27th St	WB Right	Movement exceeds 200 vph.
Normal Blvd & South St	SB/EB/WB Right	Movements exceed 200 vph.
Normal Blvd & S. 40th St	NB/EB/WB Right	Movements exceed 300 vph.
Normal Blvd & S. 48th St	EB/WB Right	Movements exceed 400 vph.
Normal Blvd & S. 56th St	EB/WB Right	Movements exceed 400 vph.
Cornhusker Hwy & N. 29th St	WB Left	Movement exceeds 300 vph.
O Street & 27th Street	NB/SB/EB/WB Right	Intersection and movements at capacity, all exceed or approach 100 vph, Crash Study recommendation.

* Denotes where the additional lane can be provided by pavement marking modifications

3.2.2 Left-Turn Storage Length

During field observations, locations where turn bay length is not sufficient to store queued vehicles during peak volume times of the day were noted. Some of these locations have 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. Locations where vehicles spilled out of the turn bay and into the adjacent through traffic lane, which have additional median length available to lengthen the storage bay, are noted below:

- S. 70th Street & Normal Boulevard (unsignalized); NB Left turn
- N. 84th Street & Adams Street; NB Left turn
- N. 84th Street & Holdrege Street; NB and SB Left turns
- 84th Street & O Street; EB Left turn
- Antelope Valley Parkway & Vine St; SB Left turn
- Capitol Parkway & S. 27th Street; EB Left turn
- Nebraska Highway 2 & S. 56th Street; EB Left turn
- Nebraska Highway 2 & Old Cheney Road; EB Left turn
- Nebraska Highway 2 & S. 70th Street; EB Left turn

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

3.2.3 Left-Turn Phasing

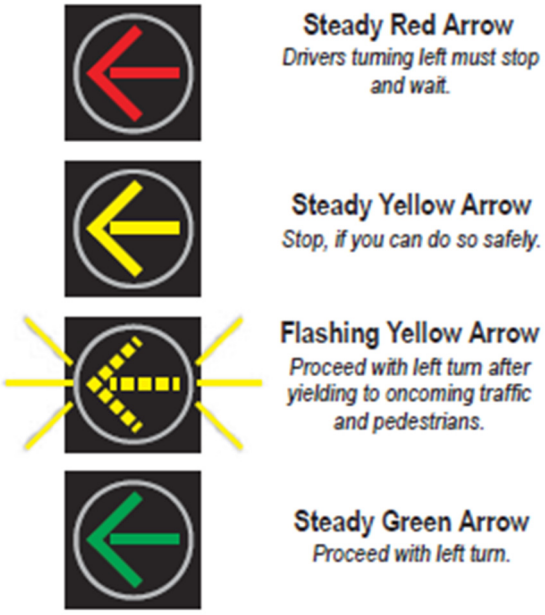
An analysis of left-turn phasing was conducted to determine the least restrictive level of control that could be used to operate left-turn movements efficiently and safely. This analysis was conducted based on the guidance provided in the City of Lincoln *Traffic Signal Timing Guidelines*. The results 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.

3.2.4 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:

- Flexibility to use any type of left-turn operation (i.e., permissive, protected/permissive, protected)
- 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 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 states 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.

3.2.5 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.

- O Street & 44th Street – Insufficient sight distance for NB right-turn (add No Turn On Red for NB right turn)
- O Street & 52nd Street – SB left queue blocks the Hy-Vee drive north of O Street
- Capitol Parkway & Randolph Street – EB queues back to J Street; eliminate dual WB Right
- Railroad preemption can cause random stops along Cornhusker Highway during train events and for a few minutes after the train preemption ends while controllers work to get back into coordination time step at the following locations:
    - Cornhusker Highway & N. 33rd Street
    - Cornhusker Highway & N. 35th Street
    - Cornhusker Highway & N. 44th Street
- Intersection approach lane utilization at two-lane approaches heavily favors the inside through lane at locations with lane drops shortly downstream of study intersections. These intersection approaches include:
    - Nebraska Highway 2 & S. 27th Street – NB approach
    - Nebraska Highway 2 & S. 40th Street – NB approach

- Nebraska Highway 2 & S. 48th Street – NB approach
- Normal Boulevard & S. 48th Street – NB approach
- O Street & 48th Street – WBL approach
- O Street & 70th Street – NB approach
- Vine Street & N. 33rd Street – NB and SB approaches
- Vine Street & N. Cotner Boulevard – EB approach
- Vine Street & N. 66th Street – NB approach

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 *2012 Crash Study* was reviewed for recommendations specific to project intersections. A field review was conducted at those locations to determine if the recommendations had been implemented and if not, if they were still applicable. Findings from the field review were summarized and submitted to the City of Lincoln. The majority of countermeasures recommended from the crash study at project intersections involve signal timing updates and/or phasing changes. Those countermeasures that involved signal timing related improvements were implemented as part of this project, which resulted in implementation of 41 countermeasures identified in the *2012 Crash Study*. The countermeasures implemented as part of this project are summarized in **Appendix B**.

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 (min) green, yellow, all red, WALK, 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 min green, yellow, all red, WALK, 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

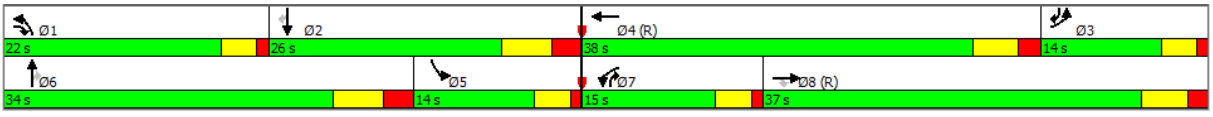
An optimum cycle length provides sufficient green time to efficiently serve all movements at an intersection while providing efficient flow of traffic along a corridor from one intersection to the next. Long cycle lengths generally accommodate efficient flow of traffic, however, they generally cause greater delays for the minor approaches. Short cycle lengths sometimes work well to reduce delay for minor approaches, however, the traffic flow along the corridor can be easily disrupted. An optimum cycle length balances these two considerations of delay and flow. 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 a similar cycle length 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
- Flow of traffic

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 for the cross coordination of corridors that intersect each other. 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 because it is able to satisfy the demand at the majority of the project intersections while providing efficient flow along the corridors. Some intersections would likely have benefited from a longer cycle length, but the improvement in operations at those few locations would have been outweighed by the increase in delay at other intersections. 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.

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 the Tru-Traffic software. Coordination along the corridors was determined 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 2** provides a graphical illustration of 24-hour volume data, which show the variation in traffic volumes throughout the day 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. **Table 2** illustrates the implemented time-of-day schedule.

Figure 2: Weekday 24-Hour Count Data Graph

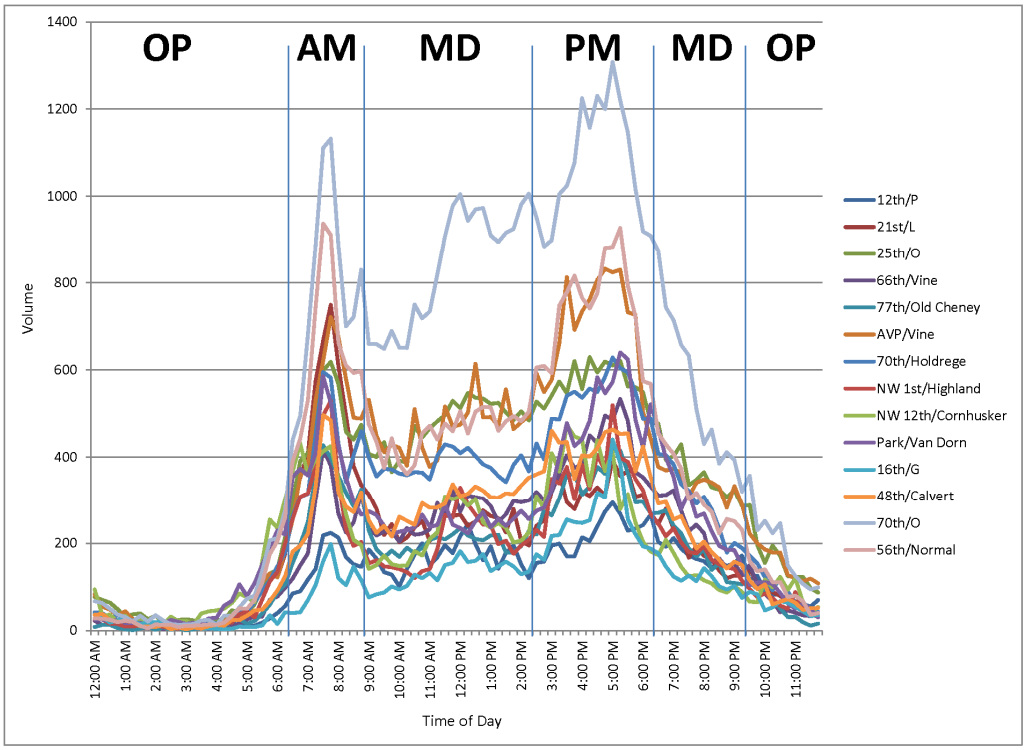


Table 2: Time-of-Day Schedule

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

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 2017. 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 files. Final Synchro 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
- MD peak period – 11:15 AM – 1:00 PM (Weekday) - All study corridors
- PM peak period – 4:00 PM – 6:00 PM (Weekday) - All study corridors
- Other (non-peak) period – Varied by corridor
    - Mid-morning (MM) – 9:00 AM – 10:30 AM (Weekday) – S. 84th Street, Capitol Pkwy / Normal Blvd, Vine Street
    - Post-PM (PP) – 7:00 PM – 8:30 PM (Weekday) – S. 70th Street, Cornhusker Highway, O Street
    - Saturday (SA) – 1:00 PM – 5:00 PM (Saturday) – N. 84th Street, Antelope Valley Parkway, Nebraska Highway 2

The "Before" travel time studies were conducted in fall 2017 prior to implementation of new signal timings. The "After" travel time studies were conducted later in the fall of 2017 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 2017 local demographics, and procedures outlined in the City of Lincoln *Traffic Signal Timing Guidelines*. 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 nine study corridors produced substantial benefits to the community. A summary of corridor-specific performance measures are 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 3** 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 four time periods, and for nine corridors. Of the 72 travel time comparisons, 63 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 (less than 30 seconds). 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.
- Railroad preemption with greater impacts to "After" studies than "Before" studies.
- Day-to-day variation in traffic demand.

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

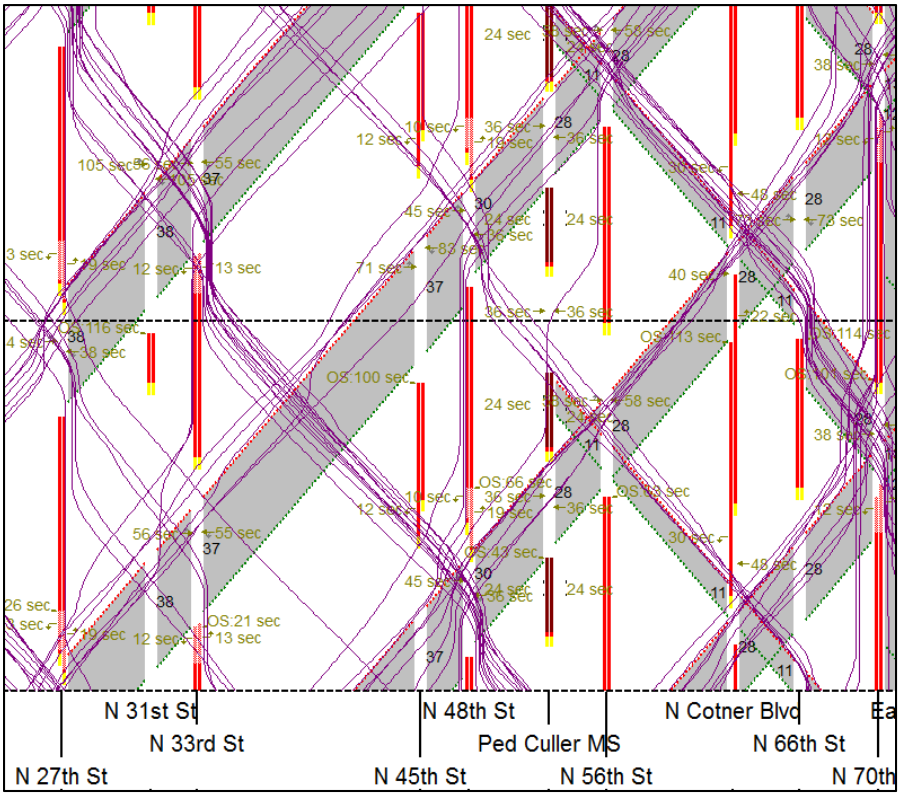


Table 3: Travel Time Comparison from "Before" to "After" Conditions

Corridor	Period	Travel Time Change (Min:Sec)[1]		
		NB/EB	SB/WB	Total
S. 70th Street (Pine Lake Road – O Street)	AM	-0:36	-1:18	-1:54
	MD	-0:54	-1:01	-1:55
	PM	0:17	-1:33	-1:50
	PP	-1:46	0:53	-0:53
S. 84th Street (Nebraska Highway 2 – O Street)	AM	-1:25	-1:40	-3:05
	MD	-1:27	-1:46	-3:13
	PM	-2:02	1:00	-1:02
	MM	-1:25	-1:36	-3:01
N. 84th Street (O Street – Cornhusker Highway)	AM	-0:43	0:18	-0:25
	MD	-0:19	-0:52	-1:11
	PM	0:11	-0:49	-0:38
	SA	-0:08	-1:26	-1:34
Antelope Valley Parkway (K Street – Military Road)	AM	-1:52	-0:23	-2:15
	MD	-2:12	-1:03	-3:15
	PM	-1:43	-2:40	-4:23
	SA	-2:06	-1:28	-3:34
Capitol Pkwy / Normal Blvd (Antelope Valley Pkwy – S. 56th Street)	AM	-0:42	-0:33	-1:15
	MD	-0:41	-1:08	-1:49
	PM	0:20	0:03	0:23
	MM	-1:31	-1:13	-2:44
Cornhusker Highway (N. 11th Street – N. 56th Street)	AM	0:05	-1:34	-1:29
	MD	-0:51	-2:06	-2:57
	PM	-2:16	-2:28	-4:44
	PP	-0:37	-0:28	-1:05
Nebraska Highway 2 (Van Dorn Street – S. 91st Street)	AM	-1:08	-2:52	-4:00
	MD	-1:43	-2:14	-3:57
	PM	-3:25	-3:54	-7:19
	SA	-2:00	-2:44	-4:44
O Street (25th Street – Skyway Road)	AM	-1:08	-1:37	-2:45
	MD	-1:14	-0:39	-1:53
	PM	-1:53	-3:05	-4:58
	PP	-1:11	-0:39	-1:50
Vine Street (N. 27th Street – N. 70th Street)	AM	-0:16	-1:48	-2:04
	MD	-1:28	-1:57	-3:25
	PM	-1:05	-1:06	-2:11
	MM	-0:52	-2:03	-2:55

[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 4**. 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 437,000 hours of delay and $8.8 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**.

Table 4: Corridor Performance Results

Corridor	Annual Savings (From "Before" to "After" Conditions)				
	Delay (Veh-Hours)	Fuel (Gallons)	Stops (Million Veh-Stops)	Emissions (Kilograms)	User Savings[1] ($)
S. 70th Street (Pine Lake Road – O Street)	33,300	62,900	3.7	6,300	$701,900
S. 84th Street (Nebraska Highway 2 – O Street)	36,400	54,000	2.6	5,400	$731,400
N. 84th Street (O Street – Cornhusker Highway)	19,200	35,800	1.7	3,600	$403,300
Antelope Valley Parkway (K Street – Military Road)	45,500	72,300	4.4	7,200	$923,700
Capitol Pkwy / Normal Blvd (Antelope Valley Pkwy – S. 56th Street)	20,700	5,000	1.9	500	$353,300
Cornhusker Highway (N. 11th Street – N. 56th Street)	41,800	51,400	2.0	5,100	$846,000
Nebraska Highway 2 (Van Dorn Street – S. 91st Street)	117,500	117,000	6.4	11,700	$2,356,500
O Street (25th Street – Skyway Road)	93,500	132,700	6.7	13,200	$1,863,400
Vine Street (N. 27th Street – N. 70th Street)	29,300	43,900	3.0	4,400	$586,700
TOTALS	437,200	575,000	32.4	57,400	$8,766,200

[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 $8.8 million, as shown in **Table 4**. The costs for the project are outlined below:

- Consultant services = $ 516,200
- Equipment = $1,269,700
- Contractor services = $ 539,200
- Total = $2,325,100

The Federal Highway Administration (FHWA) recommends that signal timings be updated at least every 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 $43.8 million.

The benefit-to-cost ratio is calculated to be 19:1. 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 (also not monetized), is expected to provide added safety benefits by reducing crashes. 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 qualitative benefit-to-cost ratio is much greater than 19:1.

5.0 Summary/Conclusion

The overall purpose of this project was to prepare and implement optimized traffic signal timing plans along signalized corridors and to quantify the changes in traffic operations resulting from signal equipment upgrades and signal timing changes with "Before" and "After" performance measures. Travel time studies conducted after the new signal timings were implemented showed a decrease in travel times from the "Before" conditions for most corridor study periods. 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 437,000 hours of delay and 575,000 gallons of fuel per year, equating to $8.8 million annual user savings. The benefit-to-cost ratio over a five-year period (recommended period between retiming efforts) is 19:1. These savings are only inclusive for the portion of the day for which travel time data was collected. Thus, benefits are being experienced during other hours of the day. The implementation of new timings also resulted in 41 countermeasures from the *2012 Crash Study* being implemented, which should provide additional safety benefits to Lincoln motorists.

It is recommended to continue retiming efforts throughout the city and retime corridors no more than every five years to further save Lincoln motorists time and money throughout the city.

APPENDIX A

Corridor Intersection Lists

Study Corridor Intersections (Table 1 of 3)

S. 70th Street	S. 84th Street	N. 84th Street
O Street	Cherrywood Drive	Cornhusker Highway
L Street	Mopac Trail Pedestrian	Havelock Avenue
Wedgewood Drive	Sandalwood Drive	Fremont Street
Teton Drive	A Street	Adams Street
A Street	LFR Station #12	Leighton Avenue
Morley Elementary Pedestrian	Van Dorn Street	Northern Lights Dr / Lexington Ave
South Street	Rockledge Road	Holdrege Street
Van Dorn Street	Firethorn Lane	Vine Street
Holmes Park Road	Pioneers Boulevard	College Park Drive
Pioneers Boulevard	Old Cheney Road	O Street
Stacy Lane	Pine Lake Road	
Glynoaks Drive	Eiger Drive	
Old Cheney Road	Nebraska Highway 2	
Nebraska Highway 2		
Pine Lake Road		
Pioneers Blvd & Pioneer Woods Dr / Stacy Ln		

Study Corridor Intersections (Table 2 of 3)

Antelope Valley Pkwy	Capitol Pkwy / Normal Blvd	Cornhusker Highway
K Street	Antelope Valley Pkwy & K Street	N. 11th Street
L Street	Antelope Valley Pkwy & L Street	N. 20th Street
N Street	S. 21st Street & K Street	N. 27th Street
O Street	S. 21st Street & L Street	State Fair Park Dr / N. 29th Street
P Street	J Street	N. 33rd Street
Q Street	Randolph Street	N. 35th Street
Vine Street	S. 27th Street	N. 44th Street
N. 17th Street	A Street	N. 48th Street
Salt Creek Road	South Street	Superior Street / Havelock Ave
Military Road	S. 40th Street	N. 56th Street
	S. 48th Street	N. 11th Street & Saunders Ave
	S. 52nd Street Pedestrian	
	S. 56th Street	
	S. 27th Street & Randolph Street	
	S. 27th Street & J Street	
	S. 40th Street & South Street	
	S. 33rd Street & A Street	

Study Corridor Intersections (Table 3 of 3)

Nebraska Highway 2	O Street	Vine Street
Van Dorn Street / 9th Street	25th Street	N. 27th Street
Van Dorn Street / 10th Street	27th Street	N. 31st Street
Pioneers Boulevard	33rd Street	N. 33rd Street
S. 13th Street / S. 14th Street	44th Street	N. 45th Street
Southwood Drive	48th Street	N. 48th Street
S. 27th Street	52nd Street	Culler Middle Pedestrian
S. 33rd Street	56th Street	N. 56th Street
S. 40th Street	N. Cotner Boulevard	N. Cotner Boulevard
S. 48th Street	Lyncrest Drive	N. 66th Street
S. 56th Street	63rd Street	N. 70th Street
Old Cheney Road	66th Street	
Apples Way	68th Street	
S. 70th Street	70th Street	
S. 84th Street	Wedgewood Drive	
S. 87th Street	Skyway Road	
S. 91st Street	N. 27th Street & P Street	
S. 27th Street & Woods Dr	N. 48th Street & Target Drive	
S. 33rd Street & Pioneers Blvd	N. 48th Street & R Street	
S. 56th Street & Shady Creek Dr		
S. 56th Street & Old Cheney Rd		
Old Cheney Rd & Vandervoort Dr		

APPENDIX B

Implemented 2012 Crash Study Countermeasures

Implemented 2012 Crash Study Countermeasures

Intersection	Crash Pattern	Countermeasure	Phase 1 Improvement
S. 70th St & Wedgewood Dr	NB Rear End	Review signal timing clearance intervals	Clearance intervals updated
N. 84th St & Holdrege St	NB & SB Rear Ends	Review signal timing clearance intervals	Clearance intervals updated
	Left Turns	Install flashing yellow arrow on NB and SB approaches and operate protected only by TOD	FYA installed on NB and SB approaches
N. 84th St & Havelock Ave	EB Rear End	Review signal timing clearance intervals	Clearance intervals updated
		Check split time for EB approach in PM, install detection if necessary	EB splits updated with new timings
Capitol Pkwy & J Street	SB Left Turn	Review signal timing clearance intervals	Clearance intervals updated
Capitol Pkwy & S. 27th Street	NB/SB/WB Rear End	Review signal timing clearance intervals	Clearance intervals updated
	NB/SB Rear End	Update signal timing to improve coordination in the NB and SB direction	Coordination improved with new timings
Normal Blvd & S. 40th St	NB Rear End	Review signal timing clearance intervals	Clearance intervals updated
Normal Blvd & S. 48th St	EB Rear End & SB Right Angle	Review signal timing clearance intervals	Clearance intervals updated
Cornhusker Hwy & N. 27th St	SB Rear End	Update Signal Timing to Improve Coordination in Both NB/SB and EB/WB Directions	Coordination improved with new timings
	NB/SB/EB Rear End	Review Signal Timing Clearance Intervals	Clearance intervals updated
Cornhusker Hwy & State Fair Park Rd	Rear End	Review Signal Timing Clearance Intervals	Clearance intervals updated
Cornhusker Hwy & N. 44th St	Rear End and Right Angle	Review Signal Timing Clearance Intervals	Clearance intervals updated
	All Crash Patterns	Conduct Signal Warrants Analysis, Consider Removing Signal	Analysis conducted - Signal warranted
Nebraska Hwy (Hwy 2) & S. 27th St	EB/WB Rear End	Update Signal Timing to Improve Coordination	Coordination improved with new timings
	NB/SB Rear End	Review Signal Phase Sequences on NB and SB Approaches to Reduce Queue Spillback	Coordination improved with new timings
Nebraska Hwy (Hwy 2) & S. 70th St	Right Angle	Review Signal Timing Clearance Intervals	Clearance intervals updated
Nebraska Hwy (Hwy 2) & S. 84th St	EB/WB Rear End	Review Signal Timing Clearance Intervals	Clearance intervals updated
	EB/WB Rear End	Consider Lead/Lag Left Turns for the EB and WB Left Turn Movements	Phasing updated with new timings
Nebraska Hwy (Hwy 2) & S. 87th St	EB/WB Rear End	Review Signal Timing Clearance Intervals	Clearance intervals updated
O Street & 25th Street	EB Rear End	Adjust signal timing at 27th street to prevent queue spillback	Timing adjusted with new timings
	NB Right Angle	Review signal timing clearance intervals	Clearance intervals updated
	NB Right Angle	Update NB split if necessary	NB split adjusted with new timings
	All Crash Patterns	Conduct signal warrants analysis, consider removing signal	Analysis conducted - Signal warranted
O Street & 27th Street	NB/SB Rear End	Update signal timing to improve coordination on the NB and SB approaches	Coordination improved with new timings
O Street & 48th Street	EB/WB Rear End	Update signal timing to improve coordination	Coordination improved with new timings
	EB/WB/SB Rear End	Review signal timing clearance intervals	Clearance intervals updated
O Street & 52th Street	EB & WB Left Turn	Review signal timing clearance intervals	Clearance intervals updated
O Street & 56th Street	SB Right Angle & EB Rear End	Review signal timing clearance intervals	Clearance intervals updated
O Street & N. Cotner Blvd	EB Rear End & NB Right Angle	Review signal timing clearance intervals	Clearance intervals updated
O Street & 66th Street	SB Rear End	Review signal timing clearance intervals	Clearance intervals updated
O Street & 70th Street	NB Rear End	Review Signal timing for NB queue clearing	Timing adjusted with new timings
S. 27th Street & J Street	EB Right Angle	Review Signal timing clearance intervals	Clearance intervals updated

Implemented 2012 Crash Study Countermeasures (Continued)

Intersection	Crash Pattern	Countermeasure	Phase 1 Improvement
Vine Street & N. 27th Street	NB Rear End	Update Signal Timing to Improve Coordination	Coordination improved with new timings
	SB Left Turn	Implement Flashing Yellow Arrow Signal Indications on all Approaches	FYA installed on all approaches
	NB Rear End and SB Left Turn	Review Signal Timing Clearance Intervals	Clearance intervals updated
Vine Street & N. 33rd Street	Left Turn	Implement Flashing Yellow Arrow Operation on all Approaches	FYA installed on all approaches
	Left Turn and Right Angle	Review Signal Timing Clearance Intervals	Clearance intervals updated
Vine Street & N. 48th Street	NB/EB Rear End	Review Signal Timing Clearance Intervals	Clearance intervals updated
Vine Street & N. 70th Street	EB/NB Rear End	Review Signal Timing Clearance Intervals	Clearance intervals updated

APPENDIX C

Travel Time Results

Travel Time Results

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. 70th Street (Pine Lake Road – O Street)	AM	10:54	11:20	22:14	10:18	10:02	20:20	-0:36	-1:18	-1:54
	MD	11:10	10:06	21:16	10:16	9:05	19:21	-0:54	-1:01	-1:55
	PM	12:22	11:39	24:01	12:39	10:06	22:45	0:17	-1:33	-1:50
	PP	10:57	9:21	20:18	9:11	10:14	19:25	-1:46	0:53	-0:53
S. 84th Street (Nebraska Highway 2 – O Street)	AM	10:53	11:30	22:23	9:28	9:50	19:18	-1:25	-1:40	-3:05
	MD	9:10	9:55	19:05	7:43	8:09	15:52	-1:27	-1:46	-3:13
	PM	11:12	9:17	20:29	9:10	10:17	19:27	-2:02	1:00	-1:02
	MM	9:18	9:48	19:06	7:53	8:12	16:05	-1:25	-1:36	-3:01
N. 84th Street (O Street – Cornhusker Highway)	AM	7:05	6:59	14:04	6:22	7:17	13:39	-0:43	0:18	-0:25
	MD	6:39	7:47	14:26	6:20	6:55	13:15	-0:19	-0:52	-1:11
	PM	7:16	8:44	16:00	7:27	7:55	15:22	0:11	-0:49	-0:38
	SA	6:56	8:23	15:19	6:48	6:57	13:45	-0:08	-1:26	-1:34
Antelope Valley Parkway (K Street – Military Road)	AM	7:09	4:45	11:54	5:17	4:22	9:39	-1:52	-0:23	-2:15
	MD	6:02	5:01	11:03	3:50	3:58	7:48	-2:12	-1:03	-3:15
	PM	6:13	7:18	13:34	4:30	4:38	9:08	-1:43	-2:40	-4:23
	SA	6:17	5:48	12:05	4:10	4:20	8:30	-2:06	-1:28	-3:34
Capitol Pkwy / Normal Blvd (Antelope Valley Pkwy – S. 56th Street)	AM	7:29	5:51	13:20	6:47	5:18	12:05	-0:42	-0:33	-1:15
	MD	6:21	6:19	12:40	5:41	5:11	10:52	-0:41	-1:08	-1:49
	PM	6:47	7:14	14:01	7:07	7:17	14:24	0:20	0:03	0:23
	MM	6:13	6:20	12:33	4:42	5:07	9:49	-1:31	-1:13	-2:44
Cornhusker Highway (N. 11th Street – N. 56th Street)	AM	7:34	8:00	15:34	7:39	6:26	14:05	0:05	-1:34	-1:29
	MD	7:29	8:39	16:08	6:38	6:33	13:11	-0:51	-2:06	-2:57
	PM	8:57	9:46	18:43	6:41	7:18	13:59	-2:16	-2:28	-4:44
	PP	6:18	6:14	12:32	5:41	5:46	11:27	-0:37	-0:28	-1:05
Nebraska Highway 2 (Van Dorn Street – S. 91st Street)	AM	12:40	14:42	27:22	11:32	11:50	23:22	-1:08	-2:52	-4:00
	MD	12:13	12:45	24:58	10:30	10:31	21:01	-1:43	-2:14	-3:57
	PM	17:27	16:02	33:29	14:02	12:08	26:10	-3:25	-3:54	-7:19
	SA	12:57	13:10	26:07	10:57	10:26	21:23	-2:00	-2:44	-4:44
O Street (25th Street – Skyway Road)	AM	8:55	9:52	18:47	7:47	8:14	16:01	-1:08	-1:37	-2:45
	MD	8:24	8:35	16:59	7:10	7:56	15:06	-1:14	-0:39	-1:53
	PM	11:12	11:15	22:27	9:28	8:10	17:38	-1:53	-3:05	-4:58
	PP	7:15	8:26	15:41	6:05	7:46	13:51	-1:11	-0:39	-1:50
Vine Street (N. 27th Street – N. 70th Street)	AM	7:11	7:35	14:46	6:55	5:47	12:42	-0:16	-1:48	-2:04
	MD	6:39	6:53	13:32	5:11	4:56	10:07	-1:28	-1:57	-3:25
	PM	8:38	7:50	16:28	7:33	6:44	14:17	-1:05	-1:06	-2:11
	MM	6:12	7:00	13:12	5:20	4:57	10:17	-0:52	-2:03	-2:55

[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 D

Corridor Performance Measures

Travel Time Run System Evaluation

S. 70th Street from Pine Lake Rd to O Street
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project
Project number: 702146

	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. 70th Street	AM	12,373	33%	1,012,863	38%	19,935	12%	1,392,896	12%	271,022	12%	322,794	12%
	MD	8,180	31%	769,272	37%	15,207	10%	1,064,323	10%	207,122	10%	246,711	10%
	PM	7,388	13%	1,101,261	26%	16,565	7%	1,155,622	7%	224,849	7%	267,825	7%
	PP	5,387	33%	789,381	62%	11,158	12%	778,537	12%	151,471	12%	180,442	12%
	Total	33,328	24%	3,672,778	36%	62,865	10%	4,391,378	10%	854,464	10%	1,017,771	10%

Delay Reduction Per Year (hours)	33,328
Value of Travel Time Savings ($/Hour) (Personal Travel)	$12.98
Value of Travel Time Savings ($/Hour) (Business Travel)	$25.96
Value of Travel Time Savings ($/Hour) (Truck Travel)	$27.65
Cost per Hour of Delay	$13.87
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$554,776**
Fuel Consumption Reduction per Year (Gallons)	62,865
Cost of Fuel per Gallon	$2.34
Cost Saving per Year for Fuel Consumption Reduction	**$147,104**
Total Savings per Year	**$701,881**

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 we be in addition to those reported.

S. 84th Street Performance Measures

Travel Time Run System Evaluation

S. 84th Street from Nebraska Hwy 2 to O Street
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project
Project number: 702146

	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. 84th Street	AM	15,554	44%	1,255,507	46%	23,468	12%	1,639,111	12%	318,888	12%	379,884	12%
	MD	11,874	89%	1,092,358	86%	21,536	19%	1,503,670	19%	292,544	19%	348,487	19%
	PM	6,184	18%	-43,360	-2%	3,596	2%	252,843	2%	49,182	2%	58,599	2%
	MM	2,741	77%	266,386	74%	5,382	17%	377,083	17%	73,351	17%	87,391	17%
	Total	36,352	45%	2,570,890	43%	53,982	11%	3,772,707	11%	733,966	11%	874,362	11%

Delay Reduction Per Year (hours)	36,352
Value of Travel Time Savings ($/Hour) (Personal Travel)	$12.98
Value of Travel Time Savings ($/Hour) (Business Travel)	$25.96
Value of Travel Time Savings ($/Hour) (Truck Travel)	$27.65
Cost per Hour of Delay	$13.87
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$605,125**
Fuel Consumption Reduction per Year (Gallons)	53,982
Cost of Fuel per Gallon	$2.34
Cost Saving per Year for Fuel Consumption Reduction	**$126,318**
Total Savings per Year	**$731,443**

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 we be in addition to those reported.

N. 84th Street Performance Measures

Travel Time Run System Evaluation

N 84th Street from O Street to Cornhusker Hwy
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project
Project number: 702146

	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 84th Street	AM	2,359	18%	148,658	15%	5,095	5%	355,635	5%	69,215	5%	82,419	5%
	MD	4,374	30%	664,394	54%	11,681	13%	817,017	13%	158,952	13%	189,366	13%
	PM	6,040	16%	335,969	15%	9,331	5%	652,761	5%	126,999	5%	151,312	5%
	SAT	6,431	41%	519,376	43%	9,651	12%	675,875	12%	131,498	12%	156,624	12%
	Total	19,204	24%	1,668,398	29%	35,759	8%	2,501,288	8%	486,664	8%	579,721	8%

Delay Reduction Per Year (hours)	19,204
Value of Travel Time Savings ($/Hour) (Personal Travel)	$12.98
Value of Travel Time Savings ($/Hour) (Business Travel)	$25.96
Value of Travel Time Savings ($/Hour) (Truck Travel)	$27.65
Cost per Hour of Delay	$13.87
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$319,664**
Fuel Consumption Reduction per Year (Gallons)	35,759
Cost of Fuel per Gallon	$2.34
Cost Saving per Year for Fuel Consumption Reduction	**$83,677**
Total Savings per Year	**$403,341**

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 we be in addition to those reported.

Antelope Valley Parkway Performance Measures

Travel Time Run System Evaluation

Antelope Valley Parkway from K Street to Military Road
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project
Project number: 702146

	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 %
Antelope Valley Parkway	AM	8,110	42%	1,014,909	61%	14,914	28%	1,042,915	28%	202,922	28%	241,677	28%
	MD	7,430	62%	759,162	66%	11,809	30%	825,215	30%	160,566	30%	191,235	30%
	PM	22,940	58%	2,016,668	67%	35,056	38%	2,451,214	38%	476,965	38%	568,137	38%
	SA	6,993	57%	636,064	60%	10,525	30%	735,238	30%	143,062	30%	170,435	30%
	Total	45,472	55%	4,426,803	64%	72,304	33%	5,054,582	33%	983,516	33%	1,171,484	33%

Delay Reduction Per Year (hours)	45,472
Value of Travel Time Savings (Personal Travel)	$12.98
Value of Travel Time Savings (Business Travel)	$25.96
Value of Travel Time Savings (Truck Travel)	$27.65
Cost per Hour of Delay	$13.83
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$754,526**
Fuel Consumption Reduction per Year (Gallons)	72,304
Cost of Fuel per Gallon	$2.34
Cost Saving per Year for Fuel Consumption Reduction	**$169,192**
Total Savings per Year	**$923,718**

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 we be in addition to those reported.

Capitol Parkway / Normal Boulevard Performance Measures

Travel Time Run System Evaluation

Capitol Parkway / Normal Boulevard from Antelope Valley Parkway to S. 56th Street
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project
Project number: 702146

	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 %
Capitol Parkway / Normal Boulevard	AM	8,012	55%	494,081	42%	5,993	15%	421,990	15%	82,126	15%	97,806	15%
	MD	7,057	75%	434,068	48%	2,147	6%	149,541	6%	29,110	6%	34,691	6%
	PM	337	1%	539,148	17%	-4,798	-5%	-336,457	-5%	-65,458	-5%	-77,951	-5%
	MM	5,308	79%	381,321	64%	1,683	7%	116,041	7%	22,590	7%	26,935	7%
	Total	20,714	36%	1,848,617	33%	5,026	4%	351,114	4%	68,368	4%	81,481	4%

Delay Reduction Per Year (hours)	20,714
Value of Travel Time Savings ($/Hour) (Personal Travel)	$12.98
Value of Travel Time Savings ($/Hour) (Business Travel)	$25.96
Value of Travel Time Savings ($/Hour) (Truck Travel)	$27.65
Cost per Hour of Delay	$13.74
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$341,530**
Fuel Consumption Reduction per Year (Gallons)	5,026
Cost of Fuel per Gallon	$2.34
Cost Saving per Year for Fuel Consumption Reduction	**$11,760**
Total Savings per Year	**$353,289**

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 we be in addition to those reported.

Cornhusker Highway Performance Measures

Travel Time Run System Evaluation

Cornhusker Highway from N. 11th Street to N. 56th Street
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project
Project number: 702146

	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 Highway	AM	3,998	21%	-91,730	-8%	431	0%	29,572	0%	5,742	0%	6,855	0%
	MD	8,515	38%	540,219	41%	12,533	12%	876,648	12%	170,543	12%	203,180	12%
	PM	26,647	52%	1,435,135	46%	35,588	19%	2,488,159	19%	484,101	19%	576,687	19%
	PP	2,666	47%	131,622	35%	2,819	5%	194,615	5%	37,819	5%	45,140	5%
	Total	41,826	41%	2,015,246	31%	51,370	11%	3,588,993	11%	698,204	11%	831,862	11%

Delay Reduction Per Year (hours)	41,826
Value of Travel Time Savings ($/Hour) (Personal Travel)	$12.98
Value of Travel Time Savings ($/Hour) (Business Travel)	$25.96
Value of Travel Time Savings ($/Hour) (Truck Travel)	$27.65
Cost per Hour of Delay	$14.46
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$725,759**
Fuel Consumption Reduction per Year (Gallons)	51,370
Cost of Fuel per Gallon	$2.34
Cost Saving per Year for Fuel Consumption Reduction	**$120,206**
Total Savings per Year	**$845,965**

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 we be in addition to those reported.

Nebraska Highway 2 Performance Measures

Travel Time Run System Evaluation

Nebraska Highway 2 from Van Dorn Street to S. 91st Street
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project
Project number: 702146

	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 %
Nebraska Highway 2	AM	27,602	49%	1,466,847	42%	40,820	16%	2,852,523	16%	554,980	16%	661,083	16%
	MD	2,766	9%	409,974	20%	-47,674	-24%	-3,334,414	-24%	-648,783	-24%	-772,754	-24%
	PM	72,367	53%	3,767,362	47%	101,258	23%	7,076,251	23%	1,376,748	23%	1,640,000	23%
	SA	14,734	61%	770,931	49%	22,589	14%	1,579,469	14%	307,299	14%	366,080	14%
	Total	117,470	48%	6,415,114	42%	116,993	11%	8,173,830	11%	1,590,245	11%	1,894,410	11%

Delay Reduction Per Year (hours)	117,470
Value of Travel Time Savings ($/Hour) (Personal Travel)	$12.98
Value of Travel Time Savings ($/Hour) (Business Travel)	$25.96
Value of Travel Time Savings ($/Hour) (Truck Travel)	$27.65
Cost per Hour of Delay	$14.78
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$2,082,784**
Fuel Consumption Reduction per Year (Gallons)	116,993
Cost of Fuel per Gallon	$2.34
Cost Saving per Year for Fuel Consumption Reduction	**$273,763**
Total Savings per Year	**$2,356,547**

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 we be in addition to those reported.

O Street Performance Measures

Travel Time Run System Evaluation

O Street from 25th Street to Skyway Road
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project
Project number: 702146

	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 %
O Street	AM	17,639	37%	1,076,633	34%	23,228	14%	1,623,963	14%	315,936	14%	376,323	14%
	MD	13,225	31%	1,414,624	43%	23,985	13%	1,677,318	13%	326,361	13%	388,713	13%
	PM	52,918	44%	3,293,033	40%	68,862	21%	4,813,015	21%	936,476	21%	1,115,467	21%
	PP	9,703	44%	951,032	53%	16,639	16%	1,164,478	16%	226,561	16%	269,861	16%
	Total	93,486	40%	6,735,322	41%	132,714	17%	9,278,773	17%	1,805,333	17%	2,150,363	17%

Delay Reduction Per Year (hours)	93,486
Value of Travel Time Savings (Personal Travel)	$12.98
Value of Travel Time Savings (Business Travel)	$25.96
Value of Travel Time Savings (Truck Travel)	$27.65
Cost per Hour of Delay	$13.84
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$1,552,885**
Fuel Consumption Reduction per Year (Gallons)	132,714
Cost of Fuel per Gallon	$2.34
Cost Saving per Year for Fuel Consumption Reduction	**$310,552**
Total Savings per Year	**$1,863,437**

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 we be in addition to those reported.

Vine Street Performance Measures

Travel Time Run System Evaluation

Vine Street from N. 27th Street to N. 70th Street
Comparison of Before and After Travel Time Runs

Traffic Signal System Optimization Project
Project number: 702146

	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 %
Vine Street	AM	5,313	50%	719,445	63%	9,287	16%	650,655	16%	126,575	16%	150,823	16%
	MD	8,127	117%	873,174	97%	11,917	24%	832,475	24%	161,978	24%	192,868	24%
	PM	11,181	42%	863,792	38%	15,254	14%	1,063,901	14%	206,981	14%	246,554	14%
	MM	4,723	116%	520,108	94%	7,399	22%	519,364	22%	101,046	22%	120,386	22%
	Total	29,344	62%	2,976,520	63%	43,857	18%	3,066,395	18%	596,579	18%	710,631	18%

Delay Reduction Per Year (hours)	29,344
Value of Travel Time Savings ($/Hour) (Personal Travel)	$12.98
Value of Travel Time Savings ($/Hour) (Business Travel)	$25.96
Value of Travel Time Savings ($/Hour) (Truck Travel)	$27.65
Cost per Hour of Delay	$13.75
Average Vehicle Occupancy	1.2
Cost Saving per Year of Delay Reduction	**$484,076**
Fuel Consumption Reduction per Year (Gallons)	43,857
Cost of Fuel per Gallon	$2.34
Cost Saving per Year for Fuel Consumption Reduction	**$102,626**
Total Savings per Year	**$586,702**

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 we be in addition to those reported.