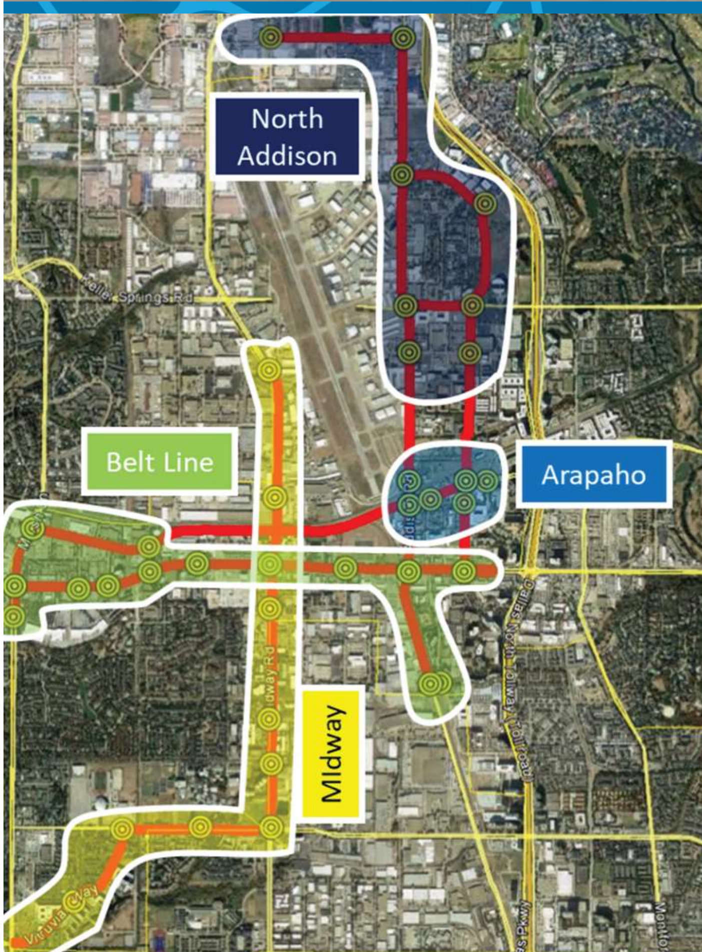
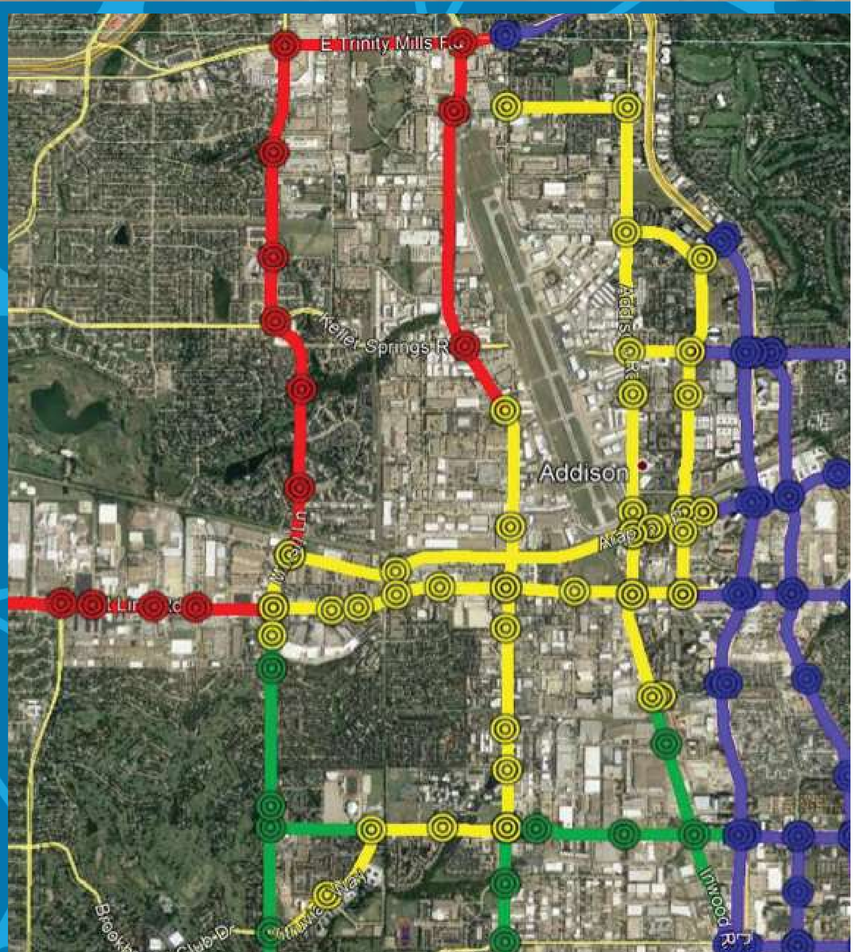
# Addison Town-Wide Signal Retiming


April 2019

Kimley»Horn

Kimley»Horn

# MEMORANDUM


| | |
|---|---|
| To: | Jason Shroyer, P.E.<br>Town of Addison |
| From: | David Halloin, P.E., PTOE<br>Tom Hartmann, P.E., PTOE, IMSA TS II<br>Lucy Richardson, EIT<br>Kimley-Horn and Associates, Inc. |
| Date: | April 1, 2019 |
| Subject: | Addison Town-Wide Retiming |


STATE OF TEXAS
DAVID M. HALLOIN
88511
LICENSED
PROFESSIONAL ENGINEER

4/1/19

Kimley-Horn and Associates contracted with the Town of Addison to develop new coordinated timing plans for all thirty-eight (38) signalized intersections within the Town limits. Addison's Town-wide traffic signal timing plans for coordinated arterial progression were last updated in 2009 and 2010. These plans provide coordination along Belt Line Road, Midway Road, Arapaho Road, Addison Road, Marsh Lane, and Spring Valley Road. Many locations are synchronized with adjacent signals in the cities of Dallas, Carrollton, and Farmers Branch. While timing has been adjusted, and maintained over time, this project revisited control strategies for the entire traffic signal system and developed new timing solutions based on current standards and state of practice.

The project included developing an updated base model for signalized intersections and roadway segments connecting these intersections; performing a baseline analysis of AM, Midday, PM, Late-Night, and Weekend peak periods; recommendations for minor intersection and signal improvements; and development, implementation, and fine-tuning of newly optimized signal timing plans. The goal of this project was to reduce delay, stops, and travel time along major corridors. This report summarizes details and discusses benefits of the new timing plans.

## Description of the Project Area

All thirty-eight (38) of the Town's signalized intersections (inclusive of the pedestrian signal on Belt Line Road) are included in the project area. Five major routes through the Town were included in this project.

Belt Line Road is the major east-west facility in Addison, traversing the entire Town from Carrollton on the west to Dallas on the east. Listed as a Principal Arterial on the 2016 Thoroughfare Plan, Belt Line Road is a six-lane divided roadway with a raised median and turn bays throughout the corridor. The posted speed is 40 mph. Regionally, Belt Line Road serves as an alternate route to the frequently congested IH 635. Belt Line Road is also a heavily commercial corridor, with dozens of restaurants fronting.

Midway Road is a Principal Arterial stretching from Carrollton on the north end of Addison to Farmers Branch on the south side of Addison. Serving as the major north-south corridor, it is a six-lane divided roadway with a raised median and turn bays throughout the corridor. Midway Road has a posted speed of 40 mph. Midway Road is the nearest north-south alternative route west of Dallas North Tollway, serving as a regional corridor. Midway Road is a significant truck route, as the two nearest arterial corridors to the west prohibit truck traffic.

Addison Road is a Minor Arterial running north-south from Trinity Mills Parkway in Carrollton to Belt Line Road. South of Belt Line Road, Addison Road becomes Inwood Road. Addison Road has a four-lane undivided cross-section with no median or midblock turn bays. The posted speed limit is 40 mph. Multiple rail lines cross Addison Road at-grade.

Arapaho Road runs parallel to Belt Line Road with a posted speed limit of 40 mph between Marsh Lane and Addison Road and 35 mph between Addison Road and Dallas North Tollway. Classified as a Minor Arterial, Arapaho Road has a four-lane divided cross-section with a raised median. At Midway Road, Arapaho Road is elevated on the Arapaho Bridge over a rail crossing. The short section of Arapaho Road between Quorum and the Dallas Parkway classified as a Principal Arterial, connecting the Dallas North Tollway corridor with Addison's transit center.

Spring Valley Road is a Principal Arterial, with a six-lane divided cross section, running east-west from Vitruvian Way to Midway Road and Farmers Branch east of Addison. West of Vitruvian Way Spring Valley Road is a minor arterial with a 4-lane cross section, intersecting Marsh Lane in Farmers Branch. Both Greenhill School and George Bush Elementary are located on this section of roadway.

Table 1 lists the thirty-eight (38) project intersections in the Town. The study area is shown in Figure 1.

*Table 1. Project Area Intersections*

| Intersection | Corridor |
|---|---|
| Spring Valley Road & Vitruvian Way | Spring Valley |
| Spring Valley Road & Greenhill School Street | Spring Valley |
| Midway Road & Spring Valley Road | Spring Valley |
| Vitruvian Way & Ponte Avenue | Spring Valley |
| Belt Line Road & Marsh Lane | Belt Line |
| Belt Line Road & Business Avenue | Belt Line |
| Belt Line Road & Commercial Drive | Belt Line |
| Belt Line Road & Surveyor Boulevard | Belt Line |
| Belt Line Road & Runyon Road | Belt Line |
| Belt Line Road & Midway Road | Belt Line |
| Belt Line Road & Beltway Drive | Belt Line |
| Belt Line Road & Addison Road | Belt Line |
| Belt Line Road & Quorum Drive | Belt Line |
| Marsh Lane & Target Driveway | Marsh |
| Marsh Lane & Arapaho Road/Realty Road | Marsh |
| Inwood Road & Landmark Place | Addison Rd |
| Addison Road & Arapaho Road | Addison Rd |
| Addison Road & Lindbergh Drive | Addison Rd |
| Addison Road & Airport Parkway | Addison Rd |
| Addison Road & Keller Springs Road | Addison Rd |
| Addison Road & Westgrove Drive | Addison Rd |
| Addison Road & Sojourn Drive | Addison Rd |
| Westgrove Drive & Sojourn Drive | Addison Rd |
| Quorum Drive & Edwin Lewis Drive | Quorum |
| Arapaho Road & Quorum Drive | Quorum |
| Quorum Drive & Airport Parkway | Quorum |
| Keller Springs Road & Quorum Drive | Quorum |
| Westgrove Drive & Quorum Drive | Quorum |
| Arapaho Road & Surveyor Boulevard | Arapaho |
| Arapaho Road & Edwin Lewis Drive | Arapaho |
| Arapaho Road & Spectrum Drive | Arapaho |
| Midway Road & Hornet Road | Midway |
| Midway Road & Proton Drive | Midway |
| Midway Road & Beltway Drive | Midway |
| Midway Road & Lindbergh Drive | Midway |
| Midway Road & Dooley Road | Midway |

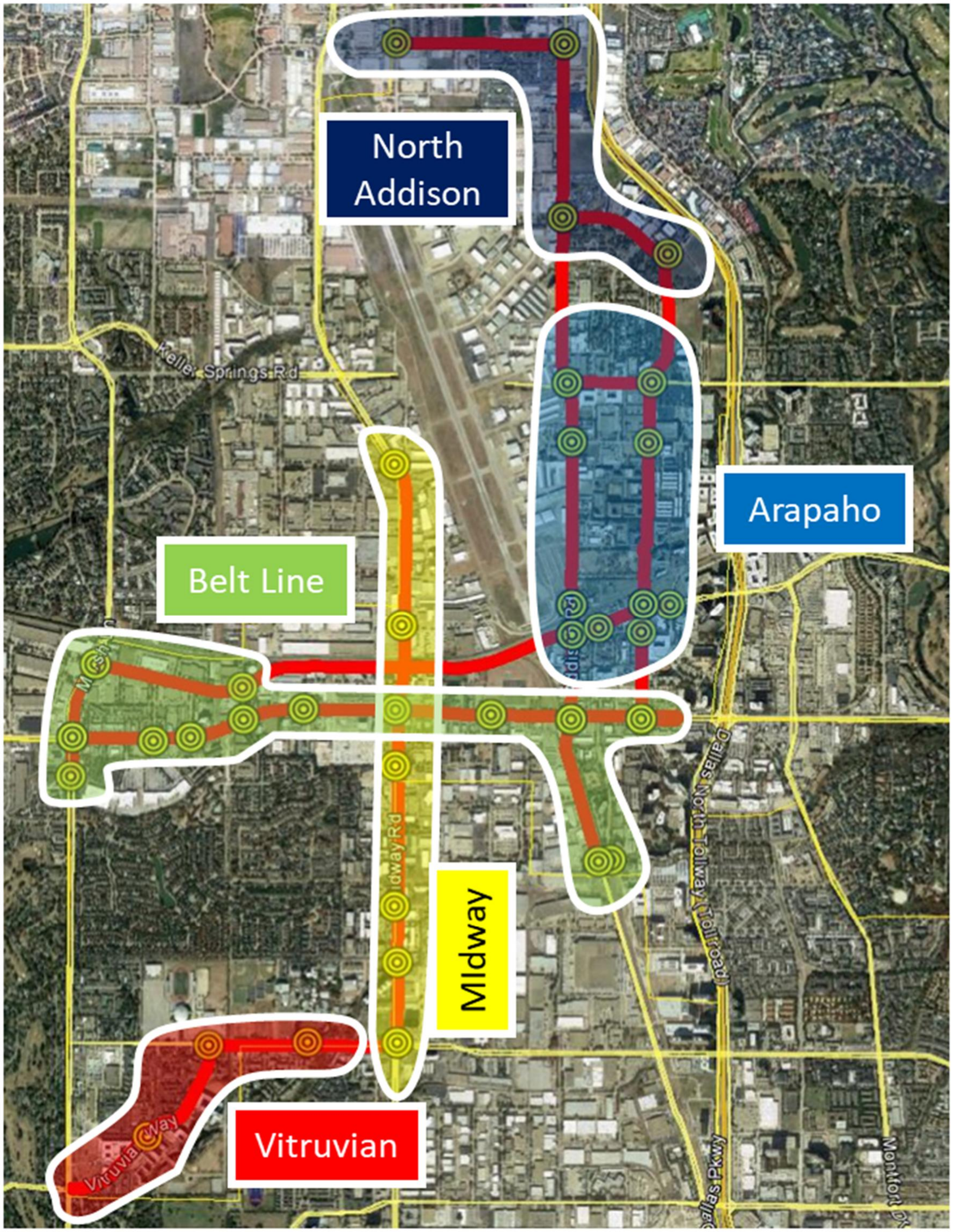



*Figure 1. Existing Control Groups*

### Project Scope

The purpose of this project was to provide optimized traffic signal timing plans at the thirty-eight (38) project intersections in the Town. during the AM, Midday, PM, Late-Night, and Weekend peak periods, and to document the results of the signal timing effort. Specifically, this report will address the following areas:

- Data Collection
- Preparation of New Timing Strategies
- Timing Plan Implementation and Fine Tuning
- Summary of Benefits

## Data Collection

Traffic data collection for this project was performed by GRAM Traffic NTX, as part of a separate town-wide traffic count program. Field verification of counts and volume trends was performed by Kimley-Horn senior staff.

### PREVIOUS OPERATIONS

Previous signal timing was coordinated with neighboring cities of Dallas and Carrollton during much of the week. Belt Line Road was coordinated with Carrollton to the west and Dallas to the east. The Town coordinated with Dallas. to the east, on Arapaho Road, Westgrove Drive, and Keller Springs Road. Timing on Midway Road was coordinated with Carrollton to the north of Addison. Marsh Lane was also coordinated with Carrollton to the north and Farmers Branch to the south.

The Town previously operated five basic timing plans, with two variants and special school plans. Since the last town-wide timing project in 2008-2009, the following significant changes occurred:

- Traffic volumes increased 7%
- Arapaho Road increased use as alternate route (open 2006)
- IH 635 (LBJ Freeway) was reconstructed
- Dallas North Tollway added a fourth lane in each direction
- Development & redevelopment, including Vitruvian Park
- Development increase in size & type
- Belt Line Road was improved
- Timing adjustments were made by neighboring agencies
- Signal equipment in the town aged by a decade
- State and national standards changed
- ADA awareness increased

There were numerous unique operations in Addison:

- Uneven Double Cycles
    - Midway Road & Lindbergh Drive
    - Belt Line Road & Surveyor Boulevard

- School plans
    - Midway Road & Hornet Road (2x's northbound left-turn operation in AM)
    - Spring Valley Road & Greenhill School
    - Addison Road & Sojourn Drive
- Special Phasing
    - Arapaho Road, east of Addison Road (half cycles)
    - Inwood/Landmark/Landmark Pl
    - Quorum Drive & Belt Line Road
- HAWK Signal
    - Belt Line Road trail crossing

The critical intersection for the entire Town is Belt Line Road & Midway Road.  The intersection of the Town's only two Primary Arterials drives the operations for a majority of the network.

The Town of Addison provided information regarding existing signal timing and phasing, including phase sequences and controller timing parameters. During field investigations, existing operations were observed and major traffic signal components at each intersection were noted.

Existing (pre-project) control groups are shown in **Figure 1**.

**Tables 2**, **3**, and **4** provide the existing (pre-project) schedules for each intersection on the corridor by control group.

*Table 2. Existing Sunday Time of Day Schedule by Control Group*

<table>
<tr><th></th><th>Vitruvian</th><th>Midway</th><th>Belt Line</th><th>Arapaho</th><th>North Addison</th></tr>
<tr><td>0:00</td><td rowspan="6">Free</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td><td rowspan="8">Free</td><td rowspan="25">Free</td></tr>
<tr><td>1:00</td></tr>
<tr><td>2:00</td></tr>
<tr><td>3:00</td><td rowspan="3">Free</td><td rowspan="3">Free</td></tr>
<tr><td>4:00</td></tr>
<tr><td>5:00</td></tr>
<tr><td>6:00</td><td rowspan="5">Plan 15<br>Late Night<br>45 s</td><td rowspan="5">Plan 15<br>Late Night<br>90 s</td><td rowspan="5">Plan 15<br>Late Night<br>90 s</td></tr>
<tr><td>7:00</td></tr>
<tr><td>7:30</td><td rowspan="3">Plan 15<br>Low Vol - Nite Coord<br>80 s</td></tr>
<tr><td>8:00</td></tr>
<tr><td>9:00</td></tr>
<tr><td>10:00</td><td rowspan="11">Plan 14<br>Weekend Day - Low<br>60 s</td><td rowspan="11">Plan 14<br>Weekend Day - Low<br>120 s</td><td rowspan="11">Plan 14<br>Weekend Day - Low<br>120 s</td><td rowspan="11">Plan 14<br>Weekend<br>90 s</td></tr>
<tr><td>10:30</td></tr>
<tr><td>12:00</td></tr>
<tr><td>13:00</td></tr>
<tr><td>14:00</td></tr>
<tr><td>15:00</td></tr>
<tr><td>16:00</td></tr>
<tr><td>17:00</td></tr>
<tr><td>18:00</td></tr>
<tr><td>19:00</td></tr>
<tr><td>20:00</td></tr>
<tr><td>21:00</td><td rowspan="3">Free</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td><td rowspan="3">Free</td></tr>
<tr><td>22:00</td></tr>
<tr><td>23:00</td></tr>
</table>

*Table 3. Existing Weekday Time of Day Schedule by Control Group*

<table>
<tr><th></th><th>Vitruvian</th><th>Midway</th><th>Belt Line</th><th>Arapaho</th><th>North Addison</th></tr>
<tr><td>0:00</td><td rowspan="7">Free</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td><td rowspan="8">Free</td><td rowspan="9">Free</td></tr>
<tr><td>1:00</td></tr>
<tr><td>2:00</td></tr>
<tr><td>3:00</td><td rowspan="2">Free</td><td rowspan="2">Free</td></tr>
<tr><td>4:00</td></tr>
<tr><td>5:00</td><td rowspan="2">Plan 15<br>Late Night<br>90 s</td><td rowspan="2">Plan 15<br>Late Night<br>90 s</td></tr>
<tr><td>5:30</td></tr>
<tr><td>6:00</td><td>Plan 25<br>Weekday Off-Peak<br>60 s</td><td>Plan 25<br>Weekday Off-Peak<br>1202 s</td><td>Plan 25<br>Weekday Off-Peak<br>1202 s</td></tr>
<tr><td>6:30</td><td rowspan="3">Plan 11<br>AM<br>80 s</td><td rowspan="3">Plan 11<br>AM<br>160 s</td><td rowspan="3">Plan 11<br>AM<br>160 s</td><td rowspan="3">Plan 11<br>AM<br>160 s</td></tr>
<tr><td>7:00</td><td rowspan="2">Plan 11<br>AM<br>120 s</td></tr>
<tr><td>8:00</td></tr>
<tr><td>9:00</td><td rowspan="3">Plan 25<br>Weekday Off-Peak<br>60 s</td><td rowspan="3">Plan 25<br>Weekday Off-Peak<br>120 s</td><td rowspan="3">Plan 25<br>Weekday Off-Peak<br>120 s</td><td rowspan="10">Plan 12<br>Midday Peak<br>90 s</td><td rowspan="2">Free</td></tr>
<tr><td>10:00</td></tr>
<tr><td>11:00</td><td rowspan="4">Plan 12<br>Off-peak<br>90 s</td></tr>
<tr><td>11:15</td><td rowspan="8">Plan 12<br>Midday Peak<br>67 s</td><td rowspan="8">Plan 12<br>Midday Peak<br>134 s</td><td rowspan="8">Plan 12<br>Midday Peak<br>134 s</td></tr>
<tr><td>12:00</td></tr>
<tr><td>13:00</td></tr>
<tr><td>13:30</td><td rowspan="2">Free</td></tr>
<tr><td>14:00</td></tr>
<tr><td>15:00</td><td rowspan="2">Plan 12<br>Off-peak<br>90 s</td></tr>
<tr><td>15:30</td></tr>
<tr><td>16:00</td><td rowspan="5">Plan 13<br>PM<br>160 s</td><td rowspan="4">Plan 13<br>PM<br>120 s</td></tr>
<tr><td>16:15</td><td rowspan="5">Plan 13<br>PM<br>80 s</td><td rowspan="5">Plan 13<br>PM<br>160 s</td><td rowspan="5">Plan 13<br>PM<br>160 s</td></tr>
<tr><td>17:00</td></tr>
<tr><td>18:00</td></tr>
<tr><td>18:30</td><td rowspan="8">Free</td></tr>
<tr><td>18:45</td><td rowspan="3">Plan 12<br>Midday Peak<br>90 s</td></tr>
<tr><td>19:00</td><td rowspan="3">Plan 25<br>Weekday Off-Peak<br>60 s</td><td rowspan="3">Plan 25<br>Weekday Off-Peak<br>120 s</td><td rowspan="3">Plan 25<br>Weekday Off-Peak<br>120 s</td></tr>
<tr><td>20:00</td></tr>
<tr><td>20:15</td><td rowspan="3">Plan 15<br>Low Vol - Nite Coord<br>80 s</td></tr>
<tr><td>21:00</td><td rowspan="3">Free</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td></tr>
<tr><td>22:00</td></tr>
<tr><td>23:00</td><td>Free</td></tr>
</table>

*Table 4. Existing Saturday Time of Day Schedule by Control Group*

<table>
<tr><th></th><th>Vitruvian</th><th>Midway</th><th>Belt Line</th><th>Arapaho</th><th>North Addison</th></tr>
<tr><td>0:00</td><td rowspan="6">Free</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td><td rowspan="3">Plan 15<br>Late Night<br>90 s</td><td rowspan="9">Free</td><td rowspan="27">Free</td></tr>
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<tr><td>2:00</td></tr>
<tr><td>3:00</td><td rowspan="3">Free</td><td rowspan="3">Free</td></tr>
<tr><td>4:00</td></tr>
<tr><td>5:00</td></tr>
<tr><td>6:00</td><td rowspan="4">Plan 15<br>Late Night<br>45 s</td><td rowspan="4">Plan 15<br>Late Night<br>90 s</td><td rowspan="4">Plan 15<br>Late Night<br>90 s</td></tr>
<tr><td>7:00</td></tr>
<tr><td>8:00</td></tr>
<tr><td>8:30</td><td rowspan="3">Plan 15<br>Low Vol - Nite Coord<br>80 s</td></tr>
<tr><td>9:00</td><td rowspan="2">Plan 14<br>Weekend Day - Low<br>60 s</td><td rowspan="2">Plan 14<br>Weekend Day - Low<br>120 s</td><td rowspan="2">Plan 14<br>Weekend Day - Low<br>120 s</td></tr>
<tr><td>10:00</td></tr>
<tr><td>11:00</td><td rowspan="8">Plan 24<br>Weekend Day -<br>High<br>67 s</td><td rowspan="8">Plan 24<br>Weekend Day -<br>High<br>134 s</td><td rowspan="8">Plan 24<br>Weekend Day -<br>High<br>134 s</td><td rowspan="9">Plan 14<br>Weekend<br>90 s</td></tr>
<tr><td>12:00</td></tr>
<tr><td>13:00</td></tr>
<tr><td>14:00</td></tr>
<tr><td>15:00</td></tr>
<tr><td>16:00</td></tr>
<tr><td>17:00</td></tr>
<tr><td>18:00</td></tr>
<tr><td>19:00</td><td rowspan="3">Plan 14<br>Weekend Day - Low<br>60 s</td><td rowspan="3">Plan 14<br>Weekend Day - Low<br>120 s</td><td rowspan="3">Plan 14<br>Weekend Day - Low<br>120 s</td></tr>
<tr><td>19:30</td><td rowspan="5">Plan 15<br>Low Vol - Nite Coord<br>80 s</td></tr>
<tr><td>20:00</td></tr>
<tr><td>21:00</td><td rowspan="4">Free</td><td rowspan="4">Plan 15<br>Late Night<br>90 s</td><td rowspan="4">Plan 15<br>Late Night<br>90 s</td></tr>
<tr><td>22:00</td></tr>
<tr><td>23:00</td></tr>
<tr><td>23:15</td><td>Free</td></tr>
</table>

## FIELD OBSERVATIONS

Field observations were conducted in May 2018. Locations with queues were noted, with potential solutions to improve those operations.

The following significant observations were made in the AM:

- Marsh & Arapaho – the southbound left turn spills out of the turn bay, blocking the thru lane and stopping on the railroad tracks
- Arapaho & Spectrum – the intersection was getting out of step due to actuations of oversized pedestrian splits

During the Midday peak the following significant observations were made:

- Many pedestrians are crossing Belt Line, so it is critical to cover pedestrian splits
- Traffic was relatively light in the North Addison group, so the 90 second plan is sufficient, and a shorter cycle length could be implemented for the off-peak period

Significant observations made during the PM peak included:

- Belt Line & Quorum – the eastbound approach of Belt Line & Dallas Parkway (City of Dallas Signal) is over capacity and spills back through the Belt Line & Quorum intersection
- Marsh & Arapaho – the westbound right turn is over capacity and has significant queuing
- Belt Line & Surveyor seemed to be a chokepoint for platoons in both directions on Belt Line

## TRAFFIC VOLUME COUNTS

Kimley-Horn identified 90-minute peak periods in the AM, Midday, PM, and Weekend peak periods for which detailed turning movement count (TMC) data was collected in 15-minute intervals at each project intersection. The data was collected on Tuesday, March 6$^{th}$, 2018, Tuesday, March 20$^{th}$, 2018, and Saturday, March 24$^{th}$, 2018 during the following peak periods:

- AM Peak: 7:00 AM – 8:30 AM
- Midday Peak: 12:00 PM – 1:30 PM
- PM Peak: 4:45 PM – 6:15 PM
- Weekend Peak: 2:00 PM – 3:30 PM

For each period, intersection peak hour TMCs were used for the signal optimization modeling. Raw turning movement count data was provided to the City in electronic format as part of the 2018 Town-Wide Count Program.

New recording machine counts were also collected as part of the 2018 Town-Wide Count Program. This data was used for retiming efforts and to develop recommended operating schedules for new timing plans.

## TRAVEL TIME RUNS

Travel time runs were made on the following arterials during each of the periods for which TMC data was collected:

- Belt Line Road, from Marsh Lane to Dallas Parkway
- Arapaho Road, from Marsh Lane to Dallas Parkway
- Addison Road, from Sojourn Drive to Belt Line Road
- Midway Road, from Keller Springs Road to Spring Valley Road

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Travel time runs were made using "floating car techniques," i.e. the driver of the test vehicle car traveled at the pace set by other traffic. *before* and *after* travel time runs were made under a separate contract, as part of the 2018 Town-Wide Traffic Count Program. The *before* runs were made prior to the implementation of any changes to the existing timing on the following dates:

- Wednesday, March 7, 2018
- Thursday, March 22, 2018
- Saturday, March 24, 2018
- Thursday, March 29, 2018
- Tuesday, April 3, 2018
- Saturday, April 7, 2018

These runs established baseline conditions (speeds, delay, and number of stops), to assist in the determination of appropriate progression speeds, and to identify areas where queue management is critical and recurrent congestion may affect progressive traffic movement.

## INRIX DATA

To supplement traditional data, Kimley-Horn obtained crowd-sourced probe-based data from INRIX for the following corridors:

- Belt Line Road (Marsh Lane to Dallas Parkway, 2.2 miles),
- Addison Road (Sojourn Drive to Inwood Road & Landmark Place, 2.5 miles), and
- Midway Road (Spring Valley Road to Dooley Road, 1.8 miles).

This data will supplement *before* and *after* travel time runs to quantify benefits of the signal retiming effort. The data can also be used by the Town to monitor their system and evaluate and rank corridors for future regional traffic signal retiming efforts, based on quantifying the natural degradation of coordinated signal timing over time.

Data from INRIX was used to estimate the signal performance *before* and *after* the corridor was retimed. The data was collected one month *before* and one month *after* implementation, excluding major special events, holidays, and changes in school schedule. Measures of effectiveness (MOEs) evaluated included:

- Speed;
- Travel time;
- Delay; and
- Travel Time Index.

INRIX aggregates speed data from more than 400 sources, including crowd-sourced, public, and proprietary data. The information collected and analyzed by INRIX includes historical GPS data from over 300 million global sources and features historical data availability for nearly 3 years up to the previous day.

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The data was examined during four time periods: weekday AM peak, midday peak, PM peak; and Saturday peak. The specific time periods were determined from travel time data extracted from INRIX. For periods lasting more than one hour, an average value of each MOE was calculated.

Traditional measures of effectiveness (MOEs) include travel time, speed, delay, and stops. INRIX, like all segment-based probe data, is capable of measuring travel time and speed; delay can be calculated as the difference between measured travel time and free flow travel time (based on speed limit). Stops are only available from traditional travel time runs. Travel time index is essentially a normalized measure of delay, calculated from travel times. Tables in the “Projects Benefits” section of this report present the traditional measures of effectiveness, gathered from INRIX data[1].

To quantify the benefits of the signal retiming effort, INRIX data was used to compare operations *before* and *after* the new timing was implemented. Crowd-sourced probe data (e.g. INRIX) has been found to be similarly accurate to Bluetooth probe data. The data (including historical data) is readily available and does not require infrastructure investment. Traditional measures of effectiveness (MOEs), such as travel time and speed are available in the data (delay can be calculated); however, stops are not available from crowd-sourced probe data. The size of the INRIX data sets, which are orders of magnitude greater than traditional travel time runs can provide, allows for calculation of advanced MOEs. These advanced MOEs include travel time index, buffer time, planning index, and confidence intervals for all MOEs. Crowd-sourced probe data does not capture stops, so the floating car travel time runs were used for analysis of that information.

## Preparation of New Timing Strategies

To develop new timing strategies, Synchro™ was used with existing timing information and TMCs for each study period. Strategies for pedestrian clearance times were reevaluated, and specific recommendations were developed for each intersection. The proposed timing plans were presented to Town staff and mutually agreed upon prior to implementation.

### VEHICLE AND PEDESTRIAN CLEARANCE TIMES

Vehicle and pedestrian change and clearance intervals were recalculated for the first time since 2009; calculation procedures have been updated since then;

Recalculation of the vehicular clearances (i.e. yellows and all-reds) was based on the approach speeds and the roadway and intersection geometry (street widths, grades, etc.). These parameters were measured and field-verified.

In the case of pedestrian timing (e.g., walk and flashing don’t walk), recalculation of these intervals was required based on new requirements that were made effective by the 2011 edition of Texas MUTCD. These changes include the following:

[1] https://analytics.inrix.com/roadway_analytics/X47i6C8FnKYugmvD4

- Assumed walking speed of 3.5 feet per second (rather than 4 feet per second); and
- Pedestrian clearance distance from near edge of travel way to far edge of traveled way (rather than from near edge of traveled way to middle of far traffic lane).

The formulas found in NCHRP Report 731 were used to calculate vehicular clearance times. NCHRP 731 forms the basis of the new ITE Recommended Practice and is considered state of the practice for calculating clearance times.

The values calculated by the NCHRP formulas are conservative. Essentially, the NCHRP calculations provide as much or more total clearance time as the ITE formula, with more yellow and slightly less red. Recalculating pedestrian speeds at 3.5 feet per second results in longer pedestrian times, which affects available bandwidth for vehicles on main phases. Per guidance in the Texas Manual on Uniform Traffic Control Devices (MUTCD), yellow and all-red times can be used as part of pedestrian clearance times, decreasing the time required to serve pedestrians. By decreasing the pedestrian clearance interval by the yellow change interval only (not the red clearance interval), bandwidth for the main platoon increased.

## RECOMMENDATIONS FOR SPECIFIC INTERSECTIONS

Recommendations were developed for low-cost modifications and long-term enhancements that could be incorporated on the corridor to further improve overall traffic operations.

The following locations were identified for flashing yellow arrow (FYA) implementation:

- Arapaho Road & Marsh Lane (NB & SB) – installed
- Belt Line Road & Surveyor Boulevard (EB & WB) – installed
- Arapaho Road & Addison Road (all 4 approaches) – Pending
- Keller Springs Road & Addison Road (all 4 approaches) – Pending
- Arapaho Road & Quorum Drive (all 4 approaches) – Pending
- Arapaho Road & Spectrum Drive (EB & WB) – Pending

These locations were selected for Addison's FYA upgrades because lead/lag sequences would allow substantially better two-way signal progression during multiple timing plans and/or allow for dual services of a left turn phase. Other locations along Midway Road will be upgraded as these signals are replaced during the upcoming Midway Road reconstruction project. Under a separate contract, Kimley-Horn is in the process of redesigning Midway Road signals between Hornet Road and Dooley Road. This includes FYA upgrades for all northbound and southbound approaches of Midway, other than the protected-only lefts at Belt Line Road, which will further enhance two-way signal progression.

At Edwin Lewis Drive & Quorum Drive, it is recommended to restripe the eastbound approach to have a shared thru/left lane and a right-turn only lane, then to operate permitted left turns for eastbound and westbound approaches.

To improve traffic operations in the Arapaho group with oversized pedestrian splits, the "return in step" feature of Cobalt controllers is recommended for experimentation.

Kimley»Horn

## NEW SIGNAL TIMING PLANS

To maintain coordination with adjacent coordinated timing in Carrollton and Dallas, cycle length changes were not made for most signals in the study area.

Several new sections of coordination were introduced in the new timing plans. A new 45-second late night plan was developed for Addison Road, to run during the overnight, off-peak, and weekend periods (which previously operated in “free” mode). Coordinated timing was developed for the first time at the intersection of Quorum Drive & Airport Parkway. The intersection of Ponte Avenue & Vitruvian Way was coordinated with Spring Valley & Vitruvian Way for the first time. The intersection of Inwood & Landmark was also tied in with Belt Line & Addison during peak periods, running a half cycle. In the morning, southbound traffic on Inwood is now able to consistently make it through the signal. In the evening, every other cycle of Inwood & Landmark ties in with the northbound service of Belt Line & Addison.

The start of the PM timing plans was adjusted to match the updated schedule at Belt Line & Dallas Parkway, which is operated by the City of Dallas. The signals at Marsh Lane & Arapaho Road and Midway Road & Dooley Road are coordinated with adjacent Carrollton signals during all peaks.

Under the proposed signal timing plans, many of the previous control groups were maintained but modified. The Belt Line Control Group was not altered at all, and it extends west to Josey Lane and East beyond Preston Road. The previous Midway and Vitruvian Control Groups were merged into a single Midway control group, aligned with the Belt Line Control Group. The North Addison Control Group was expanded to include the four (4) northernmost signals in the previous Arapaho Control Group (Addison Road & Keller Springs Road, Keller Springs Road & Quorum Drive, Addison Road & Airport Parkway, and Quorum Drive & Airport Parkway). The Arapaho Control Group was reduced by the same number of intersections.

Belt Line and Midway Control Groups run the same time-of-day schedule and the same cycle lengths to provide crossing arterial progression. The cycle lengths are as follows:

- AM Peak – 160 seconds
- Weekday Off Peak – 120 seconds
- Midday Peak – 134 seconds
- PM Peak – 160 seconds
- Weekend Low Volume – 120 seconds
- Weekend High Volume – 134 seconds
- Late Night – 90/45 seconds

Arapaho Control Group aligns with Belt Line and Midway Control Groups in the AM and PM peaks and Late Night, with different cycle lengths in the Midday/Off-Peak it operates the following cycle lengths:

- AM Peak – 160/80 seconds
- Midday/Off Peak – 90 seconds
- PM Peak – 160/80 seconds
- Weekend Low Volume – 120 seconds
- Late Night – 90/45 seconds

The North Addison Control Group time of day schedule is aligned with the Arapaho Control Group for the most part, but with different cycle lengths. This control group is now coordinated with a short, late night, plan during normal weekend operations:

- AM Peak – 120 seconds
- Midday/Off Peak – 90 seconds
- PM Peak – 120 seconds
- Late Night – 90/45 seconds

New control groups are shown in **Figure 2**.

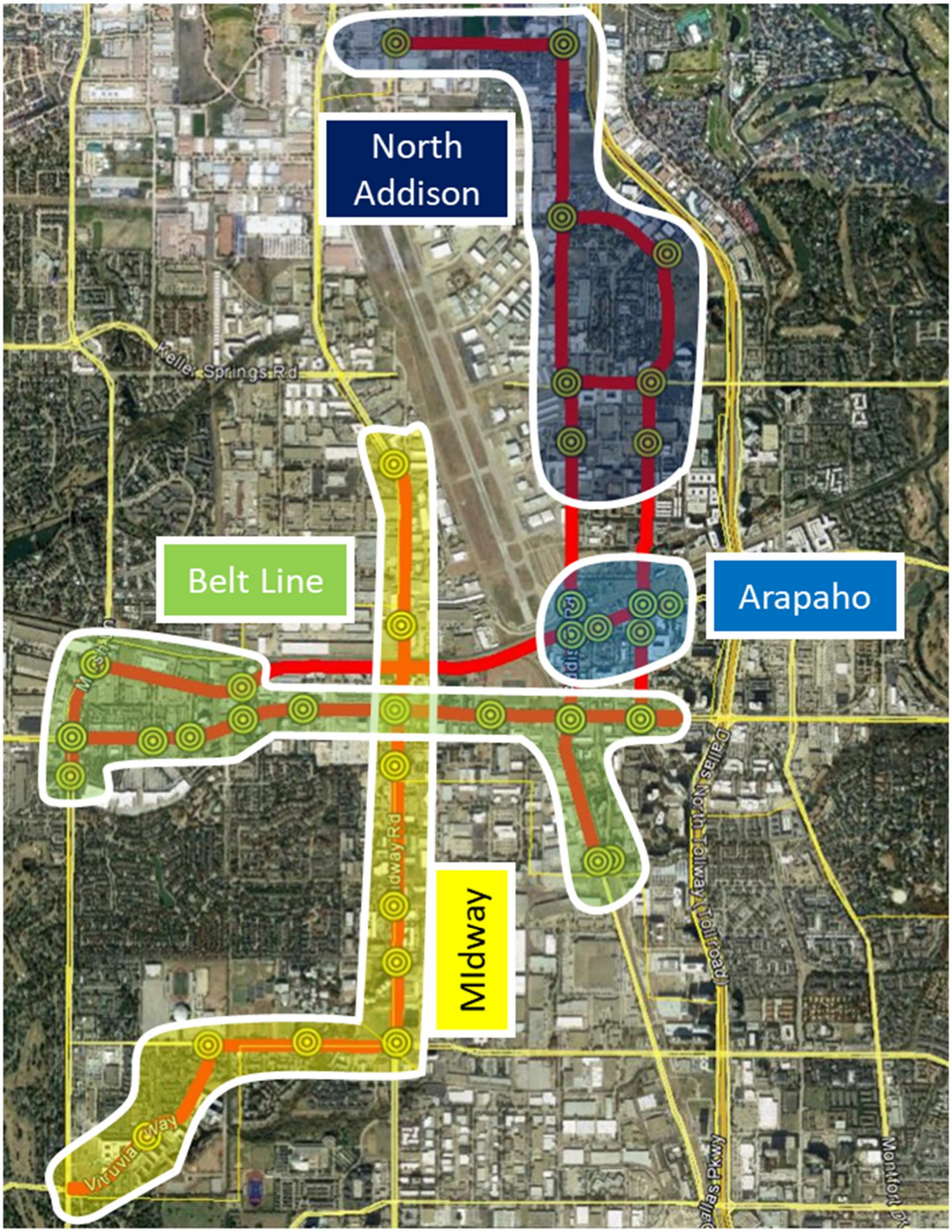


*Figure 2. New Control Groups*

**Tables 5**, **6**, and **7** detail the new operating schedules for the control groups shown in **Figure 2**.

*Table 5. New Sunday Time of Day Schedule by Control Group*

<table>
<tr><th></th><th>Midway</th><th>Belt Line</th><th>Arapaho</th><th>North Addison</th></tr>
<tr><td>0:00</td><td rowspan="10">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="10">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="10">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="24">Plan 9<br>Late Night<br>90/45 s</td></tr>
<tr><td>1:00</td></tr>
<tr><td>2:00</td></tr>
<tr><td>3:00</td></tr>
<tr><td>4:00</td></tr>
<tr><td>5:00</td></tr>
<tr><td>6:00</td></tr>
<tr><td>7:00</td></tr>
<tr><td>8:00</td></tr>
<tr><td>9:00</td></tr>
<tr><td>10:00</td><td rowspan="11">Plan 5<br>Weekend Low Volume<br>120 s</td><td rowspan="11">Plan 5<br>Weekend Low Volume<br>120 s</td><td rowspan="11">Plan 5<br>Weekend Low Volume<br>90 s</td></tr>
<tr><td>11:00</td></tr>
<tr><td>12:00</td></tr>
<tr><td>13:00</td></tr>
<tr><td>14:00</td></tr>
<tr><td>15:00</td></tr>
<tr><td>16:00</td></tr>
<tr><td>17:00</td></tr>
<tr><td>18:00</td></tr>
<tr><td>19:00</td></tr>
<tr><td>20:00</td></tr>
<tr><td>21:00</td><td rowspan="3">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="3">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="3">Plan 9<br>Late Night<br>90/45 s</td></tr>
<tr><td>22:00</td></tr>
<tr><td>23:00</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

*Table 6. New Weekday Time of Day Schedule by Control Group*

<table>
<tr><th></th><th>Midway</th><th>Belt Line</th><th>Arapaho</th><th>North Addison</th></tr>
<tr><td>0:00</td><td rowspan="6">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="6">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="7">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="7">Plan 9<br>Late Night<br>90/45 s</td></tr>
<tr><td>1:00</td></tr>
<tr><td>2:00</td></tr>
<tr><td>3:00</td></tr>
<tr><td>4:00</td></tr>
<tr><td>5:00</td></tr>
<tr><td>6:00</td><td>Plan 4<br>Weekday Off Peak<br>120 s</td><td>Plan 4<br>Weekday Off Peak<br>120 s</td></tr>
<tr><td>7:00</td><td rowspan="2">Plan 1<br>AM<br>160 s</td><td rowspan="2">Plan 1<br>AM<br>160 s</td><td rowspan="2">Plan 1<br>AM<br>160/80 s</td><td rowspan="3">Plan 1<br>AM<br>120 s</td></tr>
<tr><td>8:00</td></tr>
<tr><td>9:00</td><td rowspan="3">Plan 4<br>Weekday Off Peak<br>120 s</td><td rowspan="3">Plan 4<br>Weekday Off Peak<br>120 s</td><td rowspan="7">Plan 2<br>Midday/Off Peak<br>90 s</td></tr>
<tr><td>10:00</td><td rowspan="6">Plan 2<br>Off Peak<br>90 s</td></tr>
<tr><td>11:00</td></tr>
<tr><td>12:00</td><td rowspan="4">Plan 2<br>Midday<br>134 s</td><td rowspan="4">Plan 2<br>Midday<br>134 s</td></tr>
<tr><td>13:00</td></tr>
<tr><td>14:00</td></tr>
<tr><td>15:00</td></tr>
<tr><td>16:00</td><td rowspan="3">Plan 3<br>PM<br>160 s</td><td rowspan="3">Plan 3<br>PM<br>160 s</td><td rowspan="3">Plan 3<br>PM<br>160/80 s</td><td rowspan="3">Plan 3<br>PM Peak<br>120 s</td></tr>
<tr><td>17:00</td></tr>
<tr><td>18:00</td></tr>
<tr><td>19:00</td><td rowspan="2">Plan 4<br>Weekday Off Peak<br>120 s</td><td rowspan="2">Plan 4<br>Weekday Off Peak<br>120 s</td><td rowspan="2">Plan 2<br>Midday/Off Peak<br>90 s</td><td rowspan="2">Plan 2<br>Off Peak<br>90 s</td></tr>
<tr><td>20:00</td></tr>
<tr><td>21:00</td><td rowspan="3">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="3">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="3">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="3">Plan 9<br>Late Night<br>90/45 s</td></tr>
<tr><td>22:00</td></tr>
<tr><td>23:00</td></tr>
</table>

**Table 7. New Saturday Time of Day Schedule by Control Group**

<table>
<tr><td>0:00</td><td rowspan="9">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="9">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="11">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="24">Plan 9<br>Late Night<br>90/45 s</td></tr>
<tr><td>1:00</td></tr>
<tr><td>2:00</td></tr>
<tr><td>3:00</td></tr>
<tr><td>4:00</td></tr>
<tr><td>5:00</td></tr>
<tr><td>6:00</td></tr>
<tr><td>7:00</td></tr>
<tr><td>8:00</td></tr>
<tr><td>9:00</td><td rowspan="2">Plan 5<br>Weekend Low<br>Volume<br>120 s</td><td rowspan="2">Plan 5<br>Weekend Low<br>Volume<br>120 s</td></tr>
<tr><td>10:00</td></tr>
<tr><td>11:00</td><td rowspan="8">Plan 6<br>Weekend High<br>Volume<br>134 s</td><td rowspan="8">Plan 6<br>Weekend High<br>Volume<br>134 s</td><td rowspan="9">Plan 5<br>Weekend Low<br>Volume<br>90 s</td></tr>
<tr><td>12:00</td></tr>
<tr><td>13:00</td></tr>
<tr><td>14:00</td></tr>
<tr><td>15:00</td></tr>
<tr><td>16:00</td></tr>
<tr><td>17:00</td></tr>
<tr><td>18:00</td></tr>
<tr><td>19:00</td><td rowspan="2">Plan 5<br>Weekend Low<br>Volume<br>120 s</td><td rowspan="2">Plan 5<br>Weekend Low<br>Volume<br>120 s</td></tr>
<tr><td>20:00</td><td rowspan="4">Plan 9<br>Late Night<br>90/45 s</td></tr>
<tr><td>21:00</td><td rowspan="3">Plan 9<br>Late Night<br>90/45 s</td><td rowspan="3">Plan 9<br>Late Night<br>90/45 s</td></tr>
<tr><td>22:00</td></tr>
<tr><td>23:00</td></tr>
</table>

## Timing Plan Implementation and Fine-Tuning

New timing was implemented by control group. The North Addison group was implemented on November 13 and 14, 2018. The Midway group was implemented on November 27 and 29, 2018. The Belt Line group was implemented on February 5-7, 2019. The Arapaho group will be implemented once FYA installations are complete. During these implementations, the timing was verified to be operating as expected, and any adjustments for fine-tuning were made. Several minor adjustments were made related to detection parameters and zones.

For the North Addison group:

- The 45-second late night plan was verified to be sufficient for off-peak service on Addison Road
- No other fine-tuning changes were made
- Determination of a final operating schedule for Westgrove Drive and Sojourn Drive is still under review
- New FYA operations are pending implementation for Addison Road & Keller Springs Road.

For the Midway group:

- Midway & Hornet – in the AM, increased split time for the northbound left turn, to make sure queue was consistently clearing
- Spring Valley & Greenhill – AM school schedule was adjusted to make sure the signal was in step when the peak begins

For the Belt Line group:

- Belt Line & Surveyor – various detection adjustments were made to ensure signal timing was operating efficiently
- Marsh & Arapaho – various settings and parameters were adjusted to make sure reservicing of the southbound left turn was operating properly and all phases were extending as appropriate.

## PROJECT BENEFITS

The goal of this project was to reduce delay, stops, and travel time along Belt Line Road, Midway Road, Addison Road, and Arapaho Road. To quantify the degree of improvement, *after* travel time runs were conducted on Belt Line Road on Thursday, February 21st, 2019 and Saturday, February 23rd, 2019. Midway Road *after* travel time runs were conducted on Wednesday, February 20th, 2019 and Saturday, February 23rd, 2019. *After* travel time runs were not performed on Addison Road or Arapaho Road because new timing is not yet fully operational at three of the project intersections. The Town is in the process of upgrading to FYA at the key intersections previously identified.

A comparison of *before* and *after* travel-time runs are presented in Tables 8 and 9.

*Table 8. Travel Time Run Results – Belt Line Road*

| Before and After Travel Time Run Data for Belt Line Road | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Peak | Direction | Travel Time (sec) | | # of Stops | | Average Speed | | Delay (sec) | |
| | | Before | After | Before | After | Before | After | Before | After |
| AM Peak | EB | 299 | 257 | 2.0 | 1.6 | 24.0 | 27.9 | 119 | 80 |
| | WB | 287 | 172 | 2.4 | 0.0 | 25.0 | 41.6 | 110 | 7 |
| | **Average** | **293** | **215** | **2.2** | **0.8** | **24.5** | **34.7** | **114** | **43** |
| MD Peak | EB | 324 | 276 | 1.8 | 1.6 | 22.1 | 26.0 | 143 | 95 |
| | WB | 320 | 230 | 2.8 | 1.0 | 22.3 | 32.6 | 141 | 56 |
| | **Average** | **322** | **253** | **2.3** | **1.3** | **22.2** | **29.3** | **142** | **76** |
| PM Peak | EB | 477 | 229 | 4.0 | 0.9 | 15.1 | 32.8 | 294 | 55 |
| | WB | 403 | 240 | 3.2 | 1.1 | 17.7 | 31.1 | 224 | 65 |
| | **Average** | **440** | **235** | **3.6** | **1.0** | **16.4** | **32.0** | **259** | **60** |
| SAT Peak | EB | 323 | 237 | 2.4 | 1.1 | 22.3 | 31.5 | 141 | 63 |
| | WB | 222 | 190 | 0.8 | 0.0 | 32.1 | 37.7 | 45 | 13 |
| | **Average** | **273** | **214** | **1.6** | **0.5** | **27.2** | **34.6** | **93** | **38** |

| Before and After Travel Time Run Data for Belt Line Road | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Peak | Direction | Travel Time | | # of Stops | | Average Speed | | Delay | |
| | | Sec. | Percent | Total | Percent | mph | Percent | Sec. | Percent |
| AM Peak | EB | -42 | -14% | -0.4 | -20% | 3.9 | 16% | -39 | -33% |
| | WB | -115 | -40% | -2.4 | -100% | 16.6 | 66% | -103 | -94% |
| | **Average** | **-78** | **-27%** | **-1.4** | **-64%** | **10.2** | **42%** | **-71** | **-62%** |
| MD Peak | EB | -48 | -15% | -0.2 | -11% | 3.9 | 18% | -47 | -33% |
| | WB | -90 | -28% | -1.8 | -64% | 10.3 | 46% | -85 | -60% |
| | **Average** | **-69** | **-21%** | **-1.0** | **-43%** | **7.1** | **32%** | **-66** | **-47%** |
| PM Peak | EB | -248 | -52% | -3.1 | -77% | 17.7 | 117% | -239 | -81% |
| | WB | -163 | -40% | -2.1 | -65% | 13.4 | 76% | -159 | -71% |
| | **Average** | **-205** | **-47%** | **-2.6** | **-71%** | **15.6** | **95%** | **-199** | **-77%** |
| SAT Peak | EB | -85 | -26% | -1.3 | -55% | 9.2 | 41% | -78 | -56% |
| | WB | -32 | -14% | -0.8 | -100% | 5.6 | 17% | -31 | -70% |
| | **Average** | **-59** | **-22%** | **-1.1** | **-66%** | **7.4** | **27%** | **-55** | **-59%** |

*Table 9. Travel Time Run Results – Midway Road*

| Before and After Travel Time Run Data for Midway Road | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Peak | Direction | Travel Time (sec) | | # of Stops | | Average Speed | | Delay (sec) | |
| | | Before | After | Before | After | Before | After | Before | After |
| AM Peak | NB | 307 | 301 | 2.6 | 1.6 | 24.1 | 24.5 | 122 | 119 |
| | SB | 393 | 301 | 3.2 | 1.6 | 18.8 | 24.5 | 207 | 119 |
| | **Average** | **350** | **301** | **2.9** | **1.6** | **21.5** | **24.5** | **164** | **119** |
| MD Peak | NB | 294 | 260 | 1.8 | 1.4 | 25.2 | 28.2 | 107 | 83 |
| | SB | 308 | 233 | 2.0 | 1.4 | 24.0 | 31.6 | 123 | 55 |
| | **Average** | **301** | **247** | **1.9** | **1.4** | **24.6** | **29.9** | **115** | **69** |
| PM Peak | NB | 362 | 269 | 3.4 | 1.5 | 20.5 | 27.8 | 176 | 89 |
| | SB | 560 | 460 | 4.0 | 2.4 | 13.2 | 16.1 | 379 | 278 |
| | **Average** | **461** | **365** | **3.7** | **2.0** | **16.9** | **21.9** | **277** | **183** |
| SAT Peak | NB | 293 | 278 | 1.6 | 1.6 | 25.3 | 26.6 | 107 | 95 |
| | SB | 245 | 214 | 0.8 | 0.8 | 30.3 | 34.7 | 59 | 32 |
| | **Average** | **269** | **246** | **1.2** | **1.2** | **27.8** | **30.7** | **83** | **64** |

| Before and After Travel Time Run Data for Midway Road | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Peak | Direction | Travel Time | | # of Stops | | Average Speed | | Delay | |
| | | Sec. | Percent | Total | Percent | mph | Percent | Sec. | Percent |
| AM Peak | NB | -5 | -2% | -1.0 | -38% | 0.4 | 2% | -2 | -2% |
| | SB | -92 | -23% | -1.6 | -50% | 5.7 | 31% | -88 | -42% |
| | **Average** | **-48** | **-14%** | **-1.3** | **-45%** | **3.1** | **14%** | **-45** | **-27%** |
| MD Peak | NB | -33 | -11% | -0.4 | -22% | 3.0 | 12% | -24 | -22% |
| | SB | -75 | -24% | -0.6 | -30% | 7.6 | 32% | -68 | -56% |
| | **Average** | **-54** | **-18%** | **-0.5** | **-26%** | **5.3** | **22%** | **-46** | **-40%** |
| PM Peak | NB | -93 | -26% | -1.9 | -56% | 7.3 | 35% | -87 | -49% |
| | SB | -100 | -18% | -1.6 | -40% | 2.9 | 22% | -101 | -27% |
| | **Average** | **-96** | **-21%** | **-1.8** | **-47%** | **5.1** | **30%** | **-94** | **-34%** |
| SAT Peak | NB | -15 | -5% | 0.0 | 0% | 1.3 | 5% | -12 | -11% |
| | SB | -30 | -12% | 0.0 | 0% | 4.4 | 15% | -27 | -46% |
| | **Average** | **-23** | **-8%** | **0.0** | **0%** | **2.9** | **10%** | **-19** | **-23%** |

Travel time results were consistently positive for both corridors in all peak periods.

Belt Line Road showed excellent results. Overall, in both directions for all peaks on Belt Line Road, travel time was reduced by 32%, stops were reduced by 59%, speed increased 56% (nearly to posted speed), and delay improved by more than 62%. Of note was the elimination of stops for both the westbound AM Peak and westbound Saturday Peak travel time runs. AM delay was reduced by an average of 71 seconds and PM delay was reduced by an average of nearly 200 seconds (more than 3 minutes).

Midway Road was also significantly improved, with an 18% overall reduction in travel time, a 39% reduction in stops, a 22% increase in speed, and a 34% reduction in delay.

The following rationale was used to estimate the annual reduction in delay from the new timing plans on Belt Line Road and Midway Road, based on travel time runs:

- Total reduction in delay in both directions
- Average peak period bidirectional traffic volume
- On each weekday there will be:
    - Two hours of benefit from the AM peak timing plan
    - Two hours of benefit from the PM peak timing plan
    - Five hours of benefit from the midday timing plan
- On each Saturday, there will be five hours of benefit from the Saturday timing plan
- To be conservative, no benefit is assumed from other hours of the day even though most of the corridors operate the new timing plans for at least 12 hours per day.
- For calculations, 5 weekdays and 1 Saturday per week were used, with 52 weeks per year, resulting in 260 weekdays per year and 52 Saturdays per year.

Based on measured travel time results and the assumptions listed above, Belt Line Road and Midway Road have resulted in delay savings of more than **673,000 vehicle hours per year** (or more than 76 years of vehicle delay annually). In terms of delay savings, this translates to more than **$19 million annually** in driver delay savings. For economic analysis of transportation improvements, the cost of delay was assumed to be $28.69 per vehicle-hour (as reflected in TxDOT's 2018 Value of Time Memo).

## INRIX MEASURES OF EFFECTIVENESS

Traditional measures of effectiveness (MOEs) include travel time, speed, delay, and stops. INRIX, like all segment-based probe data, is capable of measuring travel time and speed; delay can be calculated as the difference between measured travel time and free flow travel time (based on speed limit). Stops are only available from traditional travel time runs. Travel time index is essentially a normalized measure of delay, calculated from travel times. shows the traditional measures of effectiveness. A before and after comparison of INRIX data for Belt Line Road and Midway Road corridors is presented in Table 10 and Table 11. Addison Road was not included in the analysis because the timing effort is not yet complete.

*Table 10. INRIX Traditional MOEs for Belt Line Road*

| Peak Period | | Travel Time (s) | | Speed (mph) | | Travel Time Index | | Delay (s) | |
|---|---|---|---|---|---|---|---|---|---|
| | | EB | WB | EB | WB | EB | WB | EB | WB |
| AM (7:00 AM - 9:00 AM) | Before | 318 | 278 | 21.98 | 25.00 | 1.12 | 1.06 | 121 | 81 |
| | After | 277 | 258 | 25.08 | 26.98 | 0.95 | 0.95 | 80 | 60 |
| | Δ | -41 | -21 | +3.10 | +1.98 | -0.17 | -0.11 | -41 | -21 |
| | Δ% | -13% | -7% | +14% | +8% | -15% | -10% | -34% | -26% |
| MD (11:00 AM – 1:00 PM) | Before | 324 | 277 | 21.42 | 25.09 | 1.14 | 1.05 | 127 | 79 |
| | After | 291 | 259 | 23.91 | 26.81 | 0.99 | 0.95 | 93 | 62 |
| | Δ | -34 | -18 | +2.49 | +1.73 | -0.15 | -0.10 | -34 | -17 |
| | Δ% | -10% | -6% | +12% | +7% | -13% | -10% | -27% | -22% |
| PM (4:00 PM - 6:00 PM) | Before | 372 | 301 | 18.76 | 23.16 | 1.31 | 1.14 | 175 | 104 |
| | After | 339 | 289 | 20.69 | 24.20 | 1.16 | 1.06 | 142 | 91 |
| | Δ | -33 | -13 | +1.94 | +1.04 | -0.15 | -0.08 | -33 | -13 |
| | Δ% | -9% | -4% | +10% | +4% | -11% | -7% | -19% | -13% |
| Saturday (10:00 AM – 2:00 PM) | Before | 291 | 255 | 24.13 | 27.32 | 1.02 | 0.97 | 93 | 57 |
| | After | 275 | 244 | 25.31 | 28.57 | 0.94 | 0.90 | 77 | 46 |
| | Δ | -16 | -11 | +1.19 | +1.24 | -0.08 | -0.07 | -16 | -11 |
| | Δ% | -5% | -4% | +5% | +5% | -8% | -7% | -17% | -19% |

Traditional MOEs for Belt Line Road showed improvement in both directions during all four peak periods. Overall, travel time decreased 7%, speed increased 8%, travel time index (a measure of reliability) improved by 10%, and delay was reduced by 22%. Eastbound in the AM peak showed the best results overall, with a 13% reduction in travel time, a 14% increase in speed, a 15% decrease in travel time index, and a 34% reduction in delay.

Table 11. INRIX Traditional MOEs for Midway Road

| Peak Period | | Travel Time (s) | | Speed (mph) | | Travel Time Index | | Delay (s) | |
|---|---|---|---|---|---|---|---|---|---|
| | | NB | SB | NB | SB | NB | SB | NB | SB |
| AM (7:00 AM - 9:00 AM) | Before | 288 | 268 | 25.33 | 27.55 | 1.16 | 1.07 | 90 | 71 |
| | After | 288 | 272 | 25.32 | 27.15 | 1.10 | 1.10 | 90 | 74 |
| | Δ | +0 | +4 | -0.02 | -0.40 | -0.06 | +0.03 | 0 | +3 |
| | Δ% | +0% | +1% | -0% | -1% | -5% | +3% | 0% | +4% |
| MD (11:00 AM – 1:00 PM) | Before | 266 | 273 | 27.39 | 27.06 | 1.07 | 1.09 | 68 | 76 |
| | After | 277 | 263 | 26.31 | 28.10 | 1.06 | 1.06 | 79 | 65 |
| | Δ | +11 | -10 | -1.08 | +1.04 | -0.01 | -0.03 | +11 | -11 |
| | Δ% | +4% | -4% | -4% | +4% | -1% | -3% | +16% | -14% |
| PM (4:00 PM - 6:00 PM) | Before | 284 | 319 | 25.82 | 23.27 | 1.15 | 1.27 | 87 | 121 |
| | After | 302 | 312 | 24.25 | 23.77 | 1.16 | 1.26 | 105 | 114 |
| | Δ | +18 | -7 | -1.57 | +0.50 | +0.01 | -0.01 | +18 | -7 |
| | Δ% | +6% | -2% | -6% | +2% | +1% | -1% | +21% | -6% |
| Saturday (10:00 AM – 2:00 PM) | Before | 245 | 244 | 29.81 | 30.27 | 0.99 | 0.97 | 47 | 46 |
| | After | 262 | 252 | 27.92 | 29.44 | 1.00 | 1.02 | 64 | 54 |
| | Δ | +17 | +8 | -1.90 | -0.83 | +0.01 | +0.05 | +17 | +8 |
| | Δ% | +7% | +3% | -6% | -3% | +1% | +5% | +36% | +17% |

Traditional MOEs shown in Table 11 did not reflect the positive results observed via traditional travel time runs on Midway Road (Table 9). Overall, travel time, speed, and travel time index were essentially unchanged (2% or less average change), while delay increased an average of 9% across all peaks and all directions. Some positive results were observed in the traditional MOEs, including a 5% reduction in northbound AM travel time index and a 14% reduction in midday southbound delay.

The advanced MOEs available from INRIX allow a deeper analysis of signal retiming efforts than traditional floating car travel time run studies. In addition to reducing travel times and delays and increasing speed, signal retiming can also improve operations on a corridor by improving reliability. The change in reliability can be calculated from the change in confidence intervals (CI) of the MOEs. Using the data provided by INRIX, the confidence intervals were calculated as the difference between the 95$^{th}$ percentile and the 5$^{th}$ percentile. A comparison of these advanced MOEs is presented in Table 12 and Table 13.

*Table 12. Advanced INRIX MOEs for Belt Line Road*

| Peak Period | | Travel Time CI (s) | | Speed CI (mph) | | Travel Time Index CI | | Buffer Time (s) | | Planning Index | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NB | SB | NB | SB | NB | SB | NB | SB | NB | SB |
| AM (7:00 AM - 9:00 AM) | Before | 218 | 147 | 13.89 | 12.76 | 0.77 | 0.56 | 137 | 88 | 1.60 | 1.39 |
| | After | 129 | 107 | 11.51 | 11.19 | 0.44 | 0.39 | 75 | 58 | 1.20 | 1.16 |
| | Δ | -89 | -40 | -2.39 | -1.56 | -0.33 | -0.16 | -62 | -29 | -0.40 | -0.23 |
| | Δ% | -41% | -27% | -17% | -12% | -43% | -29% | -45% | -33% | -25% | -16% |
| MD (11:00 AM – 1:00 PM) | Before | 229 | 148 | 14.57 | 12.87 | 0.80 | 0.56 | 140 | 89 | 1.63 | 1.39 |
| | After | 140 | 112 | 11.45 | 11.49 | 0.48 | 0.41 | 79 | 59 | 1.26 | 1.17 |
| | Δ | -89 | -36 | -3.12 | -1.38 | -0.33 | -0.15 | -61 | -30 | -0.37 | -0.22 |
| | Δ% | -39% | -24% | -21% | -11% | -41% | -27% | -44% | -33% | -23% | -16% |
| PM (4:00 PM - 6:00 PM) | Before | 253 | 156 | 12.08 | 11.81 | 0.89 | 0.59 | 159 | 89 | 1.87 | 1.48 |
| | After | 180 | 131 | 10.82 | 10.84 | 0.61 | 0.48 | 97 | 72 | 1.49 | 1.33 |
| | Δ | -73 | -25 | -1.26 | -0.97 | -0.28 | -0.11 | -62 | -17 | -0.38 | -0.16 |
| | Δ% | -29% | -16% | -10% | -8% | -31% | -19% | -39% | -19% | -20% | -11% |
| Saturday (10:00 AM – 2:00 PM) | Before | 184 | 107 | 14.24 | 11.09 | 0.64 | 0.41 | 111 | 62 | 1.41 | 1.20 |
| | After | 92 | 68 | 8.36 | 7.91 | 0.31 | 0.25 | 50 | 36 | 1.11 | 1.03 |
| | Δ | -92 | -39 | -5.88 | -3.17 | -0.33 | -0.16 | -61 | -26 | -0.30 | -0.18 |
| | Δ% | -50% | -36% | -41% | -29% | -51% | -39% | -55% | -41% | -21% | -15% |

As shown in Table 12, the signal retiming effort was successful in significantly improving the reliability of operations in both directions in all peaks and operations overall on the Belt Line corridor by reducing variability.  Averaged over both directions for all peaks, travel time reliability was improved by 33%, speed reliability was improved 19%, the travel time index confidence interval was reduced by 35%, buffer time was improved by 39%, and the planning index was reduced by 18%.  When these advanced MOEs are considered as a whole, drivers on Belt Line Road experience more consistent and reliable operations, reducing variability. These results compliment the results of the traditional MOEs.

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*Table 13. Advanced INRIX MOEs for Midway Road*

| Peak Period | | Travel Time CI (s) | | Speed CI (mph) | | Travel Time Index CI | | Buffer Time (s) | | Planning Index | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NB | SB | NB | SB | NB | SB | NB | SB | NB | SB |
| AM (7:00 AM - 9:00 AM) | Before | 149 | 142 | 12.96 | 14.14 | 0.60 | 0.57 | 85 | 85 | 1.51 | 1.41 |
| | After | 133 | 105 | 11.56 | 10.07 | 0.51 | 0.42 | 75 | 63 | 1.39 | 1.35 |
| | Δ | -16 | -37 | -1.40 | -4.06 | -0.09 | -0.15 | -11 | -23 | -0.12 | -0.06 |
| | Δ% | -11% | -26% | -11% | -29% | -15% | -26% | -13% | -27% | -8% | -4% |
| MD (11:00 AM – 1:00 PM) | Before | 127 | 137 | 12.58 | 12.95 | 0.51 | 0.55 | 76 | 82 | 1.38 | 1.41 |
| | After | 116 | 117 | 10.95 | 12.75 | 0.45 | 0.47 | 66 | 63 | 1.32 | 1.32 |
| | Δ | -11 | -20 | -1.63 | -0.21 | -0.07 | -0.07 | -10 | -19 | -0.06 | -0.09 |
| | Δ% | -9% | -15% | -13% | -2% | -13% | -13% | -13% | -23% | -5% | -7% |
| PM (4:00 PM - 6:00 PM) | Before | 165 | 181 | 14.29 | 12.78 | 0.66 | 0.72 | 98 | 106 | 1.54 | 1.69 |
| | After | 169 | 162 | 13.76 | 12.58 | 0.65 | 0.66 | 94 | 86 | 1.52 | 1.61 |
| | Δ | +4 | -20 | -0.52 | -0.20 | -0.02 | -0.07 | -4 | -19 | -0.02 | -0.08 |
| | Δ% | +2% | -11% | -4% | -2% | -3% | -9% | -4% | -18% | -1% | -5% |
| Saturday (10:00 AM – 2:00 PM) | Before | 104 | 92 | 11.76 | 11.42 | 0.42 | 0.37 | 65 | 52 | 1.25 | 1.18 |
| | After | 92 | 118 | 9.59 | 12.24 | 0.35 | 0.48 | 51 | 73 | 1.20 | 1.32 |
| | Δ | -12 | +26 | -2.17 | 0.83 | -0.07 | 0.11 | -13 | +22 | -0.05 | 0.14 |
| | Δ% | -12% | +28% | -18% | +7% | -16% | +30% | -20% | +42% | -4% | +12% |

The advanced MOEs for Midway Road in Table 13 showed results closer to the travel time run results. Reliability was improved in every peak in both directions, with the exception of southbound during the Saturday peak. Averaged over both directions for all peaks, travel time reliability was improved by 7%, speed reliability was improved 9%, the travel time index confidence interval was reduced by 8%, buffer time was improved by 9%, and the planning index was reduced by 3%. The signal timing effort was successful in improving reliability of operations on the Midway Road corridor.

## SYNCHRO™ MEASURES OF EFFECTIVENESS

New timing in the Addison Road and Arapaho Road control groups has not yet been completed. The Town is in the process of upgrading to FYA at the key intersections identified above. In the absence of *after* travel time runs, existing and proposed timing was compared using Synchro™ measures of effectiveness.

For a network consisting of each control group's signals, Table 14 and Table 15 compare the total delay as estimated by Synchro™.

*Table 14. Synchro™ MOEs for Addison Road*

| Timing Plan | Synchro Total Delay (veh-hrs/hr) | | % Change |
|---|---|---|---|
| | Previous | New | |
| AM Peak | 125 | 112 | -10.4% |
| MD Peak | 76 | 75 | -1.3% |
| PM Peak | 206 | 183 | -11.2% |
| Saturday Peak | 104 | 90 | -13.5% |

It should be noted that Synchro™ calculates the delay for all traffic movements at the included intersections. As modeled in Synchro™, the operational improvements on Addison Road did not come at the expense of the remainder of the network (e.g. side streets). A decrease of at least 10% in total delay for the proposed timing (to be implemented once FYA are installed) is predicted for the AM, PM, and Saturday peaks. Midday is predicted to be essentially unchanged and is shown to have relatively low delay to start with.

Arapaho Road itself is not configured as a coordinated corridor. The two signals on the west end (Marsh Lane and Surveyor Boulevard) are part of the Belt Line Road Control Group. The remainder of the signals on Arapaho Road are in the Arapaho Road Control Group, coordinated with the City of Dallas diamond interchange at Dallas Parkway. Additionally, there is a mile-long gap between Surveyor Boulevard and Addison Road, with considerable grade changes on the Arapaho Bridge. Signals further than one mile apart are typically not coordinated. In short, the entirety of Arapaho Road should not be evaluated as a coordinated corridor. The most significant goal achieved on Arapaho was to maintain the relatively short, 80-second, cycle length for the 4 intersections between Addison Road and Dallas Parkway while satisfying the new, longer, pedestrian crossing times resulting from new standards that needed to be satisfied.

Table 17 presents a comparison of Arapaho Road timing only between Dallas Parkway and Addison Road. This is where most significant enhancements were made to accommodate the longer crossing pedestrian intervals. The result of no significant increase in delay is viewed as a positive for this control group, given the impact of longer pedestrian times. The Addison intersections are not coordinated with the longer cycle length at Dallas Parkway during the Midday or Saturday periods, likely resulting in the slight increase in delay. Another reason for only minor changes on this section of Arapaho may be that timing was last updated more recently (2013-2014) than other corridors in Addison.

*Table 15. Synchro™ MOEs for Arapaho Road (Addison Road to Dallas Parkway)*

| Timing Plan | Synchro Total Delay (veh-hrs/hr) | | % Change |
|---|---|---|---|
| | Previous | New | |
| AM Peak | 80 | 80 | 0.0% |
| MD Peak | 157 | 159 | 1.3% |
| PM Peak | 201 | 202 | 0.5% |
| Saturday Peak | 46 | 52 | 13.0% |

## Conclusion and Recommendations

The project achieved the goals of reducing delay, stops, and travel time along major corridors in the Town of Addison. As shown through multiple measures of effectiveness, particularly good results were realized on the heaviest volume corridors of Belt Line Road and Midway Road. As shown through the INRIX analysis, travel time reliability was also improved.

In addition to improving operations on the major corridors in Addison, crossing arterial progression was maintained or improved. Coordination with neighboring cities was also maintained.

Future timing plan updates should be scheduled at intervals of three to five years, or as other operational improvements can be implemented in the corridor. As-yet-uninstalled FYA displays for the intersections identified will result in significant delay reductions and should yield a large benefit for a relatively low cost.

At such time as DART improvements are made to the rail crossings in Addison, the signals on Addison Road at Arapaho Road and at Lindbergh Road should be modified to operate either together on a single controller or to effectively have same operations through peer-to-peer operations, such that the two signals are able to transition back into coordination from railroad preemptions in a manner that maintains coordination through this period of transition.