# Salt Lake City Signal Traffic Management Report


PINETOP ENGINEERING, LLC

avenue | CONSULTANTS

# TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES

# EXECUTIVE SUMMARY

In coordination with Salt Lake City (SLC), PineTop Engineering (PineTop) and Avenue Consultants (Avenue), the project team, developed and implemented new signal timing plans throughout SLC with a goal to reduce travel times, delays, and emissions. This effort included the entire Downtown Area (DA) and six corridors selected by SLC. The six corridors include:

- 1300 E (3300 S to South Temple)
- 1300 S (500 W to 1300 E)
- 2100 S (700 W to 2300 E)
- Glendale Area (900 W; SR-201 to 800 S and 1300 S; Redwood to I-15)
- 300 W (2100 S to 600 S)
- California Ave (Redwood Rd to Bangerter Hwy)

The project team worked with the Utah Department of Transportation (UDOT) to incorporate state-owned signals into the new signal timing plans to maintain a seamless network of coordination throughout the city.

Before the signal timings were modified, on-site observations were performed and Automated Traffic Signal Performance Metrics (ATSPMs) were analyzed to understand current issues. Using this information, the project team, in coordination with UDOT and the Utah Transit Authority (UTA), brainstormed new signal timing strategies and modeled them in Synchro, a traffic microsimulation modeling software. Information from all these sources was used to determine what would perform the best.

The signal timing strategy implemented focused on smaller cycle lengths, which reduces wait times for pedestrians and cyclists. The small cycle lengths still provided good progression for motorists and public transportation by using half and harmonic relationships. These new timings were implemented and fine-tuned between September and December 2018.

To identify the benefit of the new timings, the project team evaluated before-after travel times collected by SLC and HERE data (GPS data) provided by UDOT. For the six corridors, the average travel time was reduced by 28 seconds per vehicle in the AM peak, 39 seconds per vehicle in the midday (MD), and by 33 seconds per vehicle in the PM peak for both directions. This also decreased total daily fuel consumption, $CO_2$ emissions, and other critical air pollutants ($PM_{2.5}$, CO, $NO_X$, VOC, and $PM_{10}$) as shown in the Table 1.

**Summary Table 1: Corridor Total Average Daily Emission Reduction**

| Route | Measure | AM | MD | PM |
|---|---|---|---|---|
| Total | Fuel (gal) | 37 | 45 | 42 |
| | $CO_2$ (lbs.) | 703 | 848 | 797 |
| | Total Critical Air Pollutants (lbs.) | 18 | 23 | 21 |

In the DA, the average travel times reduced by 52 seconds per vehicle in the AM peak, 42 seconds per vehicle in the MD, and by 64 seconds per vehicle in the PM peak for each travel directions. Based on this reduction the total daily fuel consumed and emissions produced reduced as shown in Table 2.

**Summary Table 2: DA Average Total Daily Emission Reduction**

| Route | Measure | AM | MD | PM |
|---|---|---|---|---|
| Total | Fuel (gal) | 221 | 321 | 269 |
| | CO2 (lbs.) | 4,058 | 3,824 | 5,093 |
| | Total Critical Air Pollutants (lbs.) | 65 | 87 | 73 |

The total daily saving accounts for 935 gallons of fuel, 15,323 lbs of $CO_2$ and 287 lbs of other critical air pollutants. Based on 250 work days per year this will remove over 1,915 tons of $CO_2$ and 36 tons of critical air pollutants over a year without accounting for the benefits over the weekends and holidays.

Another method to measure the effectiveness of signal timing improvements is to compare the benefit of the travel time reduction (i.e, user cost savings of the improvement) to the project cost. This benefit-to-cost ratio is derived by calculating the total financial value of the travel time savings as a result of the improvements. For this project, the total travel time savings were determined using a vehicle occupancy constant, the time cost of a standard passenger vehicle, and the time cost to operate a truck. This total travel time savings value was then compared to the project cost to determine the ratio of the benefit provided to the cost, which was 61:1 for this project. That means that the total user cost savings of the improvement is 61 times more than the total cost of the project.

# 1 INTRODUCTION

SLC is a regional destination for employment, commercial, and entertainment as well as home to a significant number of residents. Its traffic signal network is vital to the mobility of those traveling around the city in passenger vehicles, on bikes, using transit, or by walking. SLC requested that PineTop and Avenue optimize traffic signal timing and coordination throughout the city. The results of this effort reduced vehicle delays at traffic signals, which in turn reduced vehicle emissions providing for better air quality. This memo outlines the process and results of the effort including a calculation of the benefit-to-cost ratio for the project.

# 2 PROJECT OVERVIEW

The scope of this retiming project included the Downtown Area (DA) as well as six corridors located outside of the DA. The DA retiming included signals owned and operated by SLC and the UDOT, as shown in Figure 1.

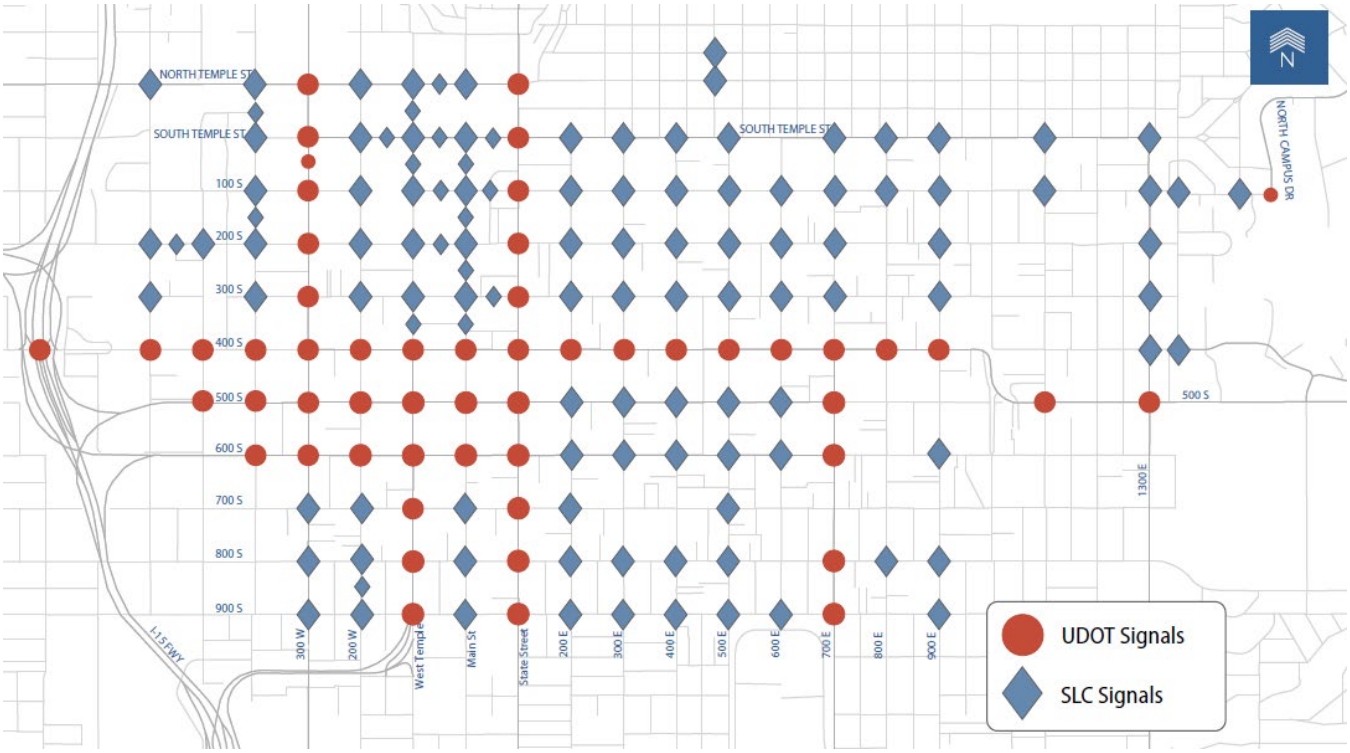



**Figure 1: Downtown Area Retiming Signal Locations**

The six corridors, selected by SLC, include the following:

- 1300 E (3300 S to South Temple)
- 1300 S (500 W to 1300 E)
- 2100 S (700 W to 2300 E)
- Glendale Area (900 W; SR-201 to 800 S and 1300 S; Redwood to I-15)
- 300 W (2100 S to 600 S)

- California Ave (Redwood Rd to Bangerter Hwy)

While the primary focus of this project was SLC's signals, timing adjustments were also made to UDOT signals (with their consent). Retiming for both the DA and corridors were performed for the weekday AM, MD, PM, overnight timing plans, and the Saturday and Sunday timing plans.

# 3 GOALS/STRATEGIES

The goal of this project was to reduce travel time and delay for all modes of transportation, which will lead to a reduction in vehicle emissions. During the initial discussion with SLC, UDOT, and UTA (the Stakeholders) several strategies were developed to help accomplish this goal in both the DA and corridors:

- Reduce traffic signal cycle lengths where possible to decrease delay for vehicles, bikes, and pedestrians.
- Coordinate SLC and UDOT signals together to provide the best opportunity for travel time improvements. When necessary, use closer harmonic cycle lengths; either half cycles or two-thirds harmonic relationships.
- Maintain existing coordination that is working well on SLC and UDOT signals. For example, UDOT mentioned the coordination is working well on 700 E in the DA.
- Make the path out of downtown on 300 W and North Temple more attractive.
- Make coordination of one-way street on 500 S and 600 S, the main connection between the DA and I-15, as close to perfect as possible. Additionally, reduce queuing on these routes in the peak hours.
- Identify potential solutions for heavy left turn movements, such as coordinating the left turn phase.
- Identify potential phasing or signal design changes to recommend to SLC and UDOT.
- Reevaluate the transition times between plans; i.e. the time when the AM plan ends, and the MD plan starts.
- Identify locations where peer-to-peer would be beneficial. This is where multiple signals share detection calls in connection with logic statements to improve their interaction.
- Prevent any additional delay to UTA routes and to help their travel times be more consistent.

These goals were considered when reviewing signal timing alternatives for the DA and each corridor. In addition to the goals, other considerations were also given based on following factors:

- Due to the high number of pedestrians crossing at intersections in the DA the pedestrian split phase should not be oversized except in rare circumstances.
- Some signals in the DA are required to run pretimed due to limited detection. These signals will also need to run a coordinated pattern overnight. It follows that the entire DA will be coordinated overnight because it doesn't make sense to have a signal running free in the middle of signals running coordination.

# 4 Data Collection

To help with the process of optimizing the signals timing in SLC, data was collected from on-site observations performed by the project team, UDOT's ATSPMs, from travel times collected by SLC, and from HERE data provided by UDOT.

## 4.1 Observations

To better determine the needs of each corridor and the DA, the project team observed the current signal timings and traffic patterns. The primary focus was to identify improvements to progression and how to reduce the delay at each signal. These observations included driving each corridor to understand the experience drivers have, observing queues and split failures.

## 4.2 Automated Traffic Signal Performance Metrics

ATSPMs are a summary of data gathered by the traffic signal controller during signal operations. The data is summarized in a variety of methods to show how the signal is performing. Some of the operation data includes signal phase split time served, pedestrian activations, phase split failures, and vehicle arrival data. The metrics available at each signal varies based on the level of detection and number of detector channels. For this project ATSPMs were used to evaluate existing conditions, including the time of day (TOD) schedule, and to provide data for the Synchro models.

One of the many metrics used to help with the evaluation of existing conditions was the Split Monitor, which shows the average split, 85$^{th}$ percentile, and percentage force-offs for each phase. This metric was used to determine the usage of the existing splits and if changes were needed. For example, if a phase had a high number of force-offs, additional time could be given to avoid failing to clear that phase. This was used in conjunction with the Split Failure metric which was used to determine if a phase consistently didn't serve the queue.

ATSPM also includes turning movement counts and approach volume which were used to help determine the appropriate transition times for the TOD schedule and in creating Synchro models. These volumes were used to evaluate the existing TOD schedule by making it possible to identify traffic pattern shifts.

When it was available, the Purdue Coordination Diagram was also used to review vehicle arrivals on green. This metric uses advanced detection to determine if vehicles approaching the intersection are going to arrive on the green phase or if they will get stopped on the red phase.

## 4.3 Travel Times

To better understand the improvements associated with the retiming efforts, vehicle travel times were collected by SLC for the corridors and on selected routes throughout the DA. The before and after travel times were collected using GPS in a probe vehicle. A probe vehicle is a single vehicle collecting GPS data while traveling with a platoon of vehicles. To increase the accuracy of the data, multiple travel time runs are performed during each period and in each direction.

Travel times were also measured using HERE data provided by UDOT. HERE data is also GPS data from probe vehicles collected over a longer period (in this case a minimum of a week). These probe vehicles include fleet vehicles and individuals using GPS devices (including smartphones using specific applications) that collect the data.

# 5 EXISTING CONDITIONS ANALYSIS

Observations of the existing conditions were performed to identify where improvements can be made. These were conducted for each of the corridors and the DA.

## 5.1 Corridors

During the observations for the corridors the cycle lengths, splits, and offsets were reviewed and potential improvements for the corridor identified.

### 5.1.1 1300 E (3300 S to South Temple)

1300 E is a major corridor through SLC because it extends between I-80 in Sugar House and the University of Utah. One of the main focuses of this retiming effort was to improve northbound progression towards the University in the AM peak and southbound toward I-80 in the PM peak. In addition, Westminster College and East High School are both located on 1300 E. While more details can be found in Appendix A, some of the critical observations are listed below:

**AM Peak Period**

- The queue in the right lane on the northbound approach to I-80 extends back to Stratford Ave because the I-80 eastbound and westbound ramps are both accessed from the right lane (lane utilization issues).
- At 500 S the eastbound traffic volume is heavier than the northbound volume. Any signal timing modifications should not interfere with eastbound traffic.
- Much of the congestion on 1300 E occurs in the section between 2100 S and 500 S where there is one lane in each direction.

**MD Period**

- Northbound heading toward I-80 still experiences lane utilization issues due to a high number of vehicles wanting to be in the right lane to get on the freeway to eastbound I-80.
- No major cycle failures were observed, the existing cycle length will not need to be increased except to standardized cycle lengths along 1300 E.

**PM Peak Period**

- The cycle length is longer than needed for the signals north of 500 S.
- The eastbound right turn and westbound left turn at 2100 S and 1300 E are heavy. These movements generally clear but moving time from these phases would create more split failures.
- At I-80 the eastbound off-ramp can fail to clear.

### 5.1.2 1300 S (500 W to 1300 E)

1300 S in SLC crosses I-15, State St, and 700 E. While both State St and 700 E carry heavy north/south volumes, the rest of the signals serve more modest volumes with 1300 S functioning as the main corridor. The Majority of stops along 1300 S are at major north/south corridors, between the major north/south corridors the current timing is working well but

could be fine-tuned to improve progression. While more details of the observations can be found in Appendix B, the main observations are listed below:

**AM Peak Period**

- With the lower traffic volumes, a 60 second cycle length could be considered, particularly at 900 E and 1100 E.

**PM Peak Period**

- Coordination at the I-15 interchange could improve arrivals to and from the interchange and avoid arriving on red at 300 W.
- Westbound at 300 W has a large volume that fails to clear.

### 5.1.3 2100 S (700 W to 2300 E)

2100 S in SLC crosses major north/south corridors such as State St and 700 E and includes an I-15 interchange. This corridor also extends through Sugar House and east of 1300 E which provides access to retail areas as well as Sugar House Park. Most of the east/west stops on 2100 S are at major north/south corridors (State St, 700 E, & 1300 E) but sections of this corridor require left and right turning vehicles to turn from a through lane which causes issues with progression. The ped crossings at 600 E and 1200 E work well without coordination. While more details of the observations can be found in Appendix C, the main observations are listed below:

**AM Peak Period**

- At 1300 E there is a long wait for eastbound traffic, but north/south is the main corridor and is getting priority.
- 1700 E provides access to Highland High School which has heavy inbound traffic when school starts.
- The eastbound left turn at 300 W is heavy with vehicles using 300 W to access commercial areas north of 2100 S.

**MD Period**

- The eastbound left turn at 300 W queued to the northbound I-15 intersection.

**PM Peak Period**

- There are issues observed where there are no turn pockets, as left turning vehicles from the through lanes block one of the two lanes of platooning vehicles.
- Based on observed volumes the PM peak plan needs to start earlier.
- The westbound left turns fail to clear at 700 E, State St, and 1300 E. The eastbound through fails to clear at State St.

### 5.1.4 Glendale Area (900 W; SR-201 to 800 S and 1300 S; Redwood to I-15)

The 900 W and the 1300 S corridors between I-15 and Redwood Rd are included in the Glendale Area. The southern end of 900 W includes the SR-201 interchange. The traffic volumes on these corridors are generally lower with much of the surrounding area being residential. For this area the same plan is used for both the AM and MD periods. Much of the heaviest traffic congestion in this area occurs at the SR-201 interchange and the signal to the

north at 2100 S. While more details of the observations can be found in Appendix D, the main observations are listed below:

**AM/MD Peak Period**

- With the close spacing of signals at 800 S and 900 S, the signals could benefit from coordination.
- Southbound 900 W at 800 S and eastbound 1300 S at 900 W can fail to clear.

### 5.1.5 300 W (2100 S to 600 S)

The 300 W corridor provides access to retail stores such as Costco and Walmart. It also provides access to and from the DA. Signals running free are causing progression issues. While more details of the observations can be found in Appendix E, the main observations are listed below:

**AM Peak Period**

- Due to the commercial nature of this corridor traffic is light during the AM peak.
- East/west traffic on 800 S,1300 S, and 2100 S is heavier than north/south traffic on 300 W.

**MD Period**

- Traffic is heavier than in the AM, with much of the traffic coming from turning movements on 1300 S and 2100 S.

**PM Peak Period**

- Only congestion on the corridor occurs at signals with more east/west traffic such as 1300 S and 2100 S.
- The southbound right turn at 2100 S is heavy and queues more than the through lanes.

### 5.1.6 California Ave (Redwood Rd to Bangerter Hwy)

California Ave (1300 S) between Redwood Rd and Bangerter Hwy serves a more industrial area with a high number of heavy trucks. It also crosses the I-215 West interchange, which is the origin of most of the traffic on the corridor, and provides access to and from the DA. While the traffic volumes aren't heavy, coordination could reduce stops for the heavy trucks. While more details of the observations can be found in Appendix F, the main observations are listed below:

**AM Peak Period**

- There is a very heavy westbound platoon coming from the northbound left turn at the I-215 interchange.
- There is high enough traffic volumes to warrant testing coordination.

**PM Peak Period**

- The southbound left turn movement at Pioneer is heavy, the split needs to be long enough or it will queue.

- The eastbound and westbound left turns at I-215 are heavy with much of the traffic accessing the freeway.

## 5.2 Downtown Area (DA)

Based on our observation of the DA several items were identified as issues to address, which are shown in Figure 2. Additional notes and details of the observations of the DA can be found in the Appendix G.

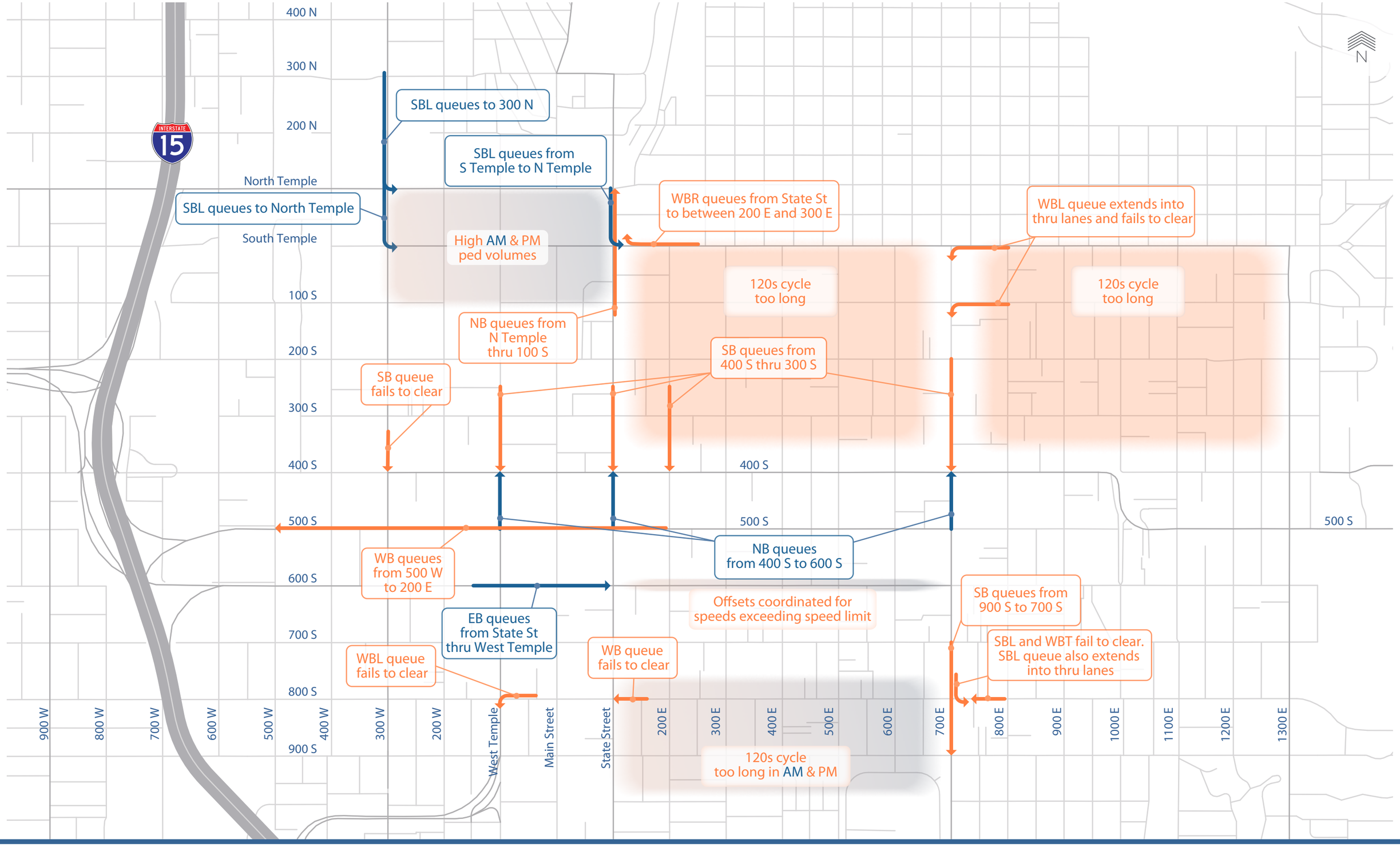



Figure 2: Existing **AM / PM** Problem Areas

Salt Lake City Traffic Signal Management

# 6 ALTERNATIVE DEVELOPMENT AND SELECTION

SLC was broken up into six corridors and the DA based on the different traffic needs and roadway characteristics. While the DA is a network of densely spaced traffic signals located at every block that experience heavy traffic in all four directions, many of the outlying corridors have sporadic signal spacing and only experience heavy traffic on the main roadway. These characteristics necessitate different approaches.

## 6.1 Corridors

In general, the corridor optimization process attempted to reduce cycle lengths while still maintaining good coordination in an effort to reduce delay and pollution. Each corridor was reviewed and retimed independently except at locations where the corridors cross. The cycle lengths used for each corridor was initially based on evaluation of ATSPM data and observations. Additionally, cycle lengths were chosen that would allow the standardization of cycle lengths allowing corridors to cross-coordinate. To accomplish this a half cycle or two-thirds harmonic was often used. Table 3 shows a summary of the cycle lengths used for each of the corridors.

**Table 1: Updated Cycle Length for SLC Corridors**

| Corridor | AM Cycle Lengths | MD Cycle Lengths | PM Cycle Lengths |
|---|---|---|---|
| 1300 E (3300 S to South Temple) | 60 / 80 / 120 | 72 / 108 | 80 / 120 |
| 1300 S (500 W to 1300 E) | 80 / 120 | 72 / 108 | 80 / 120 |
| 2100 S (700 W to 2300 E) | 60 / 80 / 120 | 72 / 108 | 80 / 120 |
| Glendale Area (900 W; SR-201 to 800 S and 1300 S; Redwood to I-15) | 72 / 108 | | 80 / 120 |
| 300 W (2100 S to 600 S) | 60 / 80 / 120 | 108 | 120 |
| California Ave (Redwood Rd to Bangerter Hwy) | 108 | 108 | 120 |

The split times for each of the signals on the corridors were evaluated based on ATSPM data and observations. The pedestrian crossing times were also considered when setting the cycle length and the split times, and in several instances governed the minimum allowable split time for specific movements. More details about each of the individual corridors can be found in Appendix A through Appendix E.

## 6.2 Downtown Area

The DA of SLC has a unique set of challenges and characteristics, including multiple stakeholders (SLC, UDOT, and UTA), a complex grid network, and various transportation modes. The signal timing and coordination alternatives developed for the DA involved a brainstorm with the stakeholders, an evaluation of multiple different timing strategies, and a unanimous decision from the stakeholders on which alternative to implement.

### 6.2.1 Alternatives Development

An initial brainstorming meeting with the stakeholders was held to determine a range of possible timing alternatives which was narrowed down in subsequent meetings. The alternatives discussed included:

- Setting all signals "free" to allow for the signals to operate at their "preferred" cycle length instead of setting a specific cycle length for the whole network usually governed by a few signals.
- Treating each unique section of the DA individually with only limited coordination between sections.
- Creating virtual one-way couplets by providing good one-way progression along the corridor, with the prioritized direction alternating throughout the DA. For example, 900 S could provide good eastbound progression while 800 S provides good westbound progression.
- Programming the eastbound and westbound phases at all signals to turn green simultaneously followed by the northbound and southbound phases.
- Treating the major roads as corridors and optimizing them without considering the network as a whole.
- Restricting all left turn phases and requiring vehicles to go around the block (three right turns) to make a left turn.
- Coordinating the system as a network with uniform cycle lengths (including half cycle lengths and at most two-thirds harmonics).

The benefits and issues of each of these possible alternatives were discussed and evaluated by the project team (including stakeholders, PineTop, and Avenue). In subsequent meetings the list of alternatives was narrowed down to the final alternative:

> *Coordinating the system as a network with uniform cycle lengths (including half cycle lengths and at most two-thirds harmonics)*

As part of this alternative, two different cycle length options were evaluated for the AM and PM peak periods, 120 seconds and 150 seconds. The intent of the 120 second cycle length was to keep the existing cycle length while providing a 60 second half-cycle length. The intent of the 150 second cycle length was to increase capacity at signals that are oversaturated in the existing conditions and to provide a more flexible 75 second half-cycle length where possible. The 120 second cycle length was unanimously selected by the project team to be implemented.

During the MD periods a 108 second cycle length was used and based on observations did not need to be increased. However, a 54 second half-cycle length was too short to meet the needs of left turn phases and pedestrian crossing times. Therefore, the project team agreed that a two-thirds harmonic would be used in place of a half-cycle during the MD periods where appropriate.

The final alternative was selected for the following reasons:

- It would allow the DA to be treated as a network and provide the best opportunity for coordinating all four directions in a tight grid network.

- Current signal timing (with 120 second cycle length) that was working well could be maintained (e.g., 700 E and State St). These cycle lengths also match other corridors entering the DA.
- Main Corridors thru the DA (e.g. State St, West Temple, and 400 S) could still be prioritized.
- Half-cycle lengths or two-thirds harmonics would be implemented where possible, decreasing delays for vehicles, bikes, and pedestrians.
- Changes to the signal operation would have minimal impact on the UTA performance for TRAX and buses.

The final alternative was modeled in Synchro with the 120 second cycle, a 60 second half-cycle lengths, and 80 second harmonic cycle lengths during the AM and PM period, while the MD was modeled with a 108 second cycle length and 72 second harmonic cycle length. Figure 3 shows the cycle length used at each signal in the DA during the AM periods, Figure 4 shows the cycle lengths during the MD period, and Figure 5 sow the cycle lengths used in the PM period. These models were used to optimize offset changes, evaluate cycle length options, and adjust lead/lag left turn signal phasing.

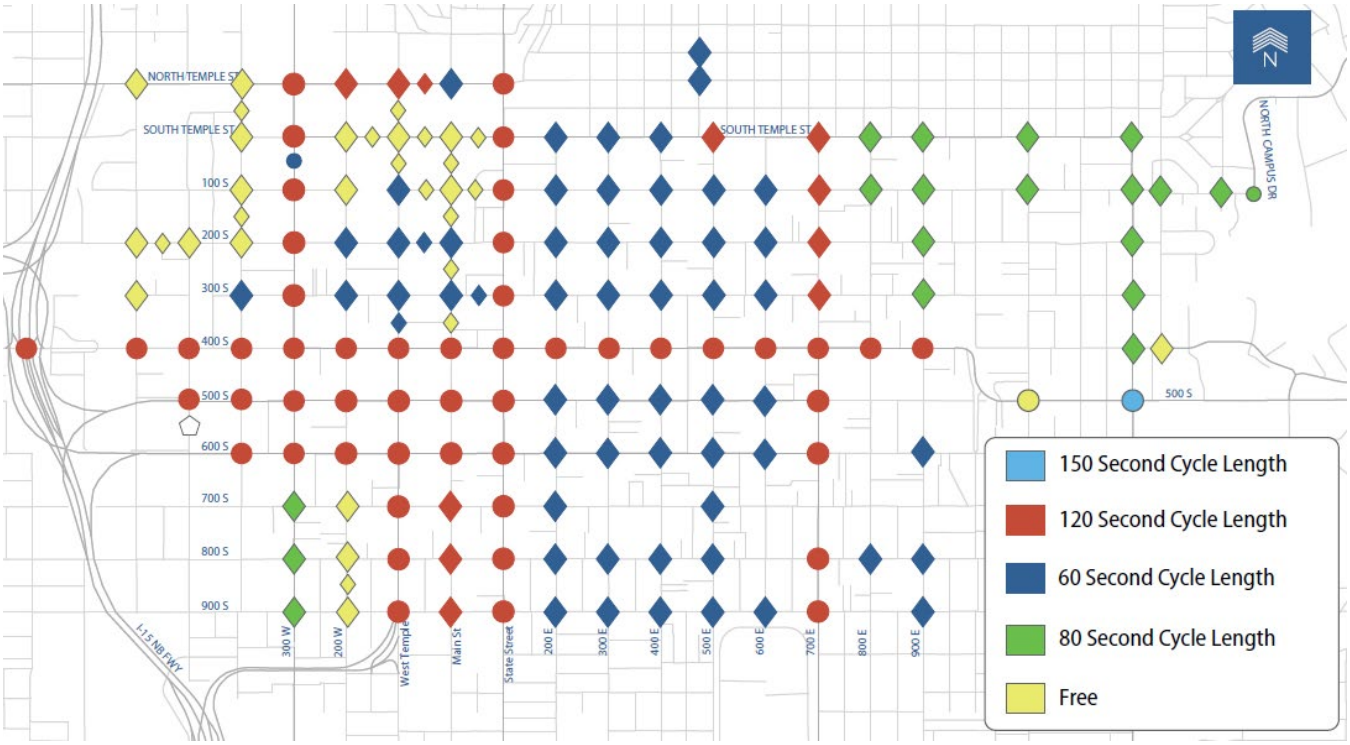



**Figure 3: DA AM Cycle Lengths**

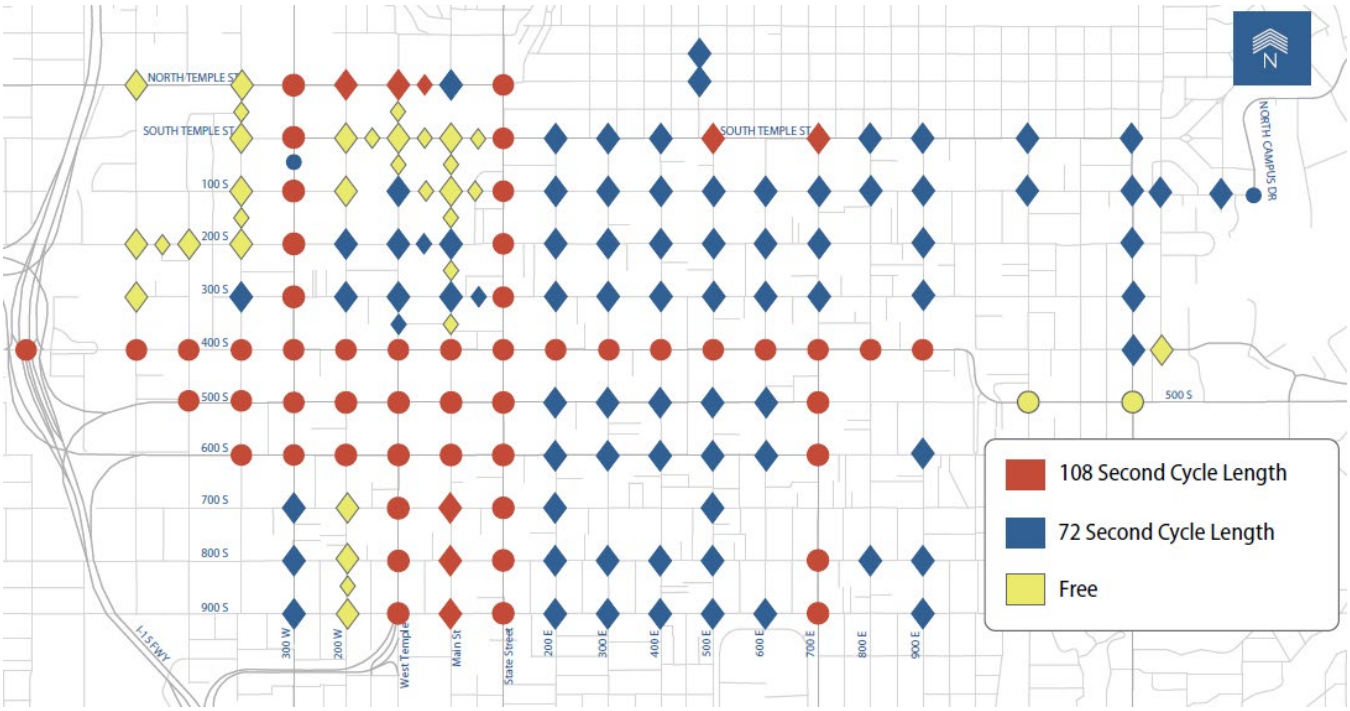



**Figure 4: DA MD Cycle Lengths**

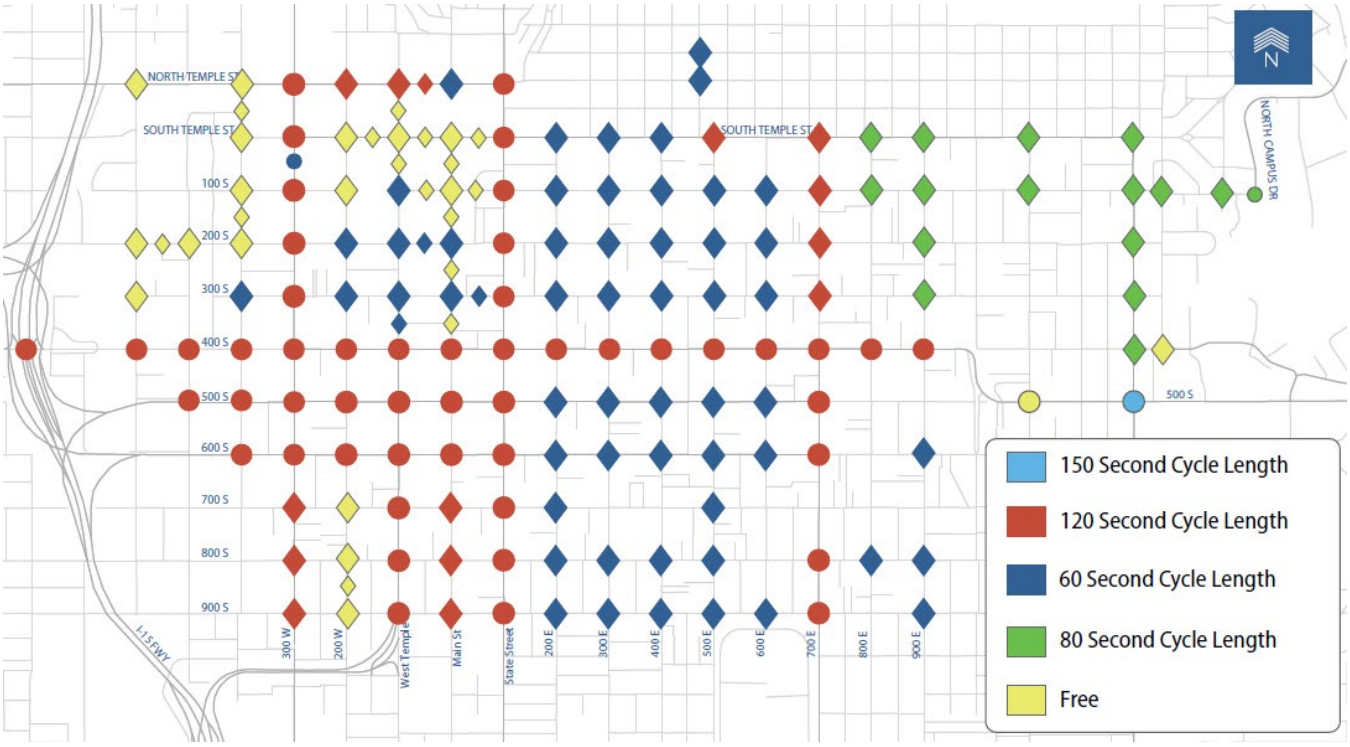



**Figure 5: DA PM Cycle Lengths**

### 6.2.2 Synchro modeling

The synchro models for the alternatives were developed from an existing conditions model of the DA provided by UDOT. To help manage the optimization the DA was divided into sections as shown in

Figure 6. These sections were based on intersection characteristics and identifying key corridors that needed to be prioritized inside of the grid network.

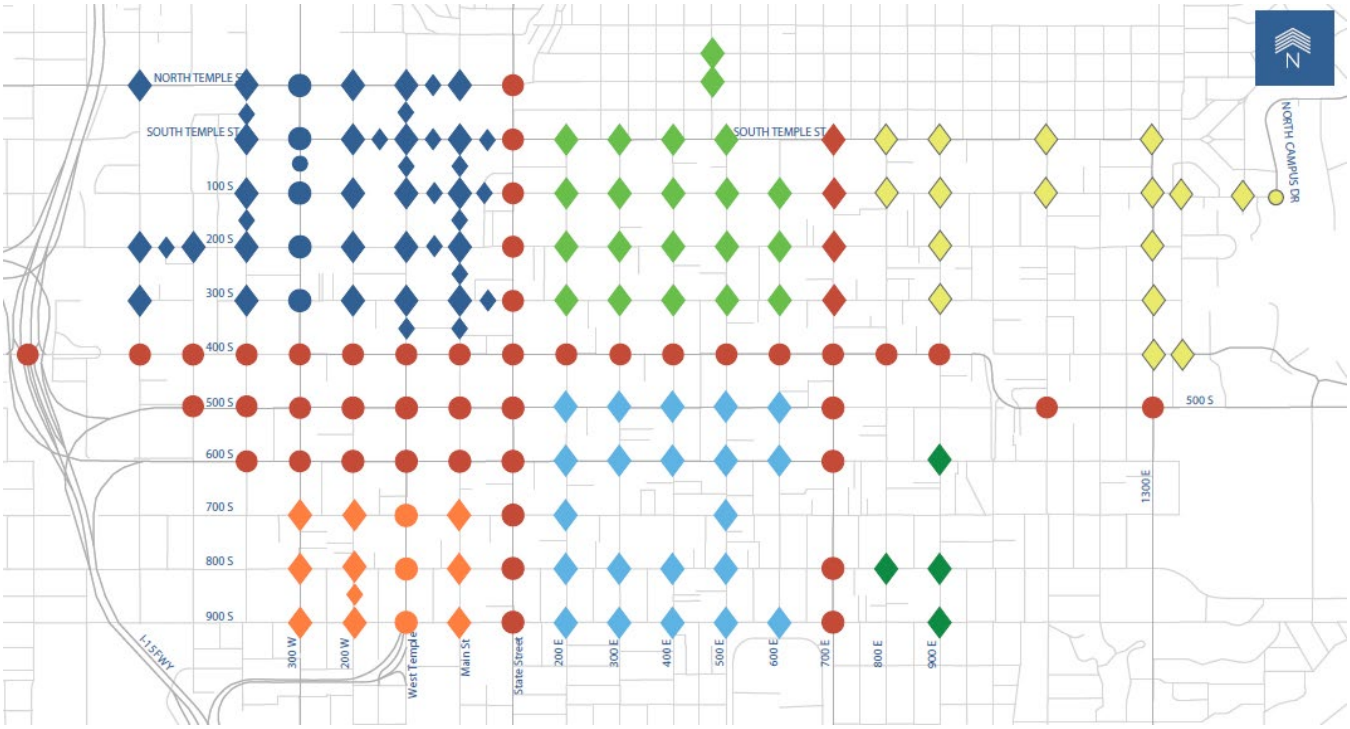



**Figure 6: DA Optimization Sections**

The first step in the optimization was reviewing each individual signal based on observations and ATSPM data to determine the appropriate splits and if a half-cycle was possible with the traffic demand and pedestrian crossing times. After each signal was reviewed the next step was a thorough review and optimization of the progression in each section. This included a review of the main corridors in each section. While the DA is a network and needed to be timed as such, some routes are also used as arterials that connect the DA with the outside corridors. These were prioritized as long as it didn't impact the performance of the overall system. The sections were then reviewed for coordination across sections, prioritizing the roadway with the highest volume because stops along these routes would create heavy congestion. However, each route connecting different section was ultimately reviewed to find the best solution for the system as a whole.

### 6.2.3 Cycle length Alternative Selection

After the 120 second and 150 second cycle length options were modeled, the results were compared using metrics from Synchro, a review of the time-space diagrams, and a comparison of the pros and cons.

*Synchro Metrics Comparison*

Table 2 summarizes the total delay, number of stops, and total travel time for the DA for the two cycle length options, more detail of individual corridors or zones can be found in the Appendix. The difference between the 120 second option and the 150 second option is also included in the table.

**Table 2: SLC DA Synchro Metric Comparison for 120 second and 150 second cycle length options**

| Metrics | AM Peak Hour | | | PM Peak Hour | | |
|---|---|---|---|---|---|---|
| | 120 s Option | 150 s Option | Difference (120 s Opt. minus 150 s Opt.) | 120 s Option | 150 s Option | Difference (120 s Opt. minus 150 s Opt.) |
| **Network Totals** | | | | | | |
| Total Delay (hr) | 1,524 | 1,628 | **-104** | 1,820 | 1,847 | **-27** |
| Stops (#) | 170,142 | 161,237 | **8,905** | 186,345 | 175,861 | **10,484** |
| Total Travel Time (hr) | 3,559 | 3,663 | **-104** | 3,989 | 4,015 | **-26** |

Based on the results of the Synchro analysis, the 120 second cycle length option provided lower total delay (1,524 vs. 1,628 hours of delay) and travel times (3,559 vs. 3,663 hours of travel) while reporting a higher number of stops. While the 150 second cycle length option might reduce the number of stops, the higher cycle length will result in longer stops. In some cases, the number of stops increased with the longer cycle lengths.

*Time Space Diagram Comparison*

A visual review of the Synchro time-space diagram showed that the progression along the major corridors was better in the 120 second cycle length option. In general, the progression with the 150 second cycle length still resulted in the same, or more, stops on the main corridors. Stops with the 150 second cycle length were also longer than with the 120 second cycle length due to the increased cycle length having more time between the end of a green phase and the start of the next green phase.

*Pros & Cons Comparison*

In addition to the delay and stops, other items were also considered when choosing between the two cycle length options, such as how the DA timing would tie into the corridors that feed into the DA. These items were separated into pros and cons and are shown in Table 3.

**Table 3: SLC DA Pros and Cons Comparison for 120 second and 150 second cycle length options**

| Option | Pros | Cons |
|---|---|---|
| 120 Second Cycle Length (w/ 60 second half-cycle) | • Snappier cycle lengths (better for Pedestrians and Bikes)<br>• 120 second cycle length will tie into State St and 700 E<br>• Keep progression that works well (e.g., 700 E)<br>• Likely to waste less green time in prior to and after AM and PM peaks | • Doesn't provide as much flexibility to improve capacity issues<br>• Fewer half cycle opportunities (mostly just 300 W between 400 S and North Temple)<br>• Requires shortening pedestrian crossing times (without violating minimum safety standards) |
| 150 Second Cycle Length (w/ 75 second half-cycle) | • More flexibility to improve capacity issues<br>• 75 second cycle length works in locations that the 60 s does not (e.g., 300 W between 400 S and North Temple)<br>• 150 second cycle length can tie into Foothill Drive<br>• Is not restricted by shorter pedestrian crossing times | • Longer delay for minor street vehicles (including bikes and pedestrians)<br>• Will not tie into State Str and 700 E coordination south of 900 S<br>• Potential for unused green time for signals with light minor streets (e.g., State St. and 700 S) |

This comparison resulted in the project team selecting to implement the 120 second cycle length option for the AM and PM peak periods.

# 7 TIME OF DAY SCHEDULE

Part of the retiming effort included reviewing TOD schedule for the weekdays and weekend. Changes were made when necessary due to observations of traffic patterns or to standardize the plans along a corridor or in the DA to start and end at the same time.

## 7.1 Corridors

The TOD schedule was set based on the ATSPM data and observations of traffic patterns. Changes for the weekday TOD plans at each corridor took into account the impact that these changes would have to vehicles traveling along the corridor and also to other considerations such as keeping the entire corridor on the same schedule, start and end times for schools located on the corridor, and delay for vehicles on the minor approaches. More details, including the transition times and the weekend TOD plans, can be found in Appendix A through Appendix E.

## 7.2 Downtown Area (DA)

The strategy for the TOD schedule in the DA was to implement consistent transition times across the entire DA to ensure that the signals will work together without any breaks in the coordination. Based

on observations, it appears that nearly all TOD transition times are suitable for current traffic volumes and patterns in the DA. The only change that was made was to move the transition time of the AM to MD patterns from 9:00 AM to 9:30 AM due to heavy traffic demand.

# 8 IMPLEMENTATION PROCESS

Due to difference in the nature and size of the corridor timing and DA timing, the implementation process varied. Each of the corridor weekday and weekend timings were installed in the late evening prior to the weekday fine tuning. The weekend timings were also fine-tuned that following weekend. Fine tuning would often take multiple weekdays and weekends in addition to reviewing ATSPM data.

For the DA, several implementation options were discussed. It was determined that the installation should be accomplished in the following steps:

- The new signal timing and TOD schedules for the entire DA were entered on Sunday, September 9, 2018. This was done in lieu of phasing the installation throughout the DA to eliminate the potential for poor interaction of previous timings between different areas. Due to the number of signals within the DA, this approach required some signals to run new timings for nearly two weeks without substantial field adjustments.
- The new timings were programmed directly into the permanent pattern locations in the controller (AM: Pattern 1, MD: Pattern 7, and PM: Pattern 13). In addition, the MD was programed to run on Saturday and Sunday. The previous patterns were saved as different pattern numbers to be available as a backup (AM: Pattern 2, MD: Pattern 10, and PM: Pattern 14).
- For fine tuning the new coordination plans, the DA was divided into four groups (shown in Figure 6). The intent was to fine-tune these groups as quickly as feasibly possible to minimize the time potential issues would occur before being fixed. The date each group was fine-tuned is also shown in Figure 7. Remaining issues were addressed on following days over the course of the next month.

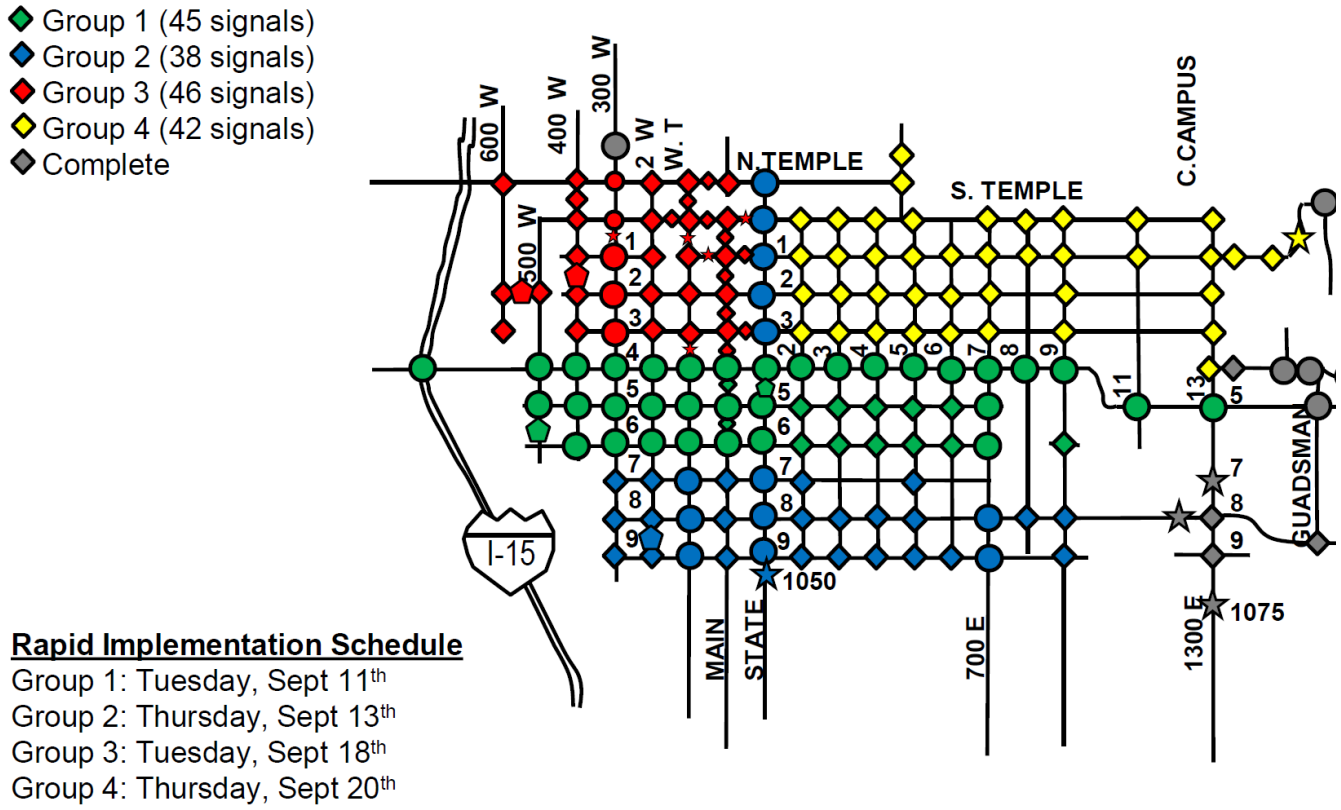



**Figure 7: DA Implementation Groupings**

- Sunday (Day Plan 1) and Saturday (Day Plan 7) were initially programed to run the same pattern as was run during the weekday MD (Pattern 7), as was done historically. These plans were reviewed in the field on Saturday, September 22, 2018 and on Sunday, September 23, 2018. While the MD pattern worked well for Saturday traffic, a unique pattern (Pattern 19) was created for Sunday traffic in the southwest DA. The MD 108 second cycle length was too large for the light Sunday traffic and a 72 second cycle length was fine-tuned on following Sundays in its place.

# 9 IMPLEMENTATION RESULTS

## 9.1 Corridor Measures of Effectiveness

The travel times collected by SLC and thru the HERE data provided by UDOT were used to evaluate the improvements made to the signals timing. The travel time savings was also used to calculate the fuel savings, reduction in $CO_2$ emissions, and other Critical Air Pollutants ($PM_{2.5}$, CO, $NO_X$, VOC and $PM_{10}$). The calculations for these pollutants were based on the 2018 MOVES model.

### 9.1.1 SLC Travel Times

A summary of the before-after travel times and differences can be found in Table 4. Where data was limited the HERE data was used to supplement and is identified with an asterisk.

**Table 4: Travel Time Comparison on Corridors**

| Route | Scenario | Southbound / Eastbound Travel Times (minutes) | | | Northbound / Westbound Travel Times (minutes) | | |
|---|---|---|---|---|---|---|---|
| | | AM | MD | PM | AM | MD | PM |
| 1300 E | Before | 16.28* | 15.03* | 15.65* | 14.18* | 16.22* | 17.49* |
| | After | 13.7 | 13.68 | 12.83 | 13.3 | 12.73 | 13.04 |
| | Difference | -2.58 | -1.35 | -2.82 | -0.88 | -3.49 | -4.45 |
| 1300 S | Before | 9.48 | 5.1 | 11.14 | 9.08 | 8.52 | 9.5 |
| | After | 10.35 | 7.49 | 9.85 | 7.44 | 8.33 | 9.96 |
| | Difference | 0.88 | 2.4 | -1.29 | -1.64 | -0.19 | 0.45 |
| 2100 S | Before | 14.98 | 13.99 | 15.8 | 14.29 | 14.97 | 17.87 |
| | After | 12.86 | 14.89 | 13.94 | 14.19 | 13.3 | 16.09 |
| | Difference | -2.12 | 0.9 | -1.86 | -0.11 | -1.67 | -1.77 |
| *Note: Travel time was collected using HERE data. | | | | | | | |

Based on the travel time data collected by SLC the average travel times were reduced by a minute during all time periods. The largest improvement is seen on 1300 E where the before travel time were collected using the HERE data which may have skewed some of the results but of the 18 different route, time period, and direction combinations 14 have travel times that decreased after the retiming effort. On average across these corridors the travel time reduced by 65 seconds in the AM peak, 34 seconds in the MD, and by 117 seconds in the PM peak for both directions. Table 5 summarizes the daily decrease in emissions for each of the corridors based on this travel time reduction.

**Table 5: Daily Reductions in Fuel Consumption and Emissions**

| Route | Measure | AM | MD | PM |
|---|---|---|---|---|
| 1300 E | Fuel (gal) | 52 | 57 | 97 |
| | CO2 (lbs.) | 973 | 1,075 | 1,828 |
| | Total Critical Air Pollutants (lbs.) | 16 | 18 | 6 |
| 1300 S | Fuel (gal) | -4 | -17 | -1 |
| | CO2 (lbs.) | -77 | -313 | -11 |
| | Total Critical Air Pollutants (lbs.) | -1 | -5 | 2 |
| 2100 S | Fuel (gal) | 30 | 7 | 34 |
| | CO2 (lbs.) | 574 | 137 | 640 |
| | Total Critical Air Pollutants (lbs.) | 9.6 | 2.3 | 2.8 |
| Total | Fuel (gal) | 78 | 48 | 130 |
| | CO2 (lbs.) | 1,470 | 899 | 2,457 |
| | Total Critical Air Pollutants (lbs.) | 25 | 15 | 10 |

The reduction in travel times along the six corridors correlates to a total daily reduction of 4,830 lbs of CO2 and 49 lbs of other critical air pollutants. Over the course of a year, assuming 250 work days, this reduction will be over 60 tons of CO2 and 6 tons of other critical air pollutants. However, this doesn't

include the benefits in reduced emission from a reduction in travel times experienced over the weekends and holidays.

### 9.1.2 HERE Data Travel Times

A summary of the before-after travel times using the HERE data can be found in Table 6. These travel times differ from those collected by SLC due to variations in the data collection methods which allowed for a larger sample size with the HERE then was possible using the probe vehicle. In some cases the extends of the HERE data collection and SLC data collection along the corridor did not exactly match.

**Table 6: HERE Travel Time Comparison on Corridors**

| Route | Scenario | Southbound / Eastbound Travel Times (minutes) | | | Northbound / Westbound Travel Times (minutes) | | |
|---|---|---|---|---|---|---|---|
| | | AM | MD | PM | AM | MD | PM |
| 1300 E | Before | 16.28 | 15.03 | 15.65 | 14.18 | 16.22 | 17.49 |
| | After | 14.86 | 14.44 | 15.29 | 13.35 | 14.24 | 16.5 |
| | Difference | -1.42 | -0.59 | -0.36 | -0.83 | -1.98 | -0.99 |
| 1300 S | Before | 13.59 | 13.57 | 14 | 12.76 | 13.35 | 13.84 |
| | After | 13.75 | 13.12 | 13.6 | 11.88 | 12.64 | 13.33 |
| | Difference | 0.16 | -0.45 | -0.4 | -0.88 | -0.71 | -0.51 |
| 2100 S | Before | 14.8 | 15.66 | 16.84 | 14.82 | 16.6 | 17.8 |
| | After | 14.63 | 15.53 | 16.38 | 14.79 | 15.39 | 17 |
| | Difference | -0.17 | -0.13 | -0.46 | -0.03 | -1.21 | -0.8 |
| 900 W | Before | 6.52 | 6.42 | 6.57 | 6.86 | 6.57 | 6.84 |
| | After | 6.11 | 5.91 | 6.2 | 6.35 | 6.19 | 6.41 |
| | Difference | -0.41 | -0.51 | -0.37 | -0.51 | -0.38 | -0.43 |
| 300 W | Before | 4.81 | 5.89 | 5.92 | 4.74 | 5.76 | 6.22 |
| | After | 4.73 | 5.39 | 5.49 | 4.67 | 5.62 | 5.57 |
| | Difference | -0.08 | -0.5 | -0.43 | -0.07 | -0.14 | -0.65 |
| California Ave | Before | 7.08 | 7.15 | 7.27 | 7.18 | 7.20 | 7.25 |
| | After | 6.54 | 6.39 | 6.46 | 6.38 | 6.77 | 6.80 |
| | Difference | -0.54 | -0.76 | -0.81 | -0.8 | -0.43 | -0.45 |

Nearly all corridors show a decrease in travel times for the AM, MD, and PM periods. The only increase in travel times was for eastbound vehicles on 1300 S, where the travel time increased by 10 seconds. This increase is offset by a 53 second decrease in travel time in the westbound direction. The largest decrease in travel time occurred in the northbound direction on 1300 E where the travel time reduced by almost 2 minutes. On average across these corridors the travel time reduced by 28 seconds in the AM peak, 39 seconds in the MD, and by 33 seconds in the PM peak for both directions. Table 7 summarizes the daily decrease in emissions for each of the corridors based on this travel time reduction.

**Table 7: Daily Reductions in Fuel Consumption and Emissions based on HERE data**

| Route | Measure | AM | MD | PM |
|---|---|---|---|---|
| 1300 E | Fuel (gal) | 16 | 16 | 10 |
| | CO2 (lbs.) | 307 | 310 | 184 |
| | Total Critical Air Pollutants (lbs.) | 10 | 10 | 6 |
| 1300 S | Fuel (gal) | 4 | 8 | 4 |
| | CO2 (lbs.) | 83 | 152 | 74 |
| | Total Critical Air Pollutants (lbs.) | 1 | 3 | 2 |
| 2100 S | Fuel (gal) | 1 | 5 | 8 |
| | CO2 (lbs.) | 25 | 99 | 143 |
| | Total Critical Air Pollutants (lbs.) | 1 | 3 | 4 |
| 900 W | Fuel (gal) | 5 | 5 | 5 |
| | CO2 (lbs.) | 87 | 88 | 96 |
| | Total Critical Air Pollutants (lbs.) | 2 | 2 | 2 |
| 300 W | Fuel (gal) | 1 | 3 | 6 |
| | CO2 (lbs.) | 11 | 62 | 112 |
| | Total Critical Air Pollutants (lbs.) | < 1 | 2 | 3 |
| California Ave | Fuel (gal) | 10 | 7 | 10 |
| | CO2 (lbs.) | 190 | 137 | 188 |
| | Total Critical Air Pollutants (lbs.) | 4 | 4 | 4 |
| Total | Fuel (gal) | 37 | 45 | 42 |
| | CO2 (lbs.) | 703 | 848 | 797 |
| | Total Critical Air Pollutants (lbs.) | 18 | 23 | 21 |

The reduction in travel times along the six corridors correlates to a total daily reduction of 2,348 lbs of CO2 and 61 lbs of other critical air pollutants. Over the course of a year this reduction will be over 290 tons of CO2 and 8 tons of other critical air pollutants. This is based on 250 work days during a year, additional benefit would be seen during weekends and holidays.

## 9.2 DA Measures of Effectiveness

To better understand the improvements in the DA, travel times were measured by SLC on 200 E, 500 E, 900 E, 800 S, 900 S, and 100 S and emissions calculated. Travel times on the state routes were provided by UDOT using HERE data.

### 9.2.1 SLC Travel Times

Travel times for the routes collected by SLC were obtained using a GPS tracker and a probe vehicle. Five travel time runs were collected for each route direction and time of day. A summary of the before-after travel times and the differences in the DA can be found in Table 8.

**Table 8: Travel Time Comparison on DA**

| Route | Scenario | Southbound / Eastbound Travel Times (minutes) | | | Northbound / Westbound Travel Times (minutes) | | |
|---|---|---|---|---|---|---|---|
| | | AM | MD | PM | AM | MD | PM |
| 200 E | Before | 5.89 | 6.67 | 7.02 | 4.66 | 5.20 | 5.97 |
| | After | 5.37 | 5.65 | 5.44 | 4.83 | 5.30 | 4.48 |
| | Difference | -0.52 | -1.02 | -1.58 | 0.17 | 0.10 | -1.49 |
| 500 E | Before | 5.72 | 4.35 | 6.56 | 4.28 | 4.48 | 4.17 |
| | After | 3.75 | 4.21 | 5.02 | 4.77 | 4.33 | 4.85 |
| | Difference | -1.97 | -0.14 | -1.54 | 0.49 | -0.16 | 0.68 |
| 900 E | Before | 4.29 | 3.36 | 4.22 | 2.92 | 4.03 | 4.53 |
| | After | 4.28 | 3.60 | 3.25 | 3.83 | 3.57 | 3.59 |
| | Difference | -0.02 | 0.24 | -0.97 | 0.90 | -0.46 | -0.94 |
| 800 S | Before | 8.70 | 8.01 | 7.51 | 7.00 | 6.46 | 8.55 |
| | After | 8.86 | 8.81 | 7.49 | 6.36 | 7.53 | 7.24 |
| | Difference | 0.16 | 0.80 | -0.02 | -0.64 | 1.07 | -1.31 |
| 900 S | Before | 7.65 | 8.30 | 7.05 | 6.45 | 7.53 | 7.63 |
| | After | 4.39 | 5.95 | 4.99 | 4.36 | 4.98 | 4.68 |
| | Difference | -3.26 | -2.35 | -2.07 | -2.09 | -2.55 | -2.95 |
| 100 S | Before | 8.61 | 8.82 | 9.77 | 9.68 | 9.03 | 10.20 |
| | After | 7.67 | 8.10 | 9.57 | 9.01 | 8.42 | 8.97 |
| | Difference | -0.95 | -0.72 | -0.19 | -0.67 | -0.61 | -1.23 |
| South Temple | Before | 5.55 | 5.11 | 5.67 | 4.91 | 5.57 | 5.55 |
| | After | 4.89 | 4.88 | 5.97 | 4.97 | 4.74 | 5.19 |
| | Difference | -0.66 | -0.24 | 0.30 | 0.06 | -0.83 | -0.37 |

The majority of corridors decreased in travel times during the three time periods. A few routes did have travel times that increased, but often these increases were in one direction and are offset by decreases in the other direction. For example, on South Temple in the AM peak the travel time in the westbound direction increased by 4 seconds while the eastbound decreased by 40 seconds. The corridor with the most consistent and largest increases in travel time was 800 S where detection issues may have increased the travel time for some of the after implementation travel time runs. On average across these corridors the travel time reduced by 39 seconds in the AM peak, 29 seconds in the MD, and by 59 seconds in the PM peak for both directions. Table 9 shows the decrease in emissions for each of the corridors in the DA where travel times were collected by SLC.

**Table 9: Daily Reductions in Fuel Consumption and Emissions**

| Route | Measure | AM | MD | PM |
|---|---|---|---|---|
| 200 E | Fuel (gal) | 0 | 6 | 21 |
| | CO2 (lbs.) | 0 | 115 | 387 |
| | Total Critical Air Pollutants (lbs.) | 0 | 1 | 4 |
| 500 E | Fuel (gal) | 1 | 1 | 7 |
| | CO2 (lbs.) | 18 | 21 | 140 |
| | Total Critical Air Pollutants (lbs.) | 0 | < 1 | 1 |
| 900 E | Fuel (gal) | -7 | 1 | 10 |
| | CO2 (lbs.) | -128 | 21.7 | 180.0 |
| | Total Critical Air Pollutants (lbs.) | -2 | 0 | 2 |
| 800 S | Fuel (gal) | 4 | -14 | 10 |
| | CO2 (lbs.) | 69 | -267 | 188 |
| | Total Critical Air Pollutants (lbs.) | 1 | -19 | 3 |
| 900 S | Fuel (gal) | 30 | 28 | 28 |
| | CO2 (lbs.) | 570 | 522 | 535 |
| | Total Critical Air Pollutants (lbs.) | 6 | 6 | 7 |
| 100 S | Fuel (gal) | 12 | 9 | 13 |
| | CO2 (lbs.) | 227 | 177 | 252 |
| | Total Critical Air Pollutants (lbs.) | 2 | 2 | 4 |
| South Temple | Fuel (gal) | 7 | 126 | 0 |
| | CO2 (lbs.) | 8 | 142 | 0 |
| | Total Critical Air Pollutants (lbs.) | 3 | 53 | 0 |
| Total | Fuel (gal) | 47 | 157 | 89 |
| | CO2 (lbs.) | 763 | 733 | 1682 |
| | Total Critical Air Pollutants (lbs.) | 10 | 44 | 21 |

The reduction in travel times along these seven routes in the DA correlates to a total daily reduction of 3,178 lbs of CO2 and 74.3 lbs of other critical air pollutants. Over the course of a year this reduction will be over 390 tons of CO2 and 9 tons of other critical air pollutants. This is based on 250 work days during a year, additional benefit would be seen during weekends and holidays.

### 9.2.2 HERE Data Travel Times

The HERE data before-after travel times in the DA are shown in Table 10. These are the travel times on state routes in the DA. Due to the limitations of the HERE data, i.e. not enough probe vehicles, travel times could not be collected by this method for many of the other routes in the DA. However, many were collected by SLC.

**Table 10: HERE Travel Time Comparison in the DA**

| Route | Scenario | Southbound / Eastbound Travel Times (minutes) | | | Northbound / Westbound Travel Times (minutes) | | |
|---|---|---|---|---|---|---|---|
| | | AM | MD | PM | AM | MD | PM |
| West Temple | Before | 4.8 | 5.3 | 5.5 | 4.9 | 4.5 | 5.0 |
| | After | 4.1 | 4.3 | 4.1 | 4.2 | 4.4 | 4.6 |
| | Difference | -0.7 | -1.0 | -1.5 | -0.7 | -0.1 | -0.4 |
| State St | Before | 11.8 | 11.8 | 12.4 | 12.1 | 12.0 | 12.7 |
| | After | 8.9 | 9.0 | 9.3 | 9.2 | 9.4 | 9.9 |
| | Difference | -2.9 | -2.8 | -3.0 | -2.9 | -2.6 | -2.8 |
| 700 E | Before | 7.7 | 7.3 | 8.3 | 6.8 | 7.1 | 7.5 |
| | After | 6.5 | 6.6 | 7.7 | 6.6 | 6.6 | 6.8 |
| | Difference | -1.2 | -0.7 | -0.6 | -0.2 | -0.5 | -0.7 |
| 400 S | Before | 9.9 | 10.7 | 11.5 | 11.3 | 10.7 | 11.2 |
| | After | 9.7 | 10.1 | 10.7 | 9.7 | 10.0 | 10.2 |
| | Difference | -0.2 | -0.7 | -0.9 | -1.6 | -0.7 | -1.0 |
| 500 S | Before | N/A | | | 5.61 | 5.76 | 5.6 |
| | After | | | | 4.88 | 5.49 | 4.9 |
| | Difference | | | | -0.7 | -0.3 | -0.7 |
| 600 S | Before | 6.6 | 6.2 | 5.5 | N/A | | |
| | After | 6.0 | 5.5 | 5.2 | | | |
| | Difference | -0.6 | -0.7 | -0.3 | | | |

Among all the corridors where HERE data was collected the travel times decreased after the implementation of the new signal timing. The biggest decreases were on State St where the travel times decreased by as much as three minutes. On average across these corridors the travel time reduced by 70 seconds per vehicle in the AM peak, 60 seconds in the MD, and by 71 seconds in the PM peak for both directions. Table 11 shows the decrease in emissions for each of the state routes in the DA.

**Table 11: Daily Reductions in Fuel Consumption and Emissions based on HERE data**

| Route | Measure | AM | MD | PM |
|---|---|---|---|---|
| West Temple | Fuel (gal) | 19 | 14 | 31 |
| | CO2 (lbs.) | 366 | 273 | 588 |
| | Total Critical Air Pollutants (lbs.) | 7 | 3 | 14 |
| State St | Fuel (gal) | 76 | 71 | 80 |
| | CO2 (lbs.) | 1,435 | 1,338 | 1,504 |
| | Total Critical Air Pollutants (lbs.) | 26 | 20 | 18 |
| 700 E | Fuel (gal) | 18 | 25 | 27 |
| | CO2 (lbs.) | 342 | 480 | 507 |
| | Total Critical Air Pollutants (lbs.) | 4 | 7 | 6 |
| 400 S | Fuel (gal) | 15 | 17 | 26 |
| | CO2 (lbs.) | 277 | 316 | 493 |
| | Total Critical Air Pollutants (lbs.) | 5 | 5 | 9 |
| 500 S | Fuel (gal) | 22 | 8 | 5 |
| | CO2 (lbs.) | 421 | 156 | 92 |
| | Total Critical Air Pollutants (lbs.) | 9 | 3 | 2 |
| 600 S | Fuel (gal) | 24 | 28 | 12 |
| | CO2 (lbs.) | 453 | 529 | 227 |
| | Total Critical Air Pollutants (lbs.) | 4 | 5 | 2 |
| Total | Fuel (gal) | 174 | 164 | 180 |
| | CO2 (lbs.) | 3,294 | 3,091 | 3,411 |
| | Total Critical Air Pollutants (lbs.) | 55 | 43 | 52 |

For the routes in the DA where HERE data was available the improvement in travel times correlates to a total daily reduction of 9,300 lbs of CO2 and 150 lbs of other critical air pollutants. Over the course of a year this reduction will be over 1,100 tons of CO2 and 36,000 pounds of other critical air pollutants. This is based on 250 work days during a year, additional benefit would be seen during weekends and holidays.

### 9.2.3 DA Additional Notes

In addition to the general cycle length and progression changes a few other changes of note were made and are listed below, more information about changes made during implementation can be found in Appendix G.

- **400 S; State St & 700 E –** *East/West Leading/Lagging Left Turns*
  The initial proposed timings for State St and 700 E on 400 S had the eastbound and westbound left turns operating with one leading and one lagging. However, this did not allow enough time for TRAX, which crossed the intersection when both the eastbound and westbound through

phases were green. The progression was reworked to make the east/west left turns leading during all times of the day.

- **400 S & Main St –** *Peer-to-Peer*
  Main St at 400 S runs peer-to-peer logic to mimic coordination. We worked with UDOT to set the logic to work well with the coordination strategies of each plan.
- **600 S; State & 200 E –** *216 second cycle length*
  During the MD pattern on 600 S at State St and 200 E, UDOT identified in the Synchro model that due to the harmonic every other eastbound arrival at 200 E would stop. UDOT proposed addressing this using a 216 second cycle length at both signals with State St serving each movement twice and 200 E serving each movement three times in one cycle. This allowed both eastbound arrivals at 200 E to be on green.
- **North Temple & 300 W –** *Flashing Yellow Arrow Signal Heads*
  The left turn phasing at North Temple and 300 W consisted of protected only phasing for the eastbound and westbound left turn phase and protected/permissive left turn phasing with a five-section head for the northbound and southbound left turn phase. Replacing these with flashing yellow arrow signal head would decrease the amount of split time need for the eastbound and westbound left turns and allow for the southbound left turn to be lagged in the AM peak which could provide more time for the heavy volume making this turn.
- **West Temple & 100 S –** *Exclusive Ped Phase*
  West Temple at 100 S had an exclusive pedestrian phase which was omitted in the AM and PM peaks to allow for a 60 second cycle length. This exclusive ped phase had been used to serve the high pedestrian demand created by events at the Salt Palace Convention Center, instead the exclusive pedestrian phase (and a 120 second cycle length) will only be enabled by event plans.
- **500 S; 500 W to 400 W -** *Reverse Progression*
  Due to queuing during the PM peak on 500 S, which starts at 500 W and often seen backing as far as 200 E, it was determined that reverse progression was needed between 4:50 PM to 5:40 PM. Reverse progress starts the green phase at the downstream signal first to allow the queue to start moving before vehicles upstream get the green light. While it results in more stops, it shortened the length of the overall queue and allowed the green time to be used more efficiently.
- **700 E; 800 S to 900 S** – *Reverse Progression*
  In the PM peak on 700 E, reverse progression was used at 800 S and 900 S. From 5:00 PM to 6:00 PM these signals at start their green phases sooner to ensure that the queues are moving before the platoon arrives from the north. This helped to reduce the queue length and the amount of time issue persists.
- **DA –** *Friday TOD Plan*
  The Friday MD to PM transition time was checked to evaluate if an earlier transition time was needed. Often the PM peak on Friday begins earlier than a typical weekday. However, field observations showed that it's not different enough to warrant a unique day plan and Day plan 2 should continue to be used during Friday.
- **DA –** *Event Plans*
  The current event patterns in the DA were updated to work with the changes made to the normal weekday and weekend patterns. Many of the event plans use Pattern 1 or 13 with an occasional unique pattern created to work with other Patterns 1 or 13 but better meet event traffic

demands. It was the LDS Conference Center and Vivint Smart Home Arena event plans that were the updated.

## 9.3 Benefit/Cost Analysis

A comparison of the *project cost* versus the *user cost travel time savings* was completed using HERE travel time data supplemented with travel time data collected by Salt Lake City. To obtain the financial value of the user travel time savings per year, the combined travel time savings for all vehicles using the route when the signal timing is active is multiplied by three values:

1. Average vehicle occupancy (1.25 people per vehicle)
2. Average user cost ($17.67 per person-hour for passengers & $94.04 per person-hour for large trucks)
3. Number of workdays per year (250 workdays per year)

The average vehicle occupancy and average user cost values were derived by the Texas Transportation Institute. The percentage of truck traffic was assumed to be 2% of the vehicle composition. The calculated user cost travel time savings for the DA and the corridors along with the project cost and the calculated benefit-cost ratio are summarized in Table 12.

**Table 12: Project Benefit and Cost Totals**

| Route | User Cost Travel Time Savings | Project Cost | Benefit / Cost Ratio |
|---|---|---|---|
| DA | $14,240,000 | N/A | |
| Corridors | $4,060,000 | | |
| Total | $18,300,000 | $300,000 | 61 : 1 |

# 10 CONCLUSION

New traffic signal timings were implemented in the Downtown Area (DA) and at six other corridors in SLC to help meet the city's goal to reduce emissions, reduce delay for all modes, and provide better coordination between traffic signals operated by SLC and by UDOT. Based on a review of the travel times they reduced on average by 54 seconds for the DA and by 33 seconds for the corridors retimed. Tables 13 show the travel time reductions in the DA and for the corridors.

**Table 13: Travel Time Reductions in DA and Corridors**

| Route | Southbound / Eastbound Travel Times (minutes) | | | Northbound / Westbound Travel Times (minutes) | | |
|---|---|---|---|---|---|---|
| | AM | MD | PM | AM | MD | PM |
| DA | -1.1 | -0.8 | -1.0 | -0.7 | -0.7 | -1.1 |
| Corridors | -0.4 | -0.5 | -0.5 | -0.5 | -0.8 | -0.6 |

This reduction in travel times equates to a corresponding reduction in fuel usage, $CO_2$ and other critical air pollutants as shown in Table 14. The improve travel times means that 935 less gallons of fuel will be used daily reducing emissions by 15,300 lbs of $CO_2$ and 286 lbs of other critical air pollutants. Over the course of a year this will reduce emissions from vehicles by over 1,950 tons.

The benefit of the users' travel time reduction can also be compared to the project cost to provide a benefit to cost ratio for the project. Based on factors developed to determine the financial value of the travel time saving, the value of time saved is 61 times more than the project cost (a ratio of 61:1).

**Table 14: Emissions Reduction in DA and Corridors**

| Route | Measure | AM | MD | PM |
|---|---|---|---|---|
| DA | Fuel (gal) | 221 | 321 | 269 |
| | CO2 (lbs.) | 4,057 | 3,824 | 5093 |
| | Total Critical Air Pollutants (lbs.) | 65 | 87 | 73 |
| Corridors | Fuel (gal) | 37 | 45 | 42 |
| | CO2 (lbs.) | 703 | 848 | 797 |
| | Total Critical Air Pollutants (lbs.) | 18 | 23 | 21 |

As part of this effort several strategies were discussed and implemented. Some of the key strategies included a reduction in cycle lengths, coordinating SLC and UDOT signals together, and reevaluating the transition times along each corridor and in the DA.

## 10.1 Reduce the cycle lengths where possible to decrease delay for vehicles, bikes and pedestrians.

Cycle lengths were carefully considered throughout this project. The main objective was to provide cycle lengths that would serve the traffic volumes at the signal and decrease delay by servicing vehicles, pedestrian, and bikes more frequently. To accomplish this task with minimal impact to traffic on the major corridors, a combination of half cycle lengths (e.g. a 60 second cycle length with a 120 second cycle length) and 2/3$^{rd}$ harmonics (e.g. a 80 second cycle length with a 120 second cycle length) were used. This allowed for a decrease in travel times on the major corridors by an average of 33 seconds, while also decreasing delay on the minor approaches.

The reduction in cycle lengths in the DA decreased delays for bikes and pedestrians. In the DA the cycle length decreased at over 50 signals, with many of these changing from a 120 second cycle length to a 60 second cycle length. The project team considered several solutions but determined that a 120 second cycle length in the AM and PM combined with a 60 second cycle length would provide the most benefit.

## 10.2 Coordinate SLC and UDOT traffic signals to allow for better continuity on all routes through the city, even those that cross jurisdictions.

Optimal coordination throughout SLC required collaboration with all stakeholders including SLC, UDOT, and UTA. The signals owned and maintained by SLC in the DA are separated, isolated from each other by UDOT routes. For example, 800 S crosses three state routes when traveling from 300 W to 900 E. Breaking signal coordination at each of these crossings would create unnecessary delay. In addition, three TRAX lines cross through the DA creating additional coordination obstacles. The final solution that was developed and implemented successfully involved all stakeholders.

This solution included used a combination of the full, half, and 2/3rds harmonic cycle lengths. Some signals were left running Free to provide better operations for the TRAX system. This allowed the cycle length to be scaled to the needs of each individual signal without losing the coordination between signals.

Where possible the existing coordination that was working well was maintained with only minor adjustments. This included 700 E in the DA, where UDOT expressed already had good coordination.

## 10.3 Reevaluate the transition times between plans

For each corridor the transition times were reevaluated. Ensuring that coordination patterns are only operating when needed helps to reduce the delay. During the periods of coordination, travel times are reduced for heavier volumes traveling along the corridor. However, coordination also reduces the frequency that the minor approaches can be served. When the volumes are light along the corridor, coordination unnecessarily increases the delay for vehicles on the minor approach. Timing the transition times to match the traffic patterns reduces unnecessary delay. This was done through a combination of observing traffic and reviewing ATSPM data.

A similar effort was made in the DA. Due to detection limitations in the DA, coordination is run all day but transitioning to a smaller cycle length at the appropriate time can have the same impact as a signal running Free.

# APPENDIX A: 1300 E (3300 S to South Temple)

# Salt Lake City Traffic Signal Optimization Memo

Date: December 20, 2017
**Project Name: 1300 E Corridor**
Consultant: Luke Seegmiller (PineTop) and Shawn Larson (Avenue)
Salt Lake City: Bryan Meenen and Matthew Hyer

## Travel Time Results

Before and after travel time runs on 1300 E from So. Temple to 3300 S were completed, shown below. They show a lot of improvement. However, some periods have limited sample sizes. It was especially difficult to collect the after runs while implementing new timings due to the need to stop and watch or tweak the timings periodically. The sheer length of the corridor (5 miles) added to difficulty. In short, this is certainly not scientific results but a rather a snapshot or indication that we made improvements.

| Period | NB | | | | SB | | | |
|---|---|---|---|---|---|---|---|---|
| | Before | After | Diff | % Change | Before | After | Diff | % Change |
| AM | 17:35 | 17:43 | +0:08 | 1% | 14:41 | 12:35 | -2:06 | -14% |
| MD | 14:33 | 11:28 | -3:05 | -21% | 21:28 | 13:05 | -8:23 | -39% |
| PM | 15:27 | 11:23 | -4:04 | -26% | 17:56 | -- | -- | -- |

## Scope

**Signals:**

- 1300 E from S. Temple to Brickyard
- 1100 E from S. Temple to 100 S
- 2700 S @ Highland.
- Miller Ave @ Highland (county signal - offset adjustments only)

**Time of Day:** AM, MD, PM, Saturday, and Sunday

**Data Collection:** ATSPM split monitor is available at all signals but the following signals provided additional data. Pre-timed signal splits were fine-tuned during implementation.

- #7465 100 S HAWK @ N Campus – Approach Volumes
- #7224 500 S @ 1300 E – Approach Volumes
- #7230 1300 E @ I-80 WB – Approach Volumes and Turning Movement Counts

**SPM Check:** All was working correctly.

**Synchro:** The source of the initial model was the UDOT Region 2 model. All modeling was done in a way to be able merge back together in a city wide model upon project completion.

**Goals:**

- Reduce cycle lengths north of 500 S
- Change transition times to match nearby signals and to traffic demand
- Test coordination at #7224 500 S @ 1300 E
- AM: test a reverse NB progression from 800 S to 900 S

- MD: change cycle lengths at 1300 S and 1700 S so they are a closer harmonic
- PM: improve SB arrival at 2100 S and give it more split time
- Match trifecta (2700 S @ Highland and 1300 E @ Highland and @ 2700 S) cycle lengths with that at signals to the north and south.

**Implementation Schedule:**

- Existing Observations – Wednesday, September 6, 2017
- Initial Implementation - Tuesday, October 10, 2017
- Follow-up Implementation – Wednesday, October 11, 2017
- Weekend Implementation – Saturday, November 4, 2017 and Sunday, November 5, 2017

## Time-of-day Schedule

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 10:00 | 7 | 72 | 6:30 | 1 | 80 | 9:00 | 7 | 72 |
| 21:00 | 100 | FREE | 9:00 | 7 | 72 | 22:00 | 100 | FREE |
| | | | 15:30 | 13 | 80 | | | |
| | | | 18:30 | 7 | 72 | | | |
| | | | 22:30 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 7 | 72 | 0:01 | 7 | 72 | 0:01 | 7 | 72 |
| | | | 6:30 | 1 | 80 | | | |
| | | | 9:00 | 7 | 72 | | | |
| | | | 15:30 | 13 | 80 | | | |
| | | | 18:30 | 7 | 72 | | | |

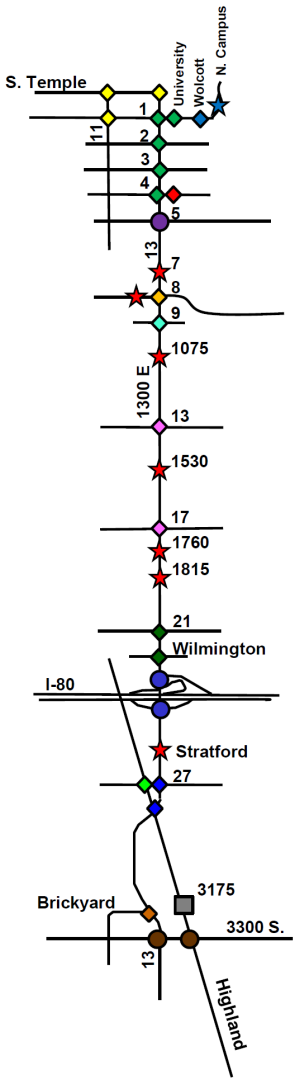
| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 10:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 7 | 108 |
| 21:00 | 100 | FREE | 7:30 | 2 | 120 | 22:00 | 100 | FREE |
| | | | 8:30 | 1 | 120 | | | |
| | | | 9:00 | 7 | 108 | | | |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 10:00 | 7 | 72 | 6:30 | 1 | 120 | 9:00 | 7 | 72 |
| 21:00 | 100 | FREE | 9:00 | 7 | 72 | 22:00 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 72 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 1 | 80 | 6:30 | 1 | 80 | 0:01 | 1 | 80 |
| 10:00 | 7 | 108 | 9:00 | 7 | 108 | 9:00 | 22 | 120 |
| 21:00 | 1 | 80 | 15:30 | 13 | 120 | 19:00 | 7 | 108 |
| | | | 19:00 | 7 | 108 | 22:00 | 1 | 80 |
| | | | 22:00 | 1 | 80 | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 9:00 | 7 | 108 | 6:30 | 1 | 60 | 8:00 | 7 | 108 |
| 20:00 | 100 | FREE | 9:00 | 7 | 108 | 22:00 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 9:00 | 7 | 108 | 5:30 | 7 | 108 | 8:00 | 7 | 108 |
| 22:00 | 100 | FREE | 6:30 | 1 | 120 | 22:00 | 100 | FREE |
| | | | 9:00 | 7 | 108 | | | |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |




| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| | | | 6:30 | 1 | 80 | | | |
| | | | 9:00 | 7 | 72 | | | |
| | | | 15:30 | 13 | 80 | | | |
| | | | 18:30 | 7 | 72 | | | |
| | | | 22:30 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| | | | 7:30 | 1 | 160 | | | |
| | | | 8:30 | 100 | FREE | | | |
| | | | 15:30 | 13 | 160 | | | |
| | | | 18:30 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 16 | 74 | 0:01 | 16 | 74 | 0:01 | 16 | 74 |
| 10:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 7 | 108 |
| 21:00 | 16 | 74 | 9:00 | 7 | 108 | 22:00 | 16 | 74 |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 16 | 74 | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 10:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 13 | 120 |
| 21:00 | 100 | FREE | 9:00 | 7 | 108 | 19:00 | 7 | 108 |
| | | | 15:30 | 13 | 120 | 22:00 | 100 | FREE |
| | | | 19:00 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 10:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 22 | 120 |
| 21:00 | 100 | FREE | 9:00 | 7 | 108 | 19:00 | 7 | 108 |
| | | | 15:30 | 13 | 120 | 22:00 | 100 | FREE |
| | | | 19:00 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 9:00 | 7 | 108 | 5:30 | 7 | 108 | 8:00 | 7 | 108 |
| 22:00 | 100 | FREE | 6:30 | 1 | 60 | 22:00 | 100 | FREE |
| | | | 9:00 | 7 | 108 | | | |
| | | | 15:30 | 13 | 60 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

## Plan Description

### General

*HAWKS*
Initially we considered testing coordination at Salt Lake City's seven HAWKs included in this task. However, during observations and implementation we found the HAWKs didn't come on often enough to significantly affect the operations. Also, the HAWKs would have to be re-phased to run coordination. Given this, we decided not to test coordination. Instead we changed parameters at 5 of the 7 so that they would no longer be able to come on back-to-back but have to wait 25 seconds before coming on again. The 25 seconds was chosen because it was found in place at other HAWKs in and even out of the city.

*400 S @ University*
Coordination was considered here. However, it was determined that it couldn't run a reasonable cycle length due the number of phases and the exclusive ped phase. It was left running free.

*500 S @ 1300 E*
Changes at 500 S and north on 1300 E were intended this to be a 1st step in an iterative process. Depending on what we end up doing in the DA, both on SR-186 and in the northeast quadrant, we plan to revisit and adjust what we've done. By implementing here we've learned a lot about the relationships between these signals and what works well, which gives us a boost as we formulate ideas about the DA.

A rough natural cycle length analysis showed that really high cycle lengths run here throughout the day. An assumed ped walking speed of 3.5 ft/sec was used here which resulted in large ped clears. Oversizing the peds is not viable because of high volume of peds. Even a 120CL is not viable. This is why the signal was set free in the past.

We discussed extensively using a 150CL with 75CL to the north. It would allow us to tie to Foothill Blvd signals to the east which run 150CLs in the AM and PM. However, an 80CL on 1300 E ties well with signals to the west in the DA on both S. Temple and 100 S, moving traffic to and from the U of U well. The northeast quadrant of the DA runs an 80CL in the AM and a 120CL in the PM (80CL is a 2/3rds harmonic). The 75CL is not a 2/3rds of any cycle length. This line of thinking drove the decision to test the 160CL at 500 S @ 1300 E. The 160CL also gives us the fringe benefit of having a 3/4ths harmonic with the 120CL running to the south rather than the 4/5ths harmonic of a 120CL to a 150CL. Also, given that 500 S @ 1300 E was running free and with a near 160-sec natural cycle length we didn't think there would be a negative impact to E/W on SR-186.

We tested an AM 160CL, MD 144CL, and PM 160CL. However, during implementation we found that the AM 160CL was only warranted from 7:30 to 8:30, the MD was too high all the time, and that the PM 160CL worked well the entire peak. This signal otherwise runs free.

*1100 E @ So. Temple*
Act coord was enabled at 1100 E @ S Temple in all patterns by Bryan Meenen so ped xing won't beep. They had received noise complaints from having it beeping with the coord phase even when there was not ped.

*Trifecta*

The existing timings had the trifecta running small unique cycle lengths not tying to signals to the north and south: AM: 90CL, MD:90CL, and PM:100CL. The initial thought was to get these cycle lengths to a closer harmonic with the surrounding signals which run: AM:120CL, MD:108CL, and PM:120CL. For example, the new cycle lengths might be AM:80CL, MD:72CL, and PM:80CL. However, we found that full cycle lengths had the most benefit. Having matching cycle lengths reduced the NB AM queuing at the I-80 EB signal and just resulted in more consistent operations throughout the day.

However, with all three signals running that same cycle, even the smaller cycles, perfect two-way progression cannot be achieved at 2700 S @ Highland (N/S Highland and E/W 2700 S). Existing plan prioritized Highland N/S arrivals. We tested a 2/3rds harmonic here which balanced the pain and arrivals were often good, but sometimes bad, both N/S Highland and E/W 2700 S. However, during MD and PM plans N/S Highland traffic is much heavier than E/W 2700 S. So, it was decided that for those periods 2700 S @ Highland should run full cycle with near perfect N/S Highland arrivals. We also found that while E/W 2700 S would stop, wait times and queueing were not excessive.

**AM**

*Cycle Length:*

- North of 500 S changed from 120CL to 80CL because the 120CL was too large for the traffic demand.
- 500 S changed from running free to 160CL for the heart of the peak to improved N/S arrivals without affecting the E/W traffic.
- At the trifecta the1300 E signals were changed from 90CL to 120CL to match cycle lengths to the north and south. This reduced NB queues at I-80 EB simply by having traffic arrive better. The signal at 2700 S @ Highland changed from a 90CL to a 80CL, a 2/3rds harmonic of the surrounding 120CLs.

*TOD Schedule:*

- The AM pattern transition times were spot on at 6:30 and 9:00.
- From 5:30 to 6:30 many signals ran the midday pattern as an early morning shoulder plan. This is unnecessary because traffic is extremely light. This was removed. Signals now run free or the overnight pattern until 6:30 when the AM pattern begins. We will evaluate overnight coord at all signals in the future.
- At 500 S the 160CL coord plan only runs from 7:30 to 8:30 during the heart of the peak. At other times the cycle length is just too big and holds green E/W when there is no traffic.

*Initial Observations:*

- North of 500 S there are a lot of vehicles continue heading north to 100 S and South Temple
- At 6:38 traffic is still light at Brickyard. We should test it at a half cycle. 3300 S is coordinated E/W and N/S waits a long time for no one. UDOT has been notified.
- At 6:43 EB at 100 S and South Temple heavier than NB.
- At 6:45 much of the NB queue in the outside lane at the I-80 interchange is going WB I-80 at the loop ramp rather than EB I-80.
- At 6:47 traffic is still light at 1700 S and 1300 S. It makes more sense why it used to start coord at 7:00 instead of 6:30 like the rest of the corridor. Ensuring good arrivals may make it worth starting coord at 6:30. At 6:53 coordination is definitely warranted.
- At 6:50 at 500 S there is a lot of EB traffic. At 6:56 there was probably 15 cars in each lane. 300 S and 400 S is light and it probably doesn't warrant coordination at this time or

maybe just not a 120CL. 100 S has a huge EB queue which cleared in the split time given.

- At 7:03 traffic is still pretty light at the trifecta, it doesn't need a 120CL but a closer harmonic would make sense. The harmonic would help Highland traffic as well which also runs a 120CL. However, matching the cycle lengths to that at I-80 may reduce queue NB queue lengths at I-80 due to better arrivals. Later at 7:34 the #3 NB lane at I-80 EB Ramps is really long, probably 40 to 50 cars.
- At 7:12 the WBL at 2100 S nearly clears all the time, that split appears to be right where it should be. Observed this again at 7:32.
- At 7:12 there is a large NB platoon leaving from 2100 S at this time. Later we observed big gaps in the platoon, which speaks to issue with keeping the platoon consolidated in a single lane. Not sure what happened.
- At 7:14 at 100 S the SBL turn is fairly heavy, about 5 to 10 cars per cycle
- At 7:15 ran into a large queue coming NB up to 900 S. The platoon arrives too early here.
- At 7:17 the EB queue at 500 S is a lot shorter; U of U traffic is heavier just before the hour.
- At 7:20 EB S. Temple traffic has really picked up at well.
- At 7:21 NB north of 2100 S queue extending back to almost 2100 S. Found a garbage truck in the one lane section causing issues, could be part of this queuing issue. Later at 7:30 there is a very long rolling NB queue at 1700 S reaching back to 2100 S. At 8:05 the NB queue extends into 2100 S, NB was green vehicles had nowhere to go (not sure of primary cause of this issue)
- At 7:35 NB Highland traffic is heavy but most of them are making the free-right turn to NB 1300 E.
- At 7:37 East High School inbound begins, a heavy NBL volume into driveway between 800 S and 900 S.
- At 7:42 EB traffic at So. Temple seems to have died down a little.
- At 7:46 the EB traffic at 500 S should not be impacted by any changes we make.
- At 7:47 the NB queue at 800 S backed through 900 S almost to Yale.
- At 8:01 NB is really sluggish just south of 1300 S. The reverse progression approach ought to reach south to 1300 S. It looks like the early arrival issue at 900 S has compounded causing queueing back thought 1300 S. At 8:10 it appears that 800 S and 900 S are the bottle neck. They both also have heavy EB traffic. Later at 8:25 the NB queue from 800 S to 900 S reaches back to the Downington Ave HAWK.
- In the AM model at 800 S we will want to place a PED recall on the side street to mimic the frequency of students crossing 1300 E. Also consider this if we want to create a shoulder plan in the off-peak pattern that addresses the school release. Essentially we cannot sneak the offset forward in hopes of getting the early return, we can't count on that.
- At 8:01 Brickyard could use a smaller cycle length, maybe a half cycle.
- At 8:10 there is a very long wait SB at 500 S. It would be interesting to know what natural cycle length 500 S is running. It seems like it might be very long.
- At 8:15 NB queues at 1700 S and 1300 S, had to wait through one cycle at both intersections.
- At 8:25 the NBR at 100 S is heavy, EB queue on 100 S backing into 1300 E. The EB queuing issue was seen again at 8:44.
- At 8:38 the NB queue is much shorter reaching to just north of 1700 S.
- At 8:58 the NB queue at 900 S is gone. The 9:00 transition time looks to be spot on.

*Optimization Notes:*

- NB 900 S to 800 S NB reverse progression was implemented and fine-tuned so that all the NB green time at 800 S is used efficiently. A shoulder plan was used. Forward progression works well on the edges of the peak and then reverse is needed in the heart of the peak.
- EB 800 S fails to clear at times in the AM peak so the plans on the edges of the peak when N/S traffic is lighter also provides more time to E/W.
- While fine-tuning the 500 S offset we tested lagging SBL so the NBT arrival at 400 S always be spot on. However, we found that the offset change necessary to make this work would make SB 500 S arrivals bad. Although we can't guarantee perfect NB arrivals at 400 S, the vast majority of time it is good. As are the SB arrivals at 500 S.
- The initial implementation was on a Tuesday. Out of concern that U of U traffic might differ by weekday we checked that the 80CL on 100 S and So. Temple worked on a Wednesday as well. We found that it did.
- The 120CL on the 1300 E trifecta signals really helps the NB arrival at the I-80 interchange reducing the long queue we saw during the initial observations.

**Midday**

*Cycle Length:*

- North of 500 S changed from an 81CL to 72CL because it is a closer harmonic to a 108CL, 3/4ths to 2/3rds.
- 500 S was tested at a 144CL but it was too large and changed back to run free.
- 1300 S and 1700 S were changed from 80CL to 72CL. These signals weren't included in other re-timings and had remained at incompatible cycle lengths. Taking these to the full 108CL would add too much side street delay.
- At the trifecta the1300 E signals were changed from 90CL to 108CL to match cycle lengths to the north and south. This improved arrivals at I-80 EB to the north and 3300 S to the south.

*TOD Schedule:* Minor common sense changes were made and some locations for consistency.

*Initial Observations:*

- At 11:42 the SB queue at 2100 S was at least 15 to 20 vehicles long.
- At 11:53 NB progression between 900 S and 800 S is poor. NB arrival at 900 S is early then again early at 800 S.
- At 12:24 NB at I-80 EB still experiences lane utilization issues with a long queue in outside lane due to vehicles trying to get to I-80 WB onramp.
- At 11:57 north of 500 S there is quite a bit of N/S traffic, maybe even more than in the AM. The 81CL works in the MD, so maybe a lower cycle length in the AM would work better like an 80CL which is a 2/3rds harmonic of the 120CL.

*Optimization Notes:*

- The proposed plans were found to be working well and only a few minor tweaks were made.

**PM**

*Cycle Length:*

- North of 500 S changed from a 120CL to 80CL.
- 500 S was changed from free to a 160CL.
- The trifecta signals were changed from a 100CL to a 120CL to match cycle lengths to the north and south. This improved arrivals at I-80 EB to the north and 3300 S to the south.

*TOD Schedule:* Transition times were not changed significantly, only to make them consistent.

*Initial Observations:*

- At 15:16 the EB I-80 off-ramp fails to clear, wonder if the PM patterns should start at 15:00 instead of 15:30.
- The cycle length is too large north of 500 S. Even at 16:03 volumes north of 500 S have not picked up yet.
- A rolling SB queue starts just south of 1300 S at 15:45. Saw this again at 17:15.
- Long wait at 500 S SB. We wondered what the natural cycle length is. Can it be coordinated at a large cycle length with a half cycle at surrounding signals?
- 2100 S to the trifecta have been retimed a few years ago. It may be safe to leave that operation intact, but there is potential to make improvements to the trifecta, with a closer harmonic or full cycle.
- Arrivals have worked well between Brickyard and 3300 S.
- At 16:00 the 2100 S SB queue extends almost to 1700 S (some of it due construction lane closed until 15:45). Observed the same queue length at 16:19. Later at 16:54 SB at 2100 S queued back past both HAWK signals. At 17:21 the back of the rolling SB 2100 S queue has reached to 1700 S.
- At 16:07 heading north from 500 S ran into start of red at 400 S queue back 2/3rds of the way to 500 S.
- At 16:20 observed that the EBL at Brickyard is heavier, larger N/S platoons than in the AM. A 120CL is right for the PM.
- At 16:40 observed that NB is heavier than SB at 100 S (NBL busy about 7 to 8 cars in queue)
- At 16:46 the SB queue at 900 S backed to 800 S (only temporarily, we arrived before the green started)
- At 17:15 we think that we should test coordinating South Temple in PM to help the NBL movement progress to the west.
- Observed congestion during the PM peak, in both directions at 17:19 between 800 S and 900 S. 800 S was green, but queue from 900 S had yet to get moving. Reverse progression strategy may be needed in the PM as well.
- On 100 S the PM peak period starts to build around 17:15. EB Progression from Wolcott to 1300 E was pretty good.
- At 17:20 the arrival SB from 900 S to 1300 S was about just right, needs to be about 10 secs sooner.
- At 17:22 there was pretty long queues E/W at 2100 S but both essentially clear but with some residual traffic in the left turn pockets. At 17:31 at 2100 S EBT and EBR didn't clear completely.
- At 17:39 the NBR turn at 2100 S queued back to Wilmington.

*Optimization Notes:*

- The reverse progression strategy used for the SB arrival at 2100 S made a big difference and removed the long queue that was overserved.
- The 160CL at 500 S made for good arrivals between signals to the north.
- The smaller cycle lengths north of 500 S worked well.
- These plans were generally found to be working well and only a few minor tweaks were made.

**Saturday**

*Cycle Length:* North of 2100 S runs the midday pattern 7 all TOD. Signals from 2100 S to the trifecta run a modified PM 120CL pattern in the heart of the peak. Brickyard runs the midday pattern 7 as well to match nearby 3300 S.

*TOD Schedule:* The 120CL section used to run it all day. However, volumes drop off to weekday midday levels at 19:00. The day plan was changed to run midday patterns from 19:00 to 22:00.

*Optimization Notes:*

- Saturday traffic had heavy demand WBL at the I-80 WB off-ramp. The weekday PM peak strategy didn't favor this movement. It has a few stops as it continues north. These were modified with sequence and offset changes from the trifecta to 2100 S using alternate patterns (pattern 22). They work well moving the movement in question and at times when that movement is light and gaps out the NBT then progresses well in its place.
- The midday patterns running north of 2100 S were working well.

**Sunday**

*Cycle Length:* The midday patterns run effectively all day (108CL and 72CL).

*TOD Schedule:* The coordination end time was changed from 22:00 to 21:00.

*Optimization Notes:*

- These plans were found to be working well. No changes made.

# APPENDIX B: 1300 S (500 W to 1300 E)

# Salt Lake City Traffic Signal Optimization Memo

Date: January 26, 2018

**Project Name: 1300 S Corridor**

Consultant: Luke Seegmiller (PineTop) and Shawn Larson (Avenue)

Salt Lake City: Bryan Meenen and Matthew Hyer

## Scope

**Signals:**

- 1300 S from 500 W to 1300 E
- 1700 S West Temple to State St

**Time of Day:** AM, MD, PM, Saturday, and Sunday

**Data Collection:** ATSPM split monitor is available at all signals but the following signals provided additional data.

- #7069 1300 S @ I-15 Ramps and 500W – Turning Movement Counts
- #7148 1300 S @ State St (US-89) – Turning Movement Counts
- #7185 1300 S @ 700 E (SR-71)– Approach Volumes and Turning Movement Counts

**SPM Check:** All was working correctly.

**Synchro:** The source of the initial model was the UDOT Region 2 model. All modeling was done in a way to be able merge back together in a city wide model upon project completion.

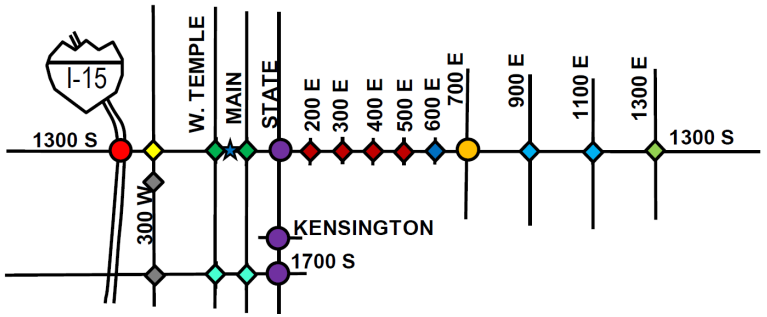
**Goals:**

- Restore coordination at West Temple
- Test West Temple and Main St at full cycle lengths during the PM peak.
- Test the concept of using a full cycles but servicing movements twice at 900 E and 1100 E.
- Test adding coordination at the I-15 interchange and 500 W.

**Implementation Schedule:**

- Existing Observations – Wednesday, November 1, 2017
- Initial Implementation – Thursday, December 7, 2017
- Follow-up Implementation – Tuesday, January 9, 2018
- Weekend Implementation – Saturday, January 13, 2018 and Sunday, January 14, 201

## Time-of-day Schedule




| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 4 | 108 | 7:00 | 1 | 120 | 9:00 | 4 | 108 |
| 19:00 | 100 | FREE | 9:00 | 4 | 108 | 21:30 | 100 | FREE |
| | | | 11:30 | 100 | FREE | | | |
| | | | 19:30 | 4 | 108 | | | |
| | | | 21:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 7:00 | 1 | 120 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 21:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 21:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 7:00 | 1 | 80 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 21:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 21:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 7:00 | 1 | 120 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 21:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 72 | 7:00 | 1 | 80 | 9:00 | 7 | 72 |
| 19:00 | 100 | FREE | 9:00 | 7 | 72 | 21:30 | 100 | FREE |
| | | | 15:30 | 13 | 80 | | | |
| | | | 18:30 | 7 | 72 | | | |
| | | | 21:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 8:30 | 19 | 108 | 5:30 | 7 | 108 | 7:30 | 19 | 108 |
| 22:00 | 100 | FREE | 6:30 | 1 | 120 | 22:30 | 100 | FREE |
| | | | 9:00 | 7 | 108 | | | |
| | | | 15:30 | 14 | 120 | | | |
| | | | 16:50 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:30 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 72 | 7:00 | 1 | 120 | 9:00 | 7 | 72 |
| 19:00 | 100 | FREE | 9:00 | 7 | 72 | 21:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 72 | | | |
| | | | 21:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 10:00 | 7 | 72 | 6:30 | 1 | 120 | 9:00 | 7 | 72 |
| 21:00 | 100 | FREE | 9:00 | 7 | 72 | 22:00 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 72 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| | | | 7:00 | 1 | 80 | | | |
| | | | 9:00 | 7 | 72 | | | |
| | | | 15:30 | 13 | 80 | | | |
| | | | 18:30 | 7 | 72 | | | |
| | | | 21:00 | 100 | FREE | | | |

## Plan Description

### General

*HAWKS*
During observations and implementation we found the Richards St HAWK and 600 E Bike Signal didn't come on often enough to significantly affect operations. The HAWK would have to be re-phased to run coordination. There is also no communication leading to clock drift over time. We did not pursue coordination at these sites.

*900 E and 1100 E Phase Re-service*
At these two signals we tested a new concept presented by Bryan Meenen. As an alternative to a half cycle the signals runs a full cycle but services each phase twice. This makes it possible to give the main platoon coming from a normal full cycle signal more time, and conversely the off service less time.

A critical component of this was that the peds must be able to service each time the phase comes on. This was difficult to program and initially. Numerous logic statements were created to make this work while still running off of detection. However, Bryan Meenen came up with an alternative way using a fixed-time approach with max and ped recalls on all phases. This eliminated the need for logic statements.

*1300 S @ I-15 Ramps and 500 S*
This is a complicated signal using multiple overlaps to control 3 intersections with a single controller. It has multiple major movements. It also requires large clearance intervals which eat up a significant portion the green time available. The 108CL midday pattern began failing at 11:30. The PM 120CL failed almost immediately. We set the signal free again after only 30 minutes at 16:00.

Using high cycle lengths, a 162CL and 180CL for which a 108CL and 120CL is a 2/3rds harmonic, was modeled for the interchange as a long shot. Surprisingly it showed that the major EB movements take turns arriving well at 300 W. It looked promising. We decided to test it and it worked well clearing all movements except for during the heart of the peak.

However, UDOT didn't like these high cycle lengths citing research that green times larger than 30 seconds become less efficient. The highest split had a green time of only 40 seconds but still UDOT would not give approval. It was decided that the slight improvement the high cycle lengths gave over free wasn't worth fighting for.

*Signals Left Unchanged*
Signals on major crossing corridors State St, 700 E, and 1300 E were left unchanged to preserve the N/S progression strategy. We typically consider lead-lag options but none of these signals had protected E/W left turns.

*Midday Transition Times*
Transition times in the middle of the day (AM to MD, MD to PM and PM back to MD) needed to match times used at the major N/S crossing corridors. This generally made sense with the E/W traffic volume changes throughout the day. However, FREE to coord and coord to FREE transitions times differ because traffic volumes ramp up and die down E/W at different times than on the N/S corridors.

**AM**

*Cycle Length:*

- State St, 700 E and 1300 E left at a 120CL
- 500 W/I-15 Ramps was changed from FREE to a 120CL
- 300 W left at a 120CL
- West Temple was change from FREE to an 80CL and Main St remained at the 80CL
- 200 E to 500 E remained at an 80CL
- 900 E and 1100 E change from 80CL to 120CL with phase re-service
- 1700 S at West Temple and Main St remain at an 80CL.

*TOD Schedule:*

- E/W traffic volumes don't warrant coordination until 7:00. This matches State St but 700 E and 1300 E start the AM pattern at 6:30. However, the AM to MD transitions matches the length of the corridor at 9:00.

*Initial Observations:*

- At 6:36 the coord feels a little early especially on the east side. Later at 6:41 there was a 5-veh long WB queue at I-15. It's getting close to justifying coord.
- Consider a 60s cycle length, particularly at 900 E and 1100 E.
- The 2/3rds harmonic between State St and 700 E is working pretty well.
- Almost never get stopped at the 600 E bike signal.
- At 6:41 there is a good portion of the WB traffic that goes all the way through the interchange rather that NB or SB I-15. It probably makes sense to tie things together on both sides of the interchange.
- At 6:45 most of the stopping E/W occurred at major NB/SB corridors (State Street, 700 E and 1300 E).
- At 6:47 there is enough 1700 S E/W traffic that it should be coordinated E/W with an attempt to coord N/S on Main St and W. Temple. 300 W should be cross coord N/S when we re-time that corridor in the future.
- At 6:57 there is not a lot of E/W traffic through 1100 E or just on the east end in general.
- At 7:02 the WB traffic is as heavy as the EB traffic, especially between State St and 700 E.
- At 7:30 the SBL I-15 off ramp to go EB is pretty heavy. It looks to be prioritized by the phasing set up.
- At 7:40 N/S Main St is extremely light which is surprising giving the 5-lane cross-section.
- Fresh green EB at 200 E runs into a red at 300 E. I saw this a few times.
- At 7:51 the WB queue at 700 E is failing to clear. There is quite a bit of traffic at this time. At 8:00 WB at 700 E queued back to near 800 E and didn't clear on green.
- At 8:10 the EB approach at 500 W has a very long queue reaching on top of the bridge and beyond.
- Traffic on 1300 S seems to have picked up at 8:00, peak might be 8:00 to 9:00.
- We'll want to test coord at West Temple, I-15, 500 W, and the signals to the west.

*Optimization Notes:*

- At 6:07 the pattern 7 shoulder that starts at 5:30 on 700 E makes sense with the amount of N/S traffic. State St traffic is still light at this time and doesn't need coord yet.

- At 6:45 E/W traffic between 700 E and 1300 E traffic is still really light. It doesn't warrant coord at this time.
- Had a poor arrival WB from 700 E at 500 E. Scott thought it was a detection issue but it ended up being large min green times on the E/W phases 2 & 6. I reduced them from 27 to 10 and the N/S phases 4 & 8 from 23 to 5.
- Changed the offset a Main St from 57 to 62 because heading EB from a fresh green at West Temple the end of the platoon was cut off at Main St.
- At 7:36 everyone is happy with the 1300 S progression strategy.
- At 7:45 Scott changed the offset at 1700 S @ Main St from 31 to 21.

**Midday**

*Cycle Length:*

- State St, 700 E and 1300 E left at a 108CL
- 500 W/I-15 Ramps was changed from FREE to a 108CL during portions of the MD period. It otherwise remained running free.
- 300 W was changed from a 110CL to a 108CL
- West Temple was changed from FREE to a 108CL and Main St changed from a 72CL to a 108CL.
- 200 E to 500 E, 900 E, and 1100 E remained at a 72CL
- 1700 S at West Temple and Main St remained at a 72CL.

*TOD Schedule:* No changes, the 9:00 to 15:30 and 18:30 to 21:00 was appropriate for the MD pattern.

*Initial Observations:*

- A fresh green at 200 E goes into red at 300 E is a problem in the MD pattern as well. Otherwise the harmonics east of State St are working pretty well.
- Need to tie into the new offset at 1300 E from 1100 E and 900 E. The cycle lengths now match (72CL). At 11:50, WB from 1300 E arrives at the beginning of red at 1100 E. The EB arrival at 1300 E isn't much better.
- At 11:50 the WBL to SB I-15 queue extended to the NB off-ramp. There were some lane utilization issues with most of the cars in the left lane
- At 12:03 traffic is much heavier E/W now than 10 minutes ago. There is heavy WB traffic a 300 W. E/W looks heavier than N/S at 300 W.
- At 12:07 there was one split failure at 1300 E for the WB movement, may have been due to a cement truck taking a while to get going.
- At 12:18 the WBT at 300 W just barely failed to clear with existing split time.

*Optimization Notes:*

- At 12:01 coming WB from 500 W through the interchange arrives at the end of green at 300 W and the back of the platoon gets cut off. However, we decided there wasn't a lot we could do because any change would hurt the WB arrival at the interchange.
- At 12:24 WB from State St every other cycle runs into a red at Main St. There is more traffic going this way now than in the AM. The WB queue reaches half way to State St. As a result of this we changed the MD cycle length at Main St and West Temple from 72CL 2/3rds harmonic to the full 108CL. Using the full cycle as a shoulder was considered but since the 2/3rds harmonic would only make sense for about 1.5 hours we decided to run the 108CL the entire MD period.
- We increased the offset at West Temple @ 1700 S from 30 to 45 to remove a double stop.
- At 12:53 the interchange is failing and we decide it should run free starting at 11:30. The 108CL is too small resulting from the large clearance times used.

**PM**

*Cycle Length:*

- State St, 700 E and 1300 E left at a 120CL
- 500 W/I-15 Ramps was left FREE
- 300 W was left at a 120CL
- West Temple was changed from FREE to a 120CL and Main St changed from an 80CL to a 120CL.
- 900 E and 1100 E change from 80CL to 120CL with phase re-service
- 1700 S at West Temple and Main St remain at an 80CL.

*TOD Schedule:* There was no change to the PM pattern start and end times at 15:30 and 18:30.

*Initial Observations:*

- Coordination at the I-15 interchange could improve arrivals to and from the interchange and avoid arriving on red at 300 W
- 2/3 harmonic seems to work well between State Street and 700 E
- At 15:28 WB is really heavy at 300 W. It failed to clear by a little bit. It's a good time to transition to the PM pattern if not a little late. Later at 16:00 WB is still failing to clear at 300 W even in the PM pattern.
- At 16:03 there was a long NB queue at 500 W about 20 vehicles long. Later it was only 5 vehicles. At 17:45 again a long queue for NB approach at 500 W about 15 cars, SBL didn't clear due to not having enough gaps.
- At 16:15 N/S on Main St is heavier than AM but E/W are still the primary movements.
- At 16:18 there was a good WB arrival at 1100 E from 1300 E. So, the 80/120 harmonic seems to be where it needs to be. At 16:20 there was one EB arrival at 1300 E about 20 seconds too late. Maybe there needs to be an adjustment in the harmonic relationship after all.

- At 16:40 EB at 500 W has a short green time. Long queue fails to clear and backs onto the bridge. It takes two cycles to get through. Even earlier at 15:43 the EB queue at the 500 W extended to crest of the bridge.

*Optimization Notes:*

- At 15:42 there is a very long WB queue is developing at the I-15 SB Ramps reaching nearly into 300 W. Later at 16:02 we set the interchange free. It needs a larger cycle length than a 120CL.
- At 17:23 there are issues with 200 E gapping out or skipping and sending the EB platoon too soon to 300 E where you stop and then you stop again at 400 E but any to the 200 E offset would negatively affect the WB arrival at State St.

**Saturday**

*Cycle Length:* The weekday MD patterns are used at all signals except 1700 S at Main St and West Temple where coord isn't warranted.

*TOD Schedule:* Found that traffic dies down at 21:30. The coord to free transition time was changed from 22:30 to 21:30 at all city signals. Coord start at 9:00 was appropriate at all signals except on 1700 S. E/W doesn't need coord as late as the N/S corridors at 700 E and 1300 E.

*Optimization Notes:*

- Found that the 108CL at the interchange handled the traffic adequately.
- The MD plans worked well.

**Sunday**

*Cycle Length:* The weekday MD patterns are used at all signals except 1700 S at Main St and West Temple where again coord isn't warranted.

*TOD Schedule:* Found that the 11:00 to 19:00 transition times worked well at all signals we were changing. E/W doesn't need coord as long as the N/S corridors at State St, 700 E. and 1300 E.

*Optimization Notes:*

- Again the 108CL at the interchange handled the traffic adequately.
- The MD plans worked well.

# APPENDIX C: 2100 S (700 W to 2300 E)

Salt Lake City Traffic Signal Optimization Memo

Date: May 22, 2018

**Project Name: 2100 S Corridor**

Consultant: Luke Seegmiller (PineTop) and Shawn Larson (Avenue)

Salt Lake City: Bryan Meenen and Matthew Hyer

**Scope**

**Signals:**

- 2100 S from 700 W to 2300 E

**Time of Day:** AM, MD, PM, Saturday, and Sunday

**Data Collection:** ATSPM split monitor is available at all signals but the following signals provided additional data.

- #7637 2100 S @ 700 W – Turning Movement Counts
- #7187 700 E @ 2100 S – Approach Volumes

**SPM Check:** All was working correctly.

**Synchro:** The source of the initial model was the UDOT Region 2 model. All modeling was done in a way to be able merge back together in a city wide model upon project completion.

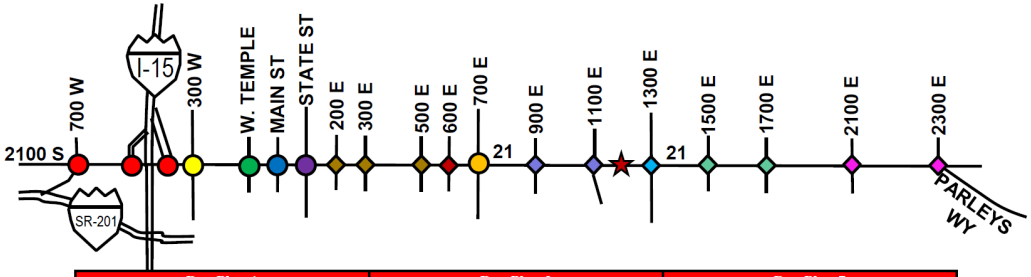
**Goals:**

- Update progression with 1300 E which was changed when new timings were implemented on that corridor.
- Test coordination at 2100 E and 2300 E at small cycle lengths.
- Test reduced cycle lengths at 1500 E and 1700 E.
- Adjust plan transition time to better fit traffic volume fluctuations, specifically start PM patterns sooner.
- Change cycle lengths at the I-15 interchange and 700 W to be closer harmonics with full-cycle signals to the east.
- Implement reverse progression for EB arriving at State St to allow the queue to get moving before the platoon arrives during the heart of the PM peak.

**Implementation Schedule:**

- Existing Observations – Thursday, December 14, 2017
- Initial Implementation – Thursday, January 18, 2018
- Weekend Implementation – Saturday, January 27, 2018 and Sunday, January 28, 2018

## Time-of-day Schedule




| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 72 | 6:30 | 1 | 80 | 9:00 | 7 | 72 |
| 19:00 | 100 | FREE | 9:00 | 7 | 72 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 80 | | | |
| | | | 18:30 | 7 | 72 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 22 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 16:45 | 14 | 120 | | | |
| | | | 17:45 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 16:45 | 14 | 120 | | | |
| | | | 17:45 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 7:00 | 1 | 120 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 21:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 6:30 | 1 | 60 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 8:30 | 7 | 108 | 5:30 | 7 | 108 | 7:30 | 7 | 108 |
| 22:00 | 100 | FREE | 6:30 | 1 | 120 | 22:30 | 100 | FREE |
| | | | 9:00 | 7 | 108 | | | |
| | | | 15:30 | 14 | 120 | | | |
| | | | 16:50 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:30 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 13 | 120 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 19:00 | 7 | 108 |
| | | | 15:30 | 13 | 120 | 22:30 | 100 | FREE |
| | | | 19:00 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 10:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 13 | 120 |
| 21:00 | 100 | FREE | 9:00 | 7 | 108 | 19:00 | 7 | 108 |
| | | | 15:30 | 13 | 120 | 22:00 | 100 | FREE |
| | | | 19:00 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 72 | 6:30 | 1 | 80 | 9:00 | 13 | 80 |
| 19:00 | 100 | FREE | 9:00 | 7 | 72 | 19:00 | 7 | 72 |
| | | | 15:30 | 13 | 80 | 22:30 | 100 | FREE |
| | | | 19:00 | 7 | 72 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 72 | 6:30 | 1 | 80 | 9:00 | 13 | 80 |
| 19:00 | 100 | FREE | 9:00 | 7 | 72 | 19:00 | 100 | FREE |
| | | | 15:30 | 13 | 80 | | | |
| | | | 19:00 | 100 | FREE | | | |

## Plan Description

### General

*HAWKS*
During observations and implementation we found the 1200 E HAWK and 600 E Bike Signal didn't come on often enough to significantly affect operations. There is also no communication leading to clock drift over time. We did not pursue coordination at these sites.

*Signals Left Unchanged*
Signals on major crossing corridors State St, 700 E, and 1300 E were left unchanged to preserve the N/S progression strategy. We typically consider lead-lag options but State St E/W lefts are FYA, at 700 E the E/W left turns are protected but there was no progression benefit to lagging them. Also, no sequence changes were made at 1300 E which lags the WBL so it can get extra time when the EBT gaps.

**AM**

*Cycle Length:*

- Most signals stay at the 120CL including crossing corridors at State St, 700 E and 1300 E
- 700 W and the I-15 interchange was changed from 90CL to an 80CL
- 200 E, 300 E, and 500 E was changed from 120CL to 60CL
- 1500 E and 1700 E was changed from 120CL to 80CL
- 2100 E and 2300 E was changed from FREE to 80CL

*TOD Schedule:* Coord start times varied from 6:15 to 6:30, to 7:00 and were changed to a consistent 6:30 with the exception of State St which was left at 7:00. The AM to MD transition time was found to be appropriate and was left at 9:00.

*Initial Observations:*

- At 6:26 the 120CL feels a little early for cord at 300 W which starts at 6:15.
- At 6:34 at 1300 E there is a long wait EB. Arrivals at 1500 E good after green but into fresh red at 1700 E. This happened again at 7:33 with a really long stop.
- At 6:42 the initial thought for 2100 E and 2300 E is that they should remain running free. Later at 7:15 it looks more feasible to add coord but it needs to be a low cycle length. Don't want to forget about the side street. At 7:40 there was a really large EB platoon just east of 1700 E making coordination look more plausible.
- At 6:48 the cycle length generally feels too big for this much traffic.
- At 6:49 there is a very heavy, maybe 20 vehicles, EBL at 300 W. EB in general is picking up.
- At 7:00 the E/W traffic is really light between 1300 E and 700 E.
- At 7:15 the WBL at State St had an 8-veh queue, but it cleared during the green phase.
- At 7:19 there is a long EB queue at West Temple, it seems to stop the platoon.
- There are issues observed where there are no turn pockets is stops half of the platoons when vehicles are turning right or left.
- Most of EB and WB stops on 2100 S are at major NB and SB corridors (State St, 700 E and 1300 E).
- An 80CL at the NB I-15 Intersection could provide better progress between it and 300 W.
- At 7:38 the signal at 1700 E gets fairly busy around the start of high school, we should avoid oversizing peds.
- Didn't stop at the ped crossings at 600 E and 1200 E very much. The work well free.
- At 8:12 the EBL at 2300 E is fairly heavy.

*Optimization Notes:*

- At 7:01 Scott found that the 2/3rds harmonic at the interchange works well because half of the EB traffic a 300 W turns left. Sometimes EB arrives well for the EBT and sometimes for the EBL.
- WB from the NB ramps runs into a red at the SB ramps. I think because of early returns but we'll wait and see how it turns out. Later at 7:45 Scott reduced the offset at the SB ramps by 5 seconds.
- Checked and found that 500 E and 300 E have audible peds. That's why act coord is enabled so it won't beep constantly during coordination.
- At 7:50 during Highland High School inbound the EBL at 1700 E failed to clear for a while. There are also a large number of peds so it is difficult to give more time to this movement without oversizing them. We considered going to a 120CL all morning, a 120CL just as a shoulder, or set is free as a shoulder. However, we have to consider

changes in school start time, early out days, and the summer. Someone has to monitor for changes. However, after moving a few seconds to the EBL and monitoring again I found the at the EBL queue only failed to clear two times just before school starts.

- We initially tested harmonics between State and 700 E and between 700 E and 1300 E but found it didn't work very well; there was a lot of stopping. Harmonics only seem to work well when there are 5 or so signals in a row running the harmonic. Here we only one group of 3 and another of 2. We later implemented half cycles between State and 700 E and full cycles at between 700 E and 1300 E.

**Midday**

*Cycle Length:*

- Most signals stay at the 108CL including crossing corridors at State St, 700 E and 1300 E
- 700 W and the I-15 interchange was changed from 90CL to a 72CL
- 1100 E was changed from a 102CL to a 108CL.
- 1500 E and 1700 E was changed from 102CL to 72CL
- 2100 E and 2300 E was changed from FREE to 72CL

*TOD Schedule:*

- The AM to MD pattern transition was found appropriate at 9:00.
- The MD to PM was changed from 16:00 to 15:30 because traffic volumes warranted it and it also matched the transition times on crossing corridors at State St, 700 E, and 1300 E.
- PM back to MD was set at 18:30 except for east of 700 E traffic stays heavy later due to the shopping areas. These signals transition later at 19:00.

*Initial Observations:*

- Coordination 2100 E and 2300 E as an island may be the best option.
- At 11:16 the WBL as State St had a 10-veh queue fail to clear, however this wasn't happening consistently.
- At 12:10 the EBL at 300 W queued to the NB I-15 intersection.
- There is a lot of friction between 900 E and 1300 E due to left turning vehicles in the thru lanes.
- At 12:27 the EBT queue at 700 E fails to clear leaving about 6 or 7 vehicles, it's kind of a lane utilization issue with most vehicles in the #1 lane.
- EB and WB platoons are heavier in the MD than in the AM.

*Optimization Notes:*

- Scott is evaluating lagging Ø3 at the SB I-15 ramps so Ø3 gets more time when Ø4 gaps.
- Scott reduced the offset at the SB ramps by 5 seconds. WB from the NB ramps had a hesitation at the SB ramps.
- At 12:10 Scott saw the NB off-ramp fail to clear leaving 8 vehicles. However, this wasn't happening consistently.

**PM**

*Cycle Length:*

- Most signals stay at the 120CL including crossing corridors at State St, 700 E and 1300 E
- 700 W and the I-15 interchange was changed from 90CL to a 80CL
- 1500 E and 1700 E was changed from 120CL to 80CL
- 2100 E and 2300 E was changed from FREE to 72CL

*TOD Schedule:* Many signals had the PM pattern start at 16:00. This was changed to 15:30. Most signals transition from PM back to MD at 18:30. However, signals east of 700 E were set to transition at 19:00 due to heavier traffic at the shopping areas. This also matches what is done at 1300 E to the N/S.

*Initial Observations:*

- Everything needs to transition at 15:30 instead of 16:00. There is heavy traffic at 15:40.
- At 16:26 the WBL turns are struggling at 700 E, 1300 E. There are progression issues at 1300 E. Traffic is light between 1500 E and 2300 E. Observed this again at 16:52.
- At 16:30 SB at 300 W is heavier that E/W traffic. So, cross-coordination will be an issue when we re-time 300 W to the north.
- At 16:43 the EBT queue failed to clear at State St by 10-veh in each lane. Later at 17:13 the EB queue is long. It's timed for forward progression.
- At 17:20 the EB queue at 1300 E is also failing to clear. Hopefully improving the progression with clear up the issue.
- At 17:34 it appears that traffic is lightening.
- At 17:50 the EB queue at State is gone .
- At 16:15 there is a long EB queue at State St in the right lane, maybe due to the shared thru/right turn lane.
- We need a full cycle between 700 E and 1300 E due to side-street traffic and turning movements.
- At 16:40 WBL at State St and 700 E are heavy and don't always clear during green phase.
- There is a decent amount of thru traffic at I-15 interchange. For the WB about 50% (rough estimate) get on SR-201 at 700 W.
- At 17:22 PM the EB queue at 1300 E is back to HAWK in the #1 lane, most vehicles are making a right turn.
- At 17:38 the EB queue at State St reaches past Main St, almost to West Temple.

*Optimization Notes:*

- We considered sequence change at 300 W to create the reverse progression. However, we found that it didn't really keep the N/S green phases in the same place as we move to the shoulder plan. So, I removed the sequence change and adjusted the offset by the same amount (15 seconds).
- At 16:36 EB at State St failed to clear. Looking for the time to start the reverse progression plans.
- At 16:58 the review progression plan was enabled east of State St. The platoon will arrived at State St 15 seconds later that it did in the earlier plans.
- At 17:16 the EB queue from State St is reaching through Main St despite the reverse progression. However, after the queue gets all settled it is short of Main St.
- We want to set the reverse progression from 16:45 to 17:45.

- At 18:07 there is a late peak especially between 900 E to 1300 E. Might be people going to dinner or shopping. Decided to keep the PM patterns running east of 700 E 30 mins later to 19:00.

**Saturday**

*Cycle Length:* The weekday MD 108CL patterns are used at all signals except at 300 W and east of 700 E. At 300 W a unique pattern with different splits than the weekday MD patter to give additional EBL split time for shopping traffic. East of 700 E runs PM 120CL patterns for most of the day due to heavy shopping traffic.

*TOD Schedule:* Found the coord start at 9:00 was appropriate. However, the coord end time was changed from 22:00 to 22:30. Pattern 13/22 (120CL) were set to run from 9:00 to 19:00 at signals east of 700 E which is the heavy shopping period.

*Optimization Notes:*

- On Saturday the MD patterns work pretty well. The only issue was EB from 900 E, 1100 E and 1300 E were queuing up, a little more at 1100 E. I've programed pattern 13 to run at these signals during the same period that 1300 E was already running.
- Also the EBL was failing to clear at 300 W. I moved 3 seconds to the EBL movement in a new pattern 22.

**Sunday**

*Cycle Length:* The weekday MD patterns are used at all signals.

*TOD Schedule:* Coord start time was set to start later from 9:00 to 11:00 and set to end earlier from 22:00 to 19:00.

*Optimization Notes:*

- Again the 108CL at the interchange handled the traffic adequately.
- The MD plans worked well.

# APPENDIX D: Glendale (900 W;SR-201 to 800 S and 1300 S; Redwood to I-15)

Salt Lake City Traffic Signal Optimization Memo

Date: May 23, 2018

**Project Name: Glendale Neighborhood**

Consultant: Luke Seegmiller (PineTop) and Shawn Larson (Avenue)

Salt Lake City: Bryan Meenen and Matthew Hyer

**Scope**

**Signals:**

- 900 W from SR-201 to 800 S
- 1300 S between I-15 to Redwood Rd
- 1700 S @ 700 W

**Time of Day:** AM, MD, PM, Saturday, and Sunday

**Data Collection:** ATSPM split monitor is available at all signals but the following signal provided additional data. Pre-timed signal splits were fine-tuned during implementation or set to cover peds.

- #1010 700 W @ 1300 S – Turning Movement Counts, Approach Volume

**SPM Check:** All was working correctly.

**Synchro:** The source of the initial model was the UDOT Region 2 model. All modeling was done in a way to be able merge back together in a city wide model upon project completion.

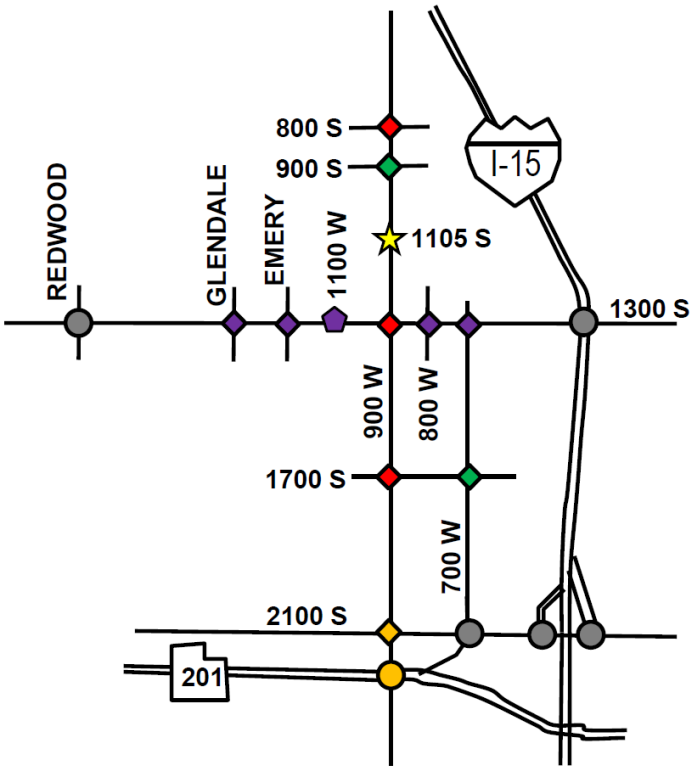
**Goals:**

- Evaluate for adding coordination at signals on 1300 S and at 900 S @ 900 W.
- Change cycle lengths to be more compatible with each other and with nearby signals on 2100 S and at Redwood Rd @ 1300 S.
- The adjust splits so the EB SR-201 off-ramp clears during the AM peak.

**Implementation Schedule:**

- Existing Observations – Tuesday, January 23, 2018
- Initial Implementation – Thursday, February 15, 2018
- Weekend Implementation – Saturday, March 24, 2018 and Sunday, March 25, 2018

## Time-of-day Schedule




| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 16 | 74 | 0:01 | 16 | 74 | 0:01 | 16 | 74 |
| 9:00 | 1 | 72 | 6:00 | 1 | 72 | 8:00 | 1 | 72 |
| 18:00 | 16 | 74 | 13:00 | 13 | 80 | 19:00 | 16 | 74 |
| | | | 18:30 | 1 | 72 | | | |
| | | | 19:30 | 16 | 74 | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 9:00 | 1 | 72 | 6:00 | 1 | 72 | 8:00 | 1 | 72 |
| 18:00 | 100 | FREE | 13:00 | 13 | 80 | 19:00 | 100 | FREE |
| | | | 18:30 | 1 | 72 | | | |
| | | | 19:30 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 16 | 74 | 0:01 | 16 | 74 | 0:01 | 16 | 74 |
| 9:00 | 1 | 72 | 6:00 | 1 | 72 | 8:00 | 1 | 72 |
| 18:00 | 16 | 74 | 13:00 | 13 | 80 | 19:00 | 16 | 74 |
| | | | 18:30 | 1 | 72 | | | |
| | | | 19:30 | 16 | 74 | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 9:00 | 1 | 72 | 6:30 | 1 | 72 | 8:00 | 1 | 72 |
| 18:00 | 100 | FREE | 13:00 | 13 | 80 | 19:00 | 100 | FREE |
| | | | 18:30 | 1 | 72 | | | |
| | | | 19:30 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 9:00 | 1 | 108 | 6:00 | 1 | 108 | 8:00 | 1 | 108 |
| 18:00 | 100 | FREE | 13:00 | 13 | 120 | 19:00 | 100 | FREE |
| | | | 18:30 | 1 | 108 | | | |
| | | | 19:30 | 100 | FREE | | | |

## Plan Description

### General

*1105 S HAWK @ 900 W*
We found the 1105 S HAWK didn't come on often enough to significantly affect the operations. Also, the HAWK would have to be re-phased to run coordination. Given this, we decided not to test coordination.

*900 S @ 900 W*
Ped times were re-evaluated at 900 S and it was found that a 72CL just barely fits. North of 2100 S this signal controls for minimum cycle length options because it is split phased and there are heavy peds because of a connection to the Jordan River Trail.

*1700 S @ 1125 W (Riverside Dr)*
There is enough E/W traffic to warrant coord at 1700 S @ 1125 W (Riverside Dr). However, SB skips frequently and there is no comm which would allow the clock to drift. For these reasons we didn't explore adding coordination here.

**AM/MD**

*Cycle Length:* Changed the cycle length north of 2100 S from 74CL to 72CL and at 2100 S and SR-201 from a 100CL to a 108CL. The 72CL is a 2/3rds harmonic of the 108CL. This also allows for Redwood @ 1300 S and signals on 2100 S at 700 W and at the I-15 interchange to also tie as a 2/3rds harmonic.

*TOD Schedule:* The schedule was changed at signals north of 2100 S on 900 W to match SR-201. It doesn't use a MD pattern but pattern 1 runs from 6:00 until 13:00. However, signals on 1300 S to the east and west of 900 W don't warrant coordination until later at 6:30.

*Initial Observations:*

- At 5:55 the SR-201 interchange is already busy. Coord is definitely needed at 6:00.
- At 6:05 on 1700 S there is enough traffic to make sense to tie coordination to the signals to the east and west.
- Redwood Rd is a long ways from the nearest signal on 1300 S. It may not make sense to try to tie to Redwood.
- At 6:13 traffic is still light everywhere.
- There is a lot of distance between 1300 S and 900 S. So, not sure how coordination between the two is going to work.
- At 6:23 the NBT from the interchange runs right into a red at 2100 S. It favors the EB off-ramp which is the heaviest movement. We have a lot of sequence options here. I wonder if we could move both movements through 2100 S somehow.
- At 6:27 on a SB run from 800 S through 1700 S I didn't stop at any signals. NB from a fresh green at 1700 S I arrive early at 900 S and wait 10 seconds and then double stop at 800 S. However, 900 S is running free. Also, traffic is picking up a little at this time.
- At 6:40 there quite a bit of SB traffic at 1300 S. Maybe 6:30 is a good coord start time north of 1700 S.
- At 6:45 I just saw a 10-veh NB platoon as well. At 6:47 there was another large NB platoon from 2100 S. It makes sense to tie signals to the north to 2100 S.
- At 6:57 there is a pretty long queue on 1300 S at the Emery St Signal. 1300 S definitely warrants coord at this time if not sooner.
- SB from 2100 S arrives well for the SBL at the interchange.
- At 7:27 the E/W traffic on 1300 S is pretty light. It makes me think twice about coordination. But there is a 6-veh platoon. It's just got to be a really low cycle length.
- At 7:38 watching at the interchange, there is a lot of traffic going NB on 900 W at 2100 S.
- At 7:47 SB at 800 S is failing to clear at least one cycle but recovers quickly.
- At 8:11 EB on 1300 S @ 900 W is struggling a little bit. I think it is failing to clear at least some of the time.
- At 8:14 the EB off-ramp failed to clear. It is a little sluggish in the relationship with 2100 S. NB 2100 S should have turn green a little sooner.
- At 8:22 the EB queuing at 1300 S is gone. Generally N/S traffic is dying down.
- At 8:33 the EB SR-201 off-ramp fails to clear again. The off-set is off a little at 2100 S, needs to be sooner, or later at the interchange.
- At 8:30 traffic is really light on 900 W and 1300 S.
- Sometime after 8:30 the EBL at SR-201 failing to clear again.
- At 11:53 1300 S has enough traffic for E/W coordination (6 to 7-veh platoons). N/S on 900 W is about the same. Later at 12:39 the traffic is even lighter.

- At 12:00 the E/W traffic on 1700 S is really light. Not really any platoons. Signals to the east and west of 900 W should probably remain free.

*Optimization Notes:*

- At 6:37 traffic volumes doesn't warrant coord on California until 6:30. However, 900 W should start coord at 6:00.
- At 7:10 all the coord seems to be working well. The EB SR-201 off-ramp clearing with the extra time given. All 8 seconds going from the 100CL to the 108CL was given to the off-ramp left turns.
- At 8:01 there are early EB arrivals at 800 W from 900 W on 1300 S. There is a crossing guard pushing the ped button each cycle. We reduced the offset by 5 seconds.
- In the late morning we gave 6 more seconds to the WBL at 2100 S @ 900 W after seeing it struggling.
- Bryan and Matthew stopped at the1100 W ped crossing on 1300 S and pushed the button to see how the arrivals are.The offset was in the right place.

**PM**

*Cycle Length:* The cycle length at SR-201 and 2100 S was not changed from the 120CL. Other signals on 900 W and 1300 S use an 80CL, a 2/3rds harmonic of the 120CL.

*TOD Schedule:* Transition times were set to match that which is in place at SR-201.

*Initial Observations:*

- At 13:20 transitioning to the PM 120CL makes sense at the interchange and 2100 S. Truck traffic really picks up for both the WBL and SBT at 2100 S.
- At 16:36 based on traffic volumes E/W should be coordinated at 1700 S @ 700 W rather than N/S.

*Optimization Notes:*

- Reduced the offset by 6 seconds at 800 S after seeing the end of the SB platoon being cut off at 900 S.
- Scott considered an offset change at 1700 S @ 700 W. Both directions between 700 W and 900 W arrive a little early. So if you make one arrive perfect than the other arrival gets worse. He ended up leaving it where it was.
- At 17:14 from a fresh WB green at 700 W the back of the platoons was cut off at 800 W. Reduced the offset at 700 W by 10 seconds.
- At 17:44 traveling at the back of a 10-veh platoon going WB on 1300 S. Everyone made it through Glendale but about 2 or 3. We increased the offset a few seconds.

**Saturday & Sunday**

*Cycle Length:* The AM/MD weekday pattern 1 (108CL/72CL) worked well both days.

*TOD Schedule:* The transition times used at SR-201 were found to be appropriate for the rest of the signals in this task.

*Optimization Notes:*

- Worked well, no additional adjustments were needed.

# APPENDIX E: 300 W (2100 S to 600 S)

# Salt Lake City Traffic Signal Optimization Memo

Date: May 30, 2018

**Project Name: 300 W**

Consultant: Luke Seegmiller (PineTop) and Shawn Larson (Avenue)

Salt Lake City: Bryan Meenen and Matthew Hyer

## Scope

**Signals:**

- 300 W between 2100 S and 600 S

**Time of Day:** AM, MD, PM, Saturday, and Sunday

**Data Collection:** Only ATSPM split monitor is available at these signals. Pre-timed signal splits were fine-tuned during implementation or set to cover peds.

**SPM Check:** All was working correctly.

**Synchro:** The source of the initial model was the UDOT Region 2 model. All modeling was done in a way to be able merge back together in a city wide model upon project completion.

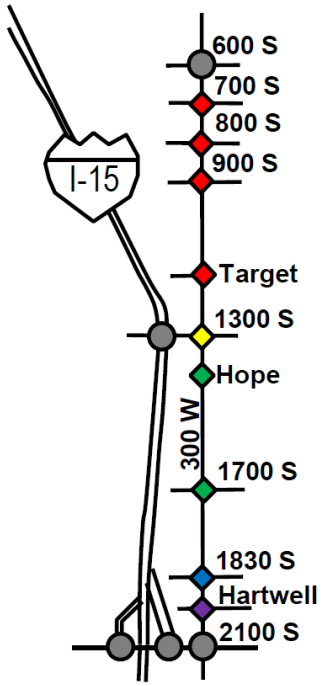
**Goals:**

- Add coordination at Hartwell Ave and Hope St
- Make cycle lengths compatible
- Tie to changes made at 1300 S and 2100 S when they were implemented.
- Cross-coordinate on 1700 S to the east/west

**Implementation Schedule:**

- Existing Observations – Tuesday, January 30, 2018
- Initial Implementation – Wednesday, February 28, 2018
- Weekend Implementation – Saturday, March 24, 2018 and Sunday, March 25, 2018

## Time-of-day Schedule




| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 6:30 | 1 | 80 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 7:00 | 1 | 80 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 21:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 21:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 6:30 | 1 | 120 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 16 | 80 | 0:01 | 16 | 80 | 0:01 | 16 | 80 |
| 11:00 | 7 | 108 | 6:30 | 1 | 60 | 9:00 | 7 | 108 |
| 19:00 | 16 | 80 | 9:00 | 7 | 108 | 22:30 | 16 | 80 |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 16 | 80 | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 11:00 | 7 | 108 | 6:30 | 1 | 60 | 9:00 | 7 | 108 |
| 19:00 | 100 | FREE | 9:00 | 7 | 108 | 22:30 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:30 | 7 | 108 | | | |
| | | | 22:00 | 100 | FREE | | | |

**Plan Description**

**AM**

*Cycle Length:* This peak period has the lightest traffic of the day time. Cycle lengths were reduced to cycle lengths that work well with surrounding 120CL patterns:

- 700 S to Target –to 80CL a 2/3rds harmonic of the 120CL
- 1830 S and Hartwell - to 60CL a ½ cycle of the 120CL. At 1830 S the E/W peds were oversized to keep from omitting the left turns. SPMs showed the left turns coming on occasionally but light peds. At Hartwell the N/S left turns were omitted.

*TOD Schedule:* Traffic volumes don't warrant coordination right at 6:30 but we thought it best to have the signals in step prior to traffic picking up. Also 600 S and 2100 S start coord at this time. So, it made sense just to match. There was no change to the AM to MD transition time.

*Initial Observations:*

- At 6:30 traffic is so light. Coord is not warranted at this time based on N/S traffic.
- At 6:34 the E/W traffic on 800 S is heavier than the N/S.
- Thinking about half cycles at some of these even if we have to oversize the peds.
- At 7:10 coord is definitely warranted by 7:00, even a little before.

*Optimization Notes:*

- Scott suggests using a lower cycle length at 7th, 8th, and 9th. Half cycle if possible or 2/3rds. Full cycle is too large. A 60CL requires oversizing E/W peds and omitting left turns. Later found that there were too many peds (14 per hr) at 800 S. Tried an 80CL 2/3rds harmonic of the 120CL, also omitting left turns, and it worked really well and covers peds.
- Otherwise the operations were really good.

**MD**

*Cycle Length:* Used a 108CL to match surrounding signals and crossing corridors. This also made sense with traffic volumes.

*TOD Schedule:* AM to MD and MD to PM were set to match crossing corridors and also made sense for N/S traffic volume fluctuations.

*Initial Observations:*

- Traffic heavier than in the AM warranting that higher 108CL at all signals.
- Free signals causing progression issues.

*Optimization Notes:*

- Proposed timing worked well. Little to no tweaks were made

**PM**

*Cycle Length:* Stayed at the 120CL to match surrounding signals and crossing corridors and it made sense with traffic volumes.

*TOD Schedule:* Changed some signals so that all would match each other and also the crossing corridors: MD to PM at 15:30 and PM back to MD at 18:30.

*Initial Observations:*

- Traffic volumes warrant the 120CL.
- Free signals are causing progression issues.

*Optimization Notes:*

- SB from 1300 S half the platoon gets cut off at Hope Ave. We increased the offset at Hope which helped. I also reduced the min green from 35 to 20.
- NBT from 2100 S sometimes part of the platoon gets cut off at 1700 S. Increased the offset at 1700 S by 6 in took 4 seconds from the side street which should add 10 seconds to the end of green so less is cut off.
- NB there is a planned stop at 800 S and then you stop at 700 S again. Took 10 seconds from the side street and reduced the offset by 10 seconds. This removed the double stop.
- Bryan Meenen set his cruse SB at 35 mph and never stopped.

**Saturday & Sunday**

*Cycle Length:* The MD weekday pattern 7 (108CL) worked well both days.

*TOD Schedule:* Transition times were set to match crossing corridors. They were found to be appropriate for the traffic volumes.

*Optimization Notes:*

- Worked well, no additional adjustments were needed.

# APPENDIX F: California Ave (Redwood to Bangerter Hwy)

# Salt Lake City Traffic Signal Optimization Memo

Date: August 20, 2018

**Project Name: California Ave Corridor**

Consultant: Luke Seegmiller (PineTop) and Shawn Larson (Avenue)

Salt Lake City: Bryan Meenen and Matthew Hyer

## Scope

**Signals:**

- California between Redwood to Bangerter

**Time of Day:** AM, MD, PM, Saturday, and Sunday

**Data Collection:** ATSPM split monitor is available at all signals but the following signals provided additional data:

- #7093 Redwood @ California – Turning Movement Counts
- #7025 California @ I-215 W SPUI – Turning Movement Counts
- #1143 California @ Pioneer – Turning Movement Counts

**SPM Check:** All were working correctly.

**Synchro:** The source of the initial model was the UDOT Region 2 model. All modeling was done in a way to be able merge back together in a city wide model upon project completion.

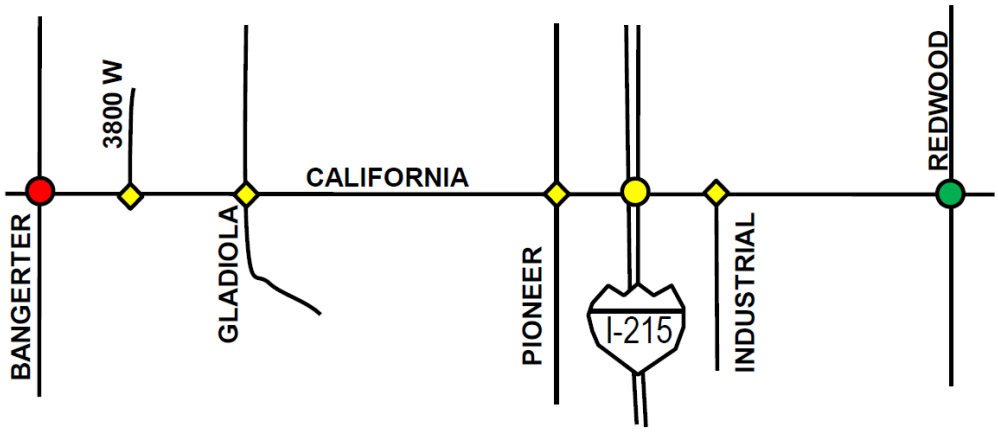
**Goals:**

- Evaluate installing coordination at these signals which historically ran free.
- Determine the appropriate cycle length and day plan transition times.
- Tie to existing timings at Redwood and Bangerter as much as possible.

**Implementation Schedule:**

- Existing Observations – Thursday, March 19, 2018 and Thursday, May 10, 2018
- PM Implementation – Tuesday, June 19, 2018
- AM & MD Implementation – Wednesday, June 20, 2018
- Weekend Implementation – Saturday, June 23, 2018

## Time-of-day Schedule




| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 7:00 | 7 | 120 | 5:00 | 1 | 120 | 6:00 | 7 | 120 |
| 22:00 | 100 | FREE | 9:00 | 7 | 120 | 23:00 | 100 | FREE |
| | | | 14:30 | 13 | 120 | | | |
| | | | 19:00 | 7 | 120 | | | |
| | | | 23:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| | | | 6:30 | 1 | 100 | | | |
| | | | 9:00 | 7 | 108 | | | |
| | | | 15:30 | 13 | 120 | | | |
| | | | 18:00 | 100 | FREE | | | |

| Day Plan 1 | | | Day Plan 2 | | | Day Plan 7 | | |
|---|---|---|---|---|---|---|---|---|
| Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length | Time | Action Plan | Cycle Length |
| 0:01 | 100 | FREE | 0:01 | 100 | FREE | 0:01 | 100 | FREE |
| 9:30 | 7 | 108 | 6:00 | 1 | 100 | 8:30 | 7 | 108 |
| 21:00 | 100 | FREE | 9:00 | 7 | 108 | 21:00 | 100 | FREE |
| | | | 15:30 | 13 | 120 | | | |
| | | | 19:00 | 7 | 108 | | | |
| | | | 21:00 | 100 | FREE | | | |

**Plan Description**

**AM**

*Cycle Length:* Changed from free to a 100CL which makes sense for the traffic volume and matches that used at Redwood.

*TOD Schedule:* While it made sense to match the AM to MD transition time used at Redwood (9:00) the start of coord was set to 6:30 rather than the 6:00 used at Redwood. Traffic just doesn't build up as early on California.

*Initial Observations:*

- Early there wasn't enough traffic to warrant coordination. However, at 6:40 there was a 7 or 8-veh long platoon. 6:30 looks like a good coord start time.
- At 6:48 the NBL at the I-215 W interchange is heavy. In 2nd place is the WBT or SBR.
- At 6:57 Pioneer has the most N/S traffic.
- At 6:59 there is a very heavy WB platoon coming from the NBL at the interchange.
- At 7:36 there is a petty long queue turning SBL at the interchange.
- Definitely enough traffic to warrant testing coordination.

*Optimization Notes:*

- It looks like we may need to increase the offset at Industrial to get the WB platoon from Redwood through the end of green.
- At Pioneer we may be cutting off some of the platoon. Later I stopped to check the offset and it looked okay.

**Midday**

*Cycle Length:* Changed from free to a 108CL which makes sense for the traffic volume and matches that used at Redwood.

*TOD Schedule:* Traffic volumes made sense to tie AM to MD and MD to PM transition times with that used at Redwood. However, after the PM peak volumes drop drastically at 18:00. Coordination doesn't make sense after this time and all signals go free rather than transition back to the MD pattern.

*Initial Observations:*

- Traffic volumes warrant coordination.

*Optimization Notes:*

- At 15:09 there long WBL queue at the I-215 W SPUI. It clears with the split we've given. Saw this again at 15:16.
- At 15:17 thought about making the left turns the coord phases at the I-215 W SPUI. So, they'll get any extra time that is available. Ended up leaving the through phases as the coord phases.
- At 15:18 at the I-215 W SPUI the EBL and WBL turns are backing quite a bit but clear for the most part.
- Debated about setting Gladiola and 3800 W free for portions of the midday but decided the coordination is a big benefit to the large volume of trucks that use California.

**PM**

*Cycle Length:* Changed from free to a 120CL which makes sense for the traffic volume and matches that used at Redwood and Bangerter.

*TOD Schedule:* While it made sense to match the MD to PM transition time used at Redwood (15:30) the end of the PM plans was set to 18:00 rather than the 19:00 used at Redwood. Traffic volumes drop dramatically on California at this time.

*Initial Observations:*

- SBL at Pioneer is very big. Need to make sure is has plenty of time in the PM.
- The EBL and WBL at I-215 W are very big. It looks like it will need at least a 120CL.
- The posted speed signs say 40 mph. However, travel speeds are less than that, like 38 mph. There are lots of trucks. I don't think anyone is going 45 mph. It's safe to model at 40 mph.

*Optimization Notes:*

- At 15:41 the WBL at Gladiola looks to be backing up but it clears.
- At 16:13 there is long EB backing from the I-215 interchange. Reduced the offset there and at Pioneer by 10 seconds. Turns out the issue is that Ø5 is holding our and skipping the EBT Ø6 or serving it really short. In the end, the controller was replaced to resolve the issue.
- At 17:20 we reduced the offset at 3800 W to keep from cutting off the end of the EB platoon from Bangerter.
- At 17:40 the E/W traffic really dies down about 17:30, especially at 3700 W and 3800 W. Going free at 18:00 makes sense.

**SAT/SUN**

*TOD Schedule:* Tested the MD 108CL on Saturday but found that volumes don't warrant coordination. After checking the available turning movement counts, Sunday volumes are even lower. Set it to run free on Sunday as well.

# APPENDIX G: DA

# DA OBSERVATIONS AND IMPLEMENTATION NOTES

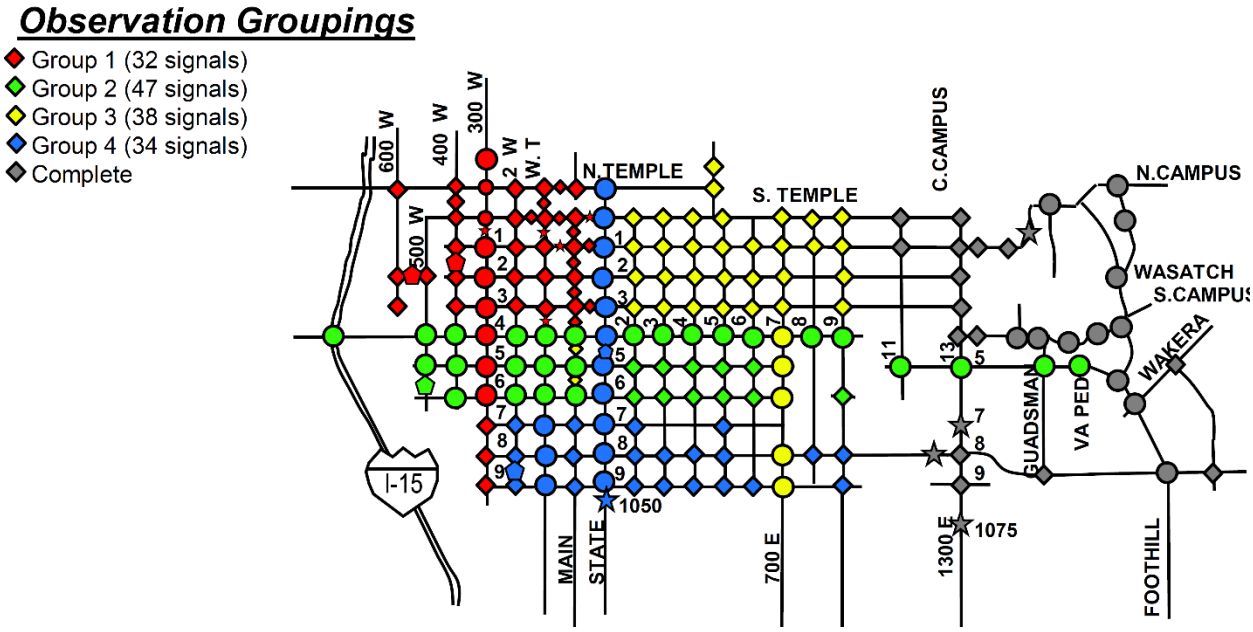
This appendix provides detailed notes from both the observations of the exiting coordination plans and the implementation of the new plans. Both efforts divided the DA into four similar groups.

## Observations

Observations were completed with the purpose of identifying both what works well along with the problem areas. Detailed notes are provided below for each of the four DA groups as illustrated below. Observations were completed on the following dates:

- Group #1 – 3/1/2018
- Group #2 – 3/13/2018
- Group #3 – 4/19/2018
- Group #4 – 4/17/2018

After the observation of each time period in each group team members including SLC, PineTop, Avenue, and at times UDOT would meet for a group discussion. Notes from these discussions are also provided below.




### Group #1: NW Quadrant and 300 W

**AM**

High number of pedestrians, in general pedestrian phases cannot be oversized

The 120CL felt too long for majority of signals

The SBL at 300 W and South Temple backs up to North Temple

The SBL at 300 W and North Temple backs up past the pedestrian crossing for West High School

North Temple is used as a major E/W corridor.

300 W

- 6:37 NB Gap outs at 600 S. There is low volume going NB. Once I got to 300 N started to set the increase in SB traffic coming into the DA.
- SB - There is pretty good flow already potentially, leave harmless as far as relative offsets are concerned.

400 W

- 6:44 SB Hit every single TRAX intersection. What is the smallest cycle length that this group can run with the train? Possible to run that all day?
- NB run, large platoon ahead of me kept bringing up the signals, so that made it smooth.

600 W has no real N/S priority. We should keep the intersection at 600 W and the Train Hub free.

200 W

- has experienced the road diet – it does not feel like a N/S corridor to consider there are a lot of NB stops – consider this in more of the grid approach.
- 7:35am SB run was clean.

W.Temple

- N/S progression already feels pretty favorable. As noted already there is a lot of NB traffic coming into the city on this corridor.
- Had a weird stop from 400 S at 200 S. We seem to lose a little bit of traffic at every cross street coming into the DA.

Main St.

- No progression, just rough all around.

300 S

- EB Cross coordinated at 300 W? There is a road diet presently and it was okay, but you can feel that it is a little tight.

200 S

- Feels like a much bigger road way than it is currently being used as. Several stops during progression State, W.Temple, 400 W, 500 W. This may be the 2nd largest E/W corridor in this segment.

100 S

- West of the Convention center, there is no need to coordinate in an E/W fashion, create it as part of the grid N/S favored.
- East of the Convention center, feels like there is a significant WB flow into the city. There is little to no EB flow.

N. Temple

- 8:00 EB Very heavy E/W LT @ West Temple. Start from 400 W until Main St, no stops. Approaching State St, there is some significant lane utilization concerns as a lot of traffic is running in the right lane to make the EBR at State St. This needs to be a favored movement during the AM period. This is the primary E/W corridor within this segment.

End of period discussion

- Agree that we will want to run the AM period longer. NB is still heavy after 9am in the morning. Focus on short cycle lengths and managing the queue storage that we have for the left turn pockets.

6:37 – Traffic is really light. We may not need coord at this time.

6:38 – N/S is waiting a long time for no one at West Temple @ 100 S.

6:39 – E/W on North Temple looks busy enough for coord but still not super heavy. North Temp @ 200 W there is EB there is an 8-veh platoon. Other than North Temple and 300 W most of these need to go to the lowest cycle they can run, maybe something compatible with the high cycle. Also there's not many peds at this time of the morning.

7:07 – EB on North Temple has good progression until you reach Main St.

7:12 – There is a good amount of traffic E/W on 200 S. So, the major E/W corridors are North Temple and 200 S but it's not so heavy you could use a small cycle length.

On 300 S motorists are driving 20 mph.

There is a good amount of traffic N/S on West Temple. If it weren't for peds this could work really well at a low cycle length.

7:56 – EB on 100 S the queue was backing into 300 W. Looks like there were vehicles turning left and also a lane closure just west of 200 W.

It is Roots Tech today at the Salt Palace.

*Group Discussion:*

Largest corridors: N/S West Temple and 300 W and E/W North Temple

300 S is coord E/W and doesn't feel coordinated well.

Challenge is small storage for turning movements. Once you're in there you can't pin down where people are going. When you get stopped it's at the end of green and you wait for no one. Lowering the cycle lengths is needed. 120CL is way too high.

Houston Model discussed but there isn't good storage. Bryan is skeptical of this.

The biggest issue is split failures. Especially in the SBLs at North Temple and South Temple @ 300 W. SBL left at South Temple was backed up to 300 N.

The phantom one-way actually worked well here but there wasn't. 300 W was NB and 400 W was SB. This was pre-TRAX which might ruin it.

400 W N/S progression was rough. A single lane and Scott and Shawn hit every single TRAX signal. We need to talk to Devin about what options we have to do quasi-coordination. What's the smallest cycle length we can run? What if we could do a 60-sec cycle? Some of these have a 7-min train frequency.

400 S needs a 120CL. 300 W north of 400 S doesn't need a 120CL. North of 400 S could use a smaller cycle length. The critical signal for determining the smallest cycle is North Temple @ 300 W.

Capitol Hill has encouraged motorists to use 300 W. It is the preferred route coming from the north.

We don't know what to do with South Temple and Main St with the train. If we can come up with some solution for that then we can bring the rest of it in. We need to talk to Devin about it. The biggest issue is that there are no ped buttons and it rests in walk until a vehicle pulls up. We can look at the natural

cycle length as provided SPMs. Maybe we can mimic the free but make is coord. The cycle length needs to be really small.

Long cycle lengths make peds do stupid things. Low cycle lengths reduce queuing.

West Temple heavy NB even late in the peak.

Generally E/W corridors work better than N/S.

There are a lot of apartments being built downtown.

300 S @ 200 W – constant ped calls because the cameras can't capture cyclists.

200 W @ 100 S – this should be set free but there is currently a detection issue. Bryan asked that we mention this in our report.

Definitely notice that the AM peak plans should stay on later than 9:00. The 9am transition is too early.

There is ATSPM count data at #1025 200 S @ 200 W but it is video count data… only good for evaluating trends.

**MD**

The 108CL worked well in the Midday. No major cycle or split failures

HAWKS are used, but there are a lot of PEDs that simply just cross the street, and then the HAWK comes on for no one. (Focus on short cycle lengths to mitigate.) Platoons are getting more spread out than in the AM period.

11:53 – N/S Main St is pretty slow. There are a lot of stops. It happens if someone is turning right or parking. Only option is a really small cycle length.

11:57 – NB on West Temple there are a lot of stops… stop after stop after stop. There was a formulated platoon that could progress to the north.

12:05 – Heading NB on 200 W there was a long stop at 300 S waiting for no one. It's the story of too high of cycle lengths. NB from a fresh green at 300 S is into a fresh red at 200 S.

12:15 – even North Temple feels too long. SB 200 W at North Temple I spend a lot of time waiting for no one. We ought to reduce the cycle length even on North Temple.

12:17 – SB arrivals on 200 W were much better. From a fresh green on North Temple I got through to 400 S.

12:21 – North of 400 S on 300 W at 108CL is too big.

*Group Discussion:*

This period was a lot better… the reason: a lower cycle length.

We think the cycle lengths can even go even lower. Platoons are getting too spread out. If we can make it snappier it's better for everyone.

Half cycles might be too small to cover peds. However, half cycles even at one signal is doable.

If we have to have a corridor in this grouping its North Temple. It does feel different than the other signals in this grouping.

600 W should be left free accept for North Temple. This would be train logic.

**PM**

In the PM peak, there is a heavy WBR at 300 W and North Temple but no major queuing issues

In the PM peak, 120s cycle length might be necessary

Trains on 400 W and South Temple cause bad progression

200 W and 100 S should run free.

Salt Palace convention center was being used but didn't seem to cause significant issues in PM peak.

Hawks become much more active during the PM period.

Main St – there is a sense of a green wave when you are travelling with the Train. Why can we not reproduce this and make it work a bit better for vehicles as well? The PED Xing times just seem to be out of control – resting there and calling the vehicle phase when detected…. It does not seem to be as rough on Main St during the PM period as the other periods, but still not great.

West Temple seems to be favorable for the SB exodus from the city. Stops at N. Temple and 200 S.

Drove the State St North Temple LT through to 300 W. and that movement is really good. No stops.

NB progression on West Temple was pretty good. I stopped once, more like a hesitation stop.

15:58 – traffic is still pretty light. I'm wondering about waiting to transition to the PM pattern until later, like 16:30 or 16:00. However, I saw a large amount of traffic going SB on West Temple right after making this note.

Looks like North Temple is also busy. This may drive the PM pattern start time of 15:30.

16:12 – other than the SB queue at 400 S on 300 W it would be fine at a shorter cycle length at this time. The SB platoon is 10 vehicles long.

On 300 W the SB arrival at 400 S actually looks good. There is a lane closure that is affecting the arrival at 400 S.

16:00 – the SB queue at 400 S on 300 W is failing to clear. Vehicles make a long queue before the main platoon arrives. We may need a reverse progression approach here and get the queue moving before the platoon arrives.

16:23 – 400 W is not that busy. Platoons and queues are only 4-veh long. Not that busy.

16:27 – The WBL at 300 W and North Temple is pretty long but is clears with the split time given.

16:34 – WB progression on North Temple is really good. From a fresh green at State St I arrived on all greens as I headed west.

16:44 – seeing the NB State St is backing down into South Temple from North Temple. There is also a long WB queue in the #2 lane on South Temple, it reaches back through to 200 E, may half way to 300 E.

Troy is reporting that on 300 W he thinks the 120CL is about where it should be. He though the progression worked better in one direction, but I can't remember which, I think SB. He had to leave at 16:50.

16:55 - 100 S from 200 W to the west has almost no traffic. Only 1-veh platoons.

17:01 – Traffic in the DA had died down watching from 500 W @ 200 S.

200 S is step up to progress WB traffic. I've well everywhere except at 400 W which is running free. Saw something similar on North Temple, it designed to progress WB traffic.

17:18 – EB arrivals on 300 S are surprisingly good. However, I ran into the back of a long queue at Main St but otherwise the arrivals have been spot on leaving from 400 W. And actually the wait at Main St wasn't long. Looks like we'll wait at State St

*Group Discussion:*

Shawn: On West Temple on 300 W he got stopped on 200 S; on West Temple was both directions but on 300 W mostly NB.

Cycle lengths: generally looking like cycle lengths are about where they should be, but we should look at lowering them.

Didn't see a sharp PM peak it was more of a plateau.

If we keep the 120CL we'll probably tighten the time that it runs; start it later and end it sooner.

Luke: On South Temple and 400 W I'm not sure, and it might be my ignorance of the light rail operation. Thinking of how the train would work with coordination. Coordination would just add another level of complication to the operation.

Fort the LRT routes we're thinking of testing really short cycle lengths. We can check SPMs and see what these signals are running currently.

We discussed using peer-to-peer to pass the call along the LRT signals for some "quazi progression". However, the close signal spacing may make it not work well on the DA routes. Simple coordination might just accomplish the same thing.

AM & MD smaller cycle lengths. How small can we go? I think 300 W can have a lower cycle length.

Bryan's Concerns in the PM peak prior to observations:

- 300 S going west to 300 W is heavy traffic
- The movement to North Temple and those leaving North Temple (South Temple up State to North Temple)
- Watch 200 S
- Discussed the freight rail in the northwest of the observation area

## Group #2: 400 S, 500 S, & 600 S

**AM**

Coord start time seemed a bit early and may need to be extended after 9:00.

Vehicles seemed to be traveling at Posted speed limit or faster.

Lane utilization for EB vehicles on 400 S and 600 S, most vehicles turn left at some point along corridor. The left two lanes on 600 S was queued between West Temple and 200 W.

On 600 S vehicles east of State Street traveling faster than the speed limit due to signals timing (vehicles going speed limit get stopped).

The 120CL is need. A longer cycle length might help some of the capacity issues.

900 W on 400 S should be coordinated with the interchange.

The SB left turn off the I-15 interchange is progressed.

EB 600 S should tie 700 E and 900 E together.

WB 500 S, 200 E is currently releasing into a Red @ State St.

400 S 700 E – is there a potential to cross coordinate the corridor?

600 E cross – coordination; work on good arrivals between 500 S and 600 S.

500 E – traffic builds throughout the AM period.

NB 400 E – traffic stops at both 600 S and 500 S.

NB 300 E – same as above.

NB 200 E – stops at 600 E and 400 E.

5:28 – on 600 S there is platoons about 3 or 4 vehs long. My initial experience is that we stop a lot likely do the early returns. The MD plans don't work the same in the early AM because of the early returns. A lot of the stops were the 1st signals after getting off the freeway. After that, east of the Maverik, the arrivals have actually been pretty good, arriving just after the lights turn green.

5:31 – on 600 S @ 700 E the signal is coordinated N/S so I spent a lot of time waiting for no one, about 25 sec. However, we might be in transition too.

WB on 500 W, I wait again at 700 E for about 45 sec for no one. However, toward the end of green I saw a larger NB platoon. So, it is moving quite a number of cars.

For the most part WB on 500 S I arrived pretty well, a little early at some signals but mostly as it turns green.

5:40 – EB on 400 S at Main St there's a 9-veh queue in one lane. There is a good amount of traffic EB on 400 S.

I am thinking that the "corridors" need the MD pattern in the early morning but the quadrants don't.

5:55 – I am seeing the justification for the 108CL on 500 S and 600 S as well.

900 E @ 600 S is coordinated N/S.

6:46 – there is a lot of hesitation stops on 500 S WB. A lot are at city signals but also at State St.

6:58 – I just saw a large group of motorists heading NB on 200 E. There is a lot of traffic using city corridors.

6:59 – EB queue on 400 S at 200 E is queueing to State St.

7:05 – Main St is a stopping point on all the corridors; 4th, 5th, and 6th. This is also true of 700 E.

WB 500 S has a hesitation stop from 700 E at 600 E and another one at West Temple.

7:21 – earlier I saw an issue with EB on 400 S at 200 E queuing into State St. It's not an issue this time through.

Not seeing a lot of NB traffic at 400 E, 200 E, or 300 E. Earlier I saw a lot on 200 E. Only 4 vehicles NB on 400 E. There are quite a few on 500 E, I saw a platoon arriving as I drove past. At 600 E there was only 2 vehicles.

7:23 – EB 400 S I went through the end of yellow at 800 E and then got cut off at 900 E.

7:30 – at 900 E @ 400 S there is a crossing guard on the NW corner pushing the button constantly, although I don't see any kids. Troy had a conversation with him and he is only there for 3 or 4 kids. Troy brought up the key switch but Bryan says the city doesn't like it.

WB 400 S I stopped at 900 E, 600 E, and 400 E and these are long stopped. Seeing a good amount of 400 E traffic N/S. There is also a stop at State St and 400 W. So, the major direction is coordinated well but other minor direction is not, we can help with this.

The major movement at the 400 S I-15 interchange is the SB off-ramp, this is want we want to arrive well as they move into the city.

900 W doesn't appear to be timed very well with the interchange on 400 S. I went from a fresh green WB from the interchange into a fresh red at 900 W.

*Group Discussion:*

Troy: side street traffic didn't pick up until 7:30. Thought it would be earlier.

Bryan & Scott: progression on 300 E was working the best.

Bryan, the whole system currently works so that if you're going faster you arrive better.

Consider a half cycle at 400 S @ 900 W and whatever we do we'll want to tie in with 200 S @ 900 W.

900 E @ 600 S might need to be coord e/w, or just cross-coordinate.

We want to look at speeds and what we model. On 400 S there were great variations in the speeds of the platoons. They aren't consistent.

Cycle lengths: look at lower cycle lengths. Half cycles on 500 S and 600 S between State St and 700 E.

**MD**

In the MD, can we half cycle 500 S and 600 S east of State St?

Overall thoughts – The cycle length is a little large, but not by much. PEDs do not seem rushed at this cycle length (I think that this is about adequate)

300 W – seems like there is a long NB wait at 500 S, with no one coming on the corridor.

900 E – has a large platoon, @11:48am EB still feels heavier on 400 S, there were multiple WB stops between State and 500 W

600 S – 30-35 mph seems like the appropriate value, clean run all the way through 200 E (where the platoon was reset) then there was a long awkward stop at 900 E, which seemed wrong.

500 S – Clean run, WB stopped @ Main St (Train present), 700 E to Main, once past Main, only other stop was at 300 W.

600 S – Signed @ 30 mph, but everyone was travelling around 35 mph. (Especially on the Eastside of the corridor).

500 E – both 500 S and 600 S had PEDs active, so there was a sense of cross-coordination at those intersections.

400 E – Seemed to stop at every cross street. (400 S, 500 S, 600 S ) SB this feels very long, with no cars crossing at the end of the main street greens. –leads to using a shorter cycle length.

300 E – NB progression is currently running well.

400 S – running @ 35 mph.

12:42 – Observed NBLT split failure at 400 S 500 W.

12:45 – 400 S EB travel, multiple stops, 500 W, 300 W, Main St (no train) 500 E, 700 E, 900 E.

600 E SB – travelling at 20 mph, you cannot make any of the intersections, but also cannot make travelling at 30 mph. Noted that it is signed at 20 mph.

WB on 500 S I turned NBL at 300 E and stopped at 200 E, State St but otherwise arrive well through 500 W.

11:41 – EB on 600 S from a fresh green at 400 W into a red at 300 W but it's a hesitation stop. The next stop is Main St and I saw that a train has just gone through. Speeds on 600 S EB are 40 mph. The next stop is 700 E with a long wait.

WB on 400 S I had a long stop on 200 E and again at State St. Looks both EB and WB had a long stop at State St. The EB queue at State St reaches into Main St.

12:07 – EB 400 S with a fresh green at 500 W, into red at 400 W. 500 W is not a good platooning intersection but theI-15 interchange is and 400 W turns green just as the platoon arrives. From a fresh green on 400 W into a fresh red on 300 W, but the wait isn't long. I stop again at Main St but again only a hesitation stop. Another stop at State St, again a hesitation. Speeds on 400 S east of State are slow about 25 mph while the posted speed is 35 mph. Then a stop at 400 E, might be related to the slow speed. Signals east of 200 E seem to have been fine turned to the slower speeds, 20-25 mph. I was cut off at 800 E. A fresh green at 800 E into a red at 900 E, again a hesitation stop.

12:54 – SB 400 E @ 400 S – the green was really short for some reason and failed to clear a 6-veh queue.

12:56 – fresh green SB 400 E @ 400 S into a fresh red at 500 S. And then right into another red at 600 S, but it's a short wait.

13:01 – NB on 300 E from 600 S I arrive well at 500 S and stop at 400 S, where it's at long wait.

13:05 – SB on 200 E from 400 S I arrive on red at 450 S, and also at 500 S. Then I got through the end of green at 600 S, but not everyone with me made it.

*Group Discussion:*

Scott: likes the 108CL. There are a lot of peds. We can't go lower that what the peds need.

600 S has early returns, but 400 S

Speed on 600 S: get past State St and by the time you get to 200 E there is a fast platoon and a speed limit platoon. The speed limit platoon gets stopped and penalized. The fast platoon makes is all the way through. Link speeds should be modeled at 30 mph, the fast platoon is going 35 mph.

On 500 S the traffic is going the posted speed at 30 mph so it is working better.

Left turns and right turns slow platoons on all 3 corridors.

Troy Noall: West Temple progression works well between 500 S and 600 S but otherwise doesn't work well.

The highest trafficked corridor is West Temple. Get that right and build off of this.

Jon Larsen (new traffic engineer) is thinking of reducing speeds on State St.

600 E: NB is okay but SB offsets aren't working – Bryan's not worried if progression is bad here.

500 E: works both ways – also a good volume of traffic working here

400 E: doesn't work well either way

300 E: worked both ways

200 E: commuter route. Troy thought it is working well but there is a lot of traffic.

Scott: early in the MD the 108CL felt too big but later it was comfortable.

**PM**

The WB queue at 400 S and State St backed almost to 200 E.

The WB left turn on 400 S and 700 E / 1300 E / State St are heavy and could use a longer split

The WB queue at 500 S and State St backed almost to 200 E.

15:40 – 400 S @ 700 E, WB flows are already heaving coming down from the university. Observed split fail WB at State St, and Main St for the WB thru movement.

16:02 – 500 S EB – there were no stops, 500 E and 400 E both had very heavy cross traffic.

400 S WB – Had multiple stops starting from 300 E to the west. Once past Main St, progression was better. Following traffic there is a lot headed to NB I-15.

400 S EB – decent progression, stops at 400 W, 200 W, State St, 200 E and then another short hesitation stop at 700 E.

500 S WB – there was decent progression, the hesitation stop at 400 W, creates a huge shockwave back 500 S through 300 W. If we can get rid of this operation – possible some reverse progression, we can eliminate the shockwave.

17:30 – 400 S WB - 900 E, 500 E, 400 E, State St, and then Main St – then good progression WB.

17:40 – 600 S – there are multiple hesitations stops, this slows the corridor down, likely due to possible early returns.

Another 500 S run – start at 700 E; 200 E stop, and this is the back of the shockwave.

15:27 – There are already hesitation stops WB at 500 W. This is obviously gets worse and worse causing the problem later in the PM Peak.

15:29 – EB 600 S from a fresh green at 400 W there is a hesitation stop at 300 W. The next stop is Main St and it was 20 seconds. To the east of all the signals are green and the ped is counting down as

you arrive at signals. The ends of platoons get cut off. It is encouraging speeding. I got cut off at 400 E. Fresh green at 400 E into a fresh red at 500 E. But I arrive at 700 E on green.

WB on 500 S I arrived somewhere in the middle of green on 700 E and I didn't stop until State St. Continuing west there are hesitation stops at 300 W and 500 W. There are a lot of hesitation stops when it should be free flow.

15:40 – there is a long SB queue at 500 W @ 500 S (probably 20 vehicles long).

15:42 – on this run EB on 600 S I hit everything green all the way through State St. On the east end I am seeing the same ped count downs as I go through the signals. I didn't stop through 700 E but I was speeding. I went through 700 E on yellow. There is not a lot of traffic on the east side; I think half cycles make sense.

15:45 – E/W is waiting a long time at 900 E @ 600 S for no one going N/S.

WB on 400 S I did pretty well. I did get cut of at 400 E. Scott: if we have to have a stopping points do it at a TRAX Station.

Fresh green at WB at 500 E on 400 S runs into a fresh red at 400 E. There is a WB lane closure between 400 E and 300 E on 400 S. Next stop is State St. After that I didn't stop until the interchange. From a fresh green at the interchange WB a I stop at 900 W and wait for 10 seconds.

EB 900 W @ 400 S turn green at the same time EB at the interchange turns red.

16:08 – EB 400 S has a planned stop at 300 W, then a long stop at Main St. Then I just barely made it through State St on the end of green. I'm at the back of a platoon. Stopped at 700 E.

SB at 700 E @ 400 S is the heaviest movement at the signal.

WB 400 S from 800 E arrived a little early at 700 E but the main platoon arrives from 900 E a little later just as the queue gets rolling at 700 E. Just the front of the platoon gets through at State St but its not much of a platoon to speak of.

There is a pretty good SB queue at 400 S @ 900 E.

From a fresh green EB at 900 E @ 400 S I arrive on a red at 1100 E @ 500 S but the wait is not too long but the whole platoon comes to a stop. 1100 E is running free.

16:31 – EB 600 S Main St turned green and cut of some of the platoon, I think because of trains. The platoon is really spread out. Just east of 300 E is the first speed limit sign that I've seen, 30mph.

NB 600 E from a fresh green at 600 S arrives well at 500 S but stops at 400 S.

SB 600 E from a fresh green at 400 S I get through 500 S and stop at 600 S.

17:03 – earlier I had an EB run on 400 S and had a bunch of stops. This EB run I only stopped at West Temple, Main St, and 900 E. The difference might have been a train.

17:13 – They opened the WB lane closure on 400 S between 300 E and 400 E.

WB from State St is queued back almost to 200 E but it looks like the queue is moving. State St was green for only a short time. I think it resulting from preemption.

17:21 – WB 500 S is in really rough shape starting at West Temple or Main St. The queues are sitting with nowhere to go while the light is green.

17:45 – the WB 500 S issue cleared up by this time. Seeing a log of EB traffic on 400 S. It must be people coming into town for food and entertainment.

17:49 – I'm EB on 400 S @ Main St for 1 train to turn and then a second train arrives and I wait again.

17:52 – WB on 500 S the big queue failures have cleared out but I'm seeing the hesitation stop again, especially at 400 W.

Seeing that same pickup in SLC inbound traffic on 600 S.

*Group Discussion:*

Matthew: saw the WB 500 S queuing reach nearly to 200 E but not quite.

The change Matt Luker made at Main St @ 400 S to make it run coord made it a lot better. Re-phase with logic makes it essentially run coord.

There is directional a shift at 17:45. Outbound until 17:45 and then inbound starts.

EB 400 S east of State St there are a lot of stops. But there are a stop WB as well. We discussed making stopping points a TRAX stations.

400 S Split failures: WBT at State St into 200 E. There were some heavy left turns but we didn't see them queue out of the storage lanes.

We talked about how UDOT would like to remove the shared left turn lanes with the TRAX trains. We're to give our input on whether this would work.

500 S WB: State St was always a stopping point for me and it sometimes queued back to 200 E. We also talked about the hesitation stops. Early peak in pattern 13 and reverse progression in pattern 14.

600 S EB: hesitation stops due to early returns. East of 200 E all the lights are green and ped counting down as you go through encouraging. They need to turn green as the platoons arrive.

500 E, 600 E, and 200 E have heavy side street traffic.

We also talked about the full-cycle with phase re-service.

200 E is the only n/s corridor with consistent issues. A big part of that is the 450 S ped signal, which we later found that it was coordinated in the PM peak. It has been coordinated at times but people complain. It's causing significant issues.

Bryan: He wants the timings east of State St on 600 S to encourage slowing the speeds. Having the lights turn green as platoons arrive.

## Group #3: Northeast Quadrant and 700 E

**AM**

In the AM peak, South Temple should be time into SB left turn on State St.

In the AM peak, the 80s cycle length works well but it could be smaller.

South Temple and 100 S are used as EB/WB corridors for U of U traffic.

Many of the 700 E signals have left turn phase, we might need to omit these phase to get to a smaller cycle length.

The NB queue at 700 E and 400 S back to 500 E.

900 E is used as an alternative NB/SB corridor.

The school zone on 700 E hurts progression.

In general vehicles on 700 E were driving between 35 mph and 40 mph.

There are a couple of corridors in this group that run fixed time: 200 E – fixed, 300 E – semi-actuated, 00 E – fixed time.

There are multiple intersections on South Temple that are split phased: 500 S, 700 S, 800 S, 900 S, 1300 S.

400 E feels bigger than 300 E.

E Street can easily be tied to what the remainder of the area is doing, South Temple will likely require a full cycle because of the split phase, but, these intersections can run a short cycle, double alternate operation and function well.

200 S is a designated bus route for UTA with even further development of a bus station on the corridor.

It was not easy to maintain the 20 mph speed limit within this segment. Will want to look at possibly using 25 and in areas signed 25 consider 30 mph. That feels more like the prevailing speeds in the area.

General thoughts from the after meeting discussion – okay looking for a single cycle length to run all day if we can make it work for the state intersections. Really want to look at what the city intersections need and what we can make work there – building out the remainder of the intersections (likely starting in this quadrant of the city)

6:35 – beginning observations.

6:44 – WB 300 S is really painful, stopping a lot, going really slow. Cars are going 25 mph.

200 S is a much wider road, 2 lanes each direction and a TWLTL. The speed limit is 30 mph.

6:46 – still no really developed platoons on 200 S.

6:49 – 100 S is the corridor that warrants coordination at this time.

6:54 – South Temple is another corridor that warrants coord at this time but it's not as heavy has 100 S.

South Temple 1100 E, 900 E, 700 E, and 500 E are all offset intersections. People are going 30 mph.

7:03 – South Temple progression isn't that bad. WB there is not a lot of vehicles with me but we didn't stop much; didn't stop much EB either. At State St there are a lot of SBL heading EB on South Temple.

7:07 – platoons on 100 S west of 700 E aren't that big; 3, 4, 5 vehicles long. NB 700 E has a lot of right turners. These appear to be where a lot of the EB 100 S traffic east of 700 E is coming from.

8:14 – NB 700 E is queueing from 600 S nearly through 800 S. There are some progression issues; getting the queue moving before the platoon arrives.

8:17 – 600 S @ 700 E could turn green 20 seconds sooner to help NB progression. And the school zone is a killer. The crossing guard is pulling the cone at 8:18. Also, the end of the NB platoon gets cut off at 400 S.

*Group Discussion:*

500 S @ 700 E has a key switch for school crossings. It runs free while the key is switched on.

The split phase intersections on South Temple can still run a low cycle lengths.

The west side of 100 S is light, the east side when traffic is heaviest at 1300 E still works at a 80CL.

Talked about the need to get a whole cohesive system.

Talked about getting down to a 60CL between State St and 700 E north of 400 S.

Just tie E St in with what is at South Temple but keep the cycle length really low. Maybe half cycles.

**MD**

A smaller cycle length might work on 700 E north of 400 S.

11:32 – traffic is really light everywhere.

11:44 – 300 S speed is 25 mph; I noticed this in the morning as well.

12:07 – Traffic light enough on 700 E that signals north of 400 S could drop cycle lengths. They don't need the 108CL. Maybe the left turn can be omitted by TOD.

12:13 – 7-veh long platoon leave NB from 400 S on 700 E. SB the only place I stopped was 400 S through to 900 S.

12:18 – NB progression on 700 E is pretty good. I stopped at 600 S and then cut off at 400 S but then arrived well after that.

*Group Discussion:*

100 S leaving from 1300 E they stopped at 1100 E, need to check this.

There is a lot of stopped at State routes.

No one saw any split failures but there were a lot of peds.

700 E speed was 40 mph except for north of 400 S it drops to 35mph.

300 S speed is 25 mph.

Bryan says we should use two design speeds: one slower for city streets and one faster for UDOT routes. Take note that people will learn what speed the need to drive well.

There is a lot of wasted green time on the side street of 400 S early in the morning.

**PM**

The WB left turn onto 700 E at 100 S (I observed a split failure here) and South Temple are heavy

The SB queue at 700 E and 400 S backs to 200 S.

The SB queue at 900 S backed thru 800 S.

The NB platoon on 700 E gets stopped at 500 S and 600 S.

SB 200 E – has a sizeable platoon going out towards 400 S.

SB 300 E – feels really hard to travel the 20 mph. If you do, you are not making the lights. • NB 600 E – Multiple stops, stop at 200 S seemed long.

900 E – okay to run at 30 mph, which is what traffic is travelling.

South Temple WB right @ State St is backed through 200 E.

16:48 – NB State St is backed through 100 S.

100 S flows at about 35 mph, stopped from State St EBLT @ 500 E, stop again at 700 E. (500 E felt like a long stop, are there semi-act ped buttons @ 500 E)

Otherwise there is good flow up towards the university campus.

300 S EB @ 400 E didn't start soon enough so the arriving platoon created a shockwave back, then the tail of the group did not make it through 500 E. Stopped again at 700 E. Observed SB backing through 300 S from 400 S on 700 E.

200 S EB 200 E to 700 E has a good flow outbound.

700 E SB – found that the intersection at 900 S is going green late, creates the shockwave spilling back.

General Notes: LTs throughout the area are much more difficult during this time period than any other. The overall volume is generally higher.

Talk with the city about the creation/configuration at South Temple 700 E for the EB right turn, the current signage and or signal operations can be improved to prevent the right turn causing the #2 lane to back significantly into the through lanes.

15:50 – SB queue on 700 E from 400 S reached to 300 S and failed to clear

15:51 – South Temple @ 500 E there is a WB 20-veh queue in each lane. I also saw an 8-veh long queue EB. There is a lot of traffic on South Temple. Later I saw there was a lane blocked causing the long queues.

SB 700 E everything north of 400 S is green but 400 S is still red. Everyone is arriving a 400 s waiting and then it turns green. There isn't much side street traffic to hold it on but this the big progression issue. SB 700 S south of 400 S has good reverse progression and I don't stop until getting cut off at 900 S. The ends of platoons get cut off at most of the signals.

NB 700 E from a fresh green at 900 S I get stopped at 600 S.

16:20 – After 600 S I make it through everything until 200 S.

16:24 – There is a surprisingly large amount of NB traffic on 600 E. There was a 5-6-veh long platoon with only 2 vehicles going SB.

I've been surprised by some of the N/S progression. Other than 700 E 200 E has the most N/S traffic in this group. The SB progression on 200 E is not that good.

16:53 – SB 700 E at 400 S is failing to clear. It's still the issue of the platoon arriving too soon. After leave 400 S SB I run into a queue at 800 S. The SBL at 800 S is queueing into the #1 through lane. 900 S is also not turning green soon enough to get the queue moving before the platoon arrives. It depends on how early the NBL gaps.

17:15 – SB 200 E from a fresh green at 100 S I got through 200 S an 300 S but queuing on 400 s is reaching to 300 S and is failing to clear.

*Group Discussion:*

17:00 – SB 700 E queues from 400 S almost to 200 S. Improving SB arrivals will make a big difference. Also, 900 S needs to turn green sooner. Queues reach back to 700 S.

200 E SB was queued back to 300 S and past some times.

700 E @ South Temple – The EBR needs better signing, a right turn on red, or an overlap. It could be a free right turn. There is a Stop Here on Red that is confusing. There is a ped on the west leg that adds some complication but it can be overcome. Maybe a "right turn on red after stop" sign would be better.

Left turns are generally much harder permissively due to fewer gaps in traffic.

WBL at both South Temple and 100 S at 700 E is very heavy and queues into the through lanes.

Reducing cycle lengths where we can should be a goal.

WB on 300 S at 400 E and some others the cycle length felt really long.

900 E at 30 mph.

100 S is good at 35 mph.

We need to talk to UDOT about changed the 5-section head at North Temple 300 W out for a FYA.

## Group #4: 700 S, 800 S, 900 S & State St

**AM**

The SBT and EBR turns are heavy at North Temple with many vehicles making as SB left turn at South Temple or 100 S. The SB left turn at South Temple backs up to North Temple.

The 120CL feels long for city signals on 700 S, 800 S, and 900 S.

800 S is used as a major EB and WB corridor.

300 E, 500 E and 900 E are used as alternative NB/SB corridors.

700 S has light volumes and the TRAX line hurts the progression.

West Temple, State St and 700 E all have significant NB volume.

700 S EB 6:45 – Hit nearly every light, side streets are moderate, which is good. Long stops occurred at State St and 200 E.

800 S WB – Start at 900 E, stopped at 700 E, Moderate wait, stop again @ 500 E (short), W Temple (moderate) 200 W (no train), 300 W (hold for that N/S coordination) **This feels like a much larger E/W corridor than 700 S.

900 S EB – 300 E stopped, then progressed through 700 E. Observed that the majority of traffic does not progress through the corridor. There is a considerable road diet that occurs between 700 E and 900 E.

900 S WB – starting from 900 E, stopped at 700 E, for the duration of the PED clear, platoon is small ~ 3 vehicles., another stop at 500 E. Then progressed through State St. Short stop at Main St, progressed through W. Temple, stopped at 200 W (train) and then squeaked through 300 W. Additional road diet section from 200 W to 300 W.

800 S – EB 300 W start, stops at W Temple. Observed a very heavy NB movement at this intersection. From there stop again at 300 E, (short) and then again at 700 E (for the WBLT queue to clear) Stop again at 800 E, and then 900 E. There is definitely something wrong here between these 3 intersections. Observed that 900 E has a steady NB queue coming to the intersection.

700 S – WB 500 E start, stop @ 200 E, State St. This run is all messed up with the trains making the crossings.

800 S – WB 07:58 300 W start, stop at West Temple. (Again there is still a steady stream coming from the off- ramp) Also, there is a heavy WBLT at West Temple 800 S (access to the freeway in the AM) had short stops from there at 300 E, 700 E, and then the full stops at 800 E, and 900 E that has already been noted.

What is going on with the coordination at 800 S 800 E

General E/W thoughts – 800 S is a much larger facility and feels like the primary route E/W in this section of the city, 900 S is a close second. The AM period could benefit from dual coordination and providing 2 way progression E/W and then working with the larger N/S corridors as well. 700 S is really a different corridor – volume seems much lower volume and the train operations. This leads the corridor to feel very broken. For the most part the side streets within these roadways are light, obvious exceptions noted are 900 E, 700 E, State St, West Temple.

State St

- 8:03 – NB State St @ North Temple is a cluster. (Recommend that we watch this one from the TOC a couple of mornings, to see what interactions are occurring and see if there is any resolution that we can come up for this section of State St. Observed split failure in SBLT queues at S. Temple and 100 S.
- 8:25 – traffic is stacked between 400 S and 500 S in the NB direction. SB Progression as expected is fairly poor. There was a very sudden stop between 500 S and 600 S, having just gained speed to progress down the corridor the signal goes to RED. Once leaving 600 S, there is another stop @ 900 S. (08:28)
- 8:30 – NB 900 S likely providing an early return, this causes traffic to come to a choke pint @ 400 S. NB at 400 S is not green long enough to cleat the full NB platoon. Is this acceptable to UDOT, or should we begin to consider a larger cycle length? We will want to again use the CCTV Coverage that is available to potentially resolve the congestion between 400 S and 500 S.
- Why is 900 S 500 E in PED re-call N/S.

Notes from group discussion with Bryan: Focus on the double alternate and work with the state signals.

6:49 – So far on 900 S it doesn't warrant coordination. Definitely not a 120CL.

WB from 700 W on 900 S you stop at 500 W but it's just a hesitation. People are going about 30 mph and it is snowing pretty hard. Otherwise WB progression is working pretty well.

6:58 – EB progression on 900 S is not as good.

7:01 – Large EB platoon on 800 S. This definitely warrants coordination at this time. This EB platoon is cut of at 900 E. EB and heavier than WB on 800 S.

The cycle length can really come down on 800 S. Maybe half cycles.

Progression on 800 S is pretty good WB. WB from fresh green at State St into a fresh red at 200 W.

On 800 S WB progression is a lot better than EB. WB even arrives well at State St.

7:22 – not sure coord make sent at 200 E @ 700 S or even 500 E. If they have to be coord it should be a half cycle.

There is hardly any E/W traffic on 700 S between State and 300 W. I don't think e/w on 700 S should be coordinated. Signals should be coordinated N/S. Or prioritize N/S progression.

7:35 – E/W on 700 S is waiting a long time at 200 E from hardly any N/S traffic.

7:53 – NB State St from a fresh green at 800 S there is a stop at 400 S but it isn't too long but there is a long standing queue that it would have been nice to get moving. There are progression issues on State St NB. There was a 20 to 30-veh long queue when 400 S NB turned green. There is also a ped flasher on just north of 400 S with 20mph sign which makes is so no every one clears. Having quite a few stops NB on State St. Not long waits but the original platoon gets getting cut off.

There is a long SB queue at South Temple @ State St. It's actually from north temple.

There is enough SB Split time at North temple to clear the queue before it drops to a single lane.

A lot of the queuing issue is the SBL at 100 S.

Progression from North Temple to South Temple is not that good. North Temple turns green and South Temple is still red.

NB West Temple from a fresh green at 900 S half the platoon gets cut off at 700 S and those that make it stop at 600 S. 400 S is another stopping point.

8:31 – 900 S platoons are very small maybe 4, 5, or 6 vehicles long. 900 S 300 E E/W stopped for no one N/S.

8:33 – EB 900 S from a fresh green at 300 E into a fresh red at 500 E. 800 S is definitely the heavier E/W corridor. 800 S may need a 120CL, but I'm not confident that 900 S does. Maybe half cycles on both.

*Group Discussion:*

We need to think about the DA as a grid not a corridor.

700 S, 800 S, and 900 S really need to flow in both directions.

300 E should be a priority for N/S progression.

If we have a double alternate that works with the State signals that it works for any direction.

900 S between State and 700 E maybe doesn't need to be coord as soon. Talked about how the grid needing to go coord at the same time.

The progression from North Temple to South Temple prioritized the North Temple EBR which makes SB progression really poor. They are trying to discourage people from come SB at that intersection.

The SBL at South Temple and 100 S are having split fails. Scott thinks the only fix is adding dual left turns.

Bryan encourages us to drive every road during every time period over the summer.

**MD**

11:00 – progression on State St seems a lot better than it was in the AM. Coming SB from North Temple I arrived as lights are turning green until 600 S where I had a short stop. I also saw NB arrive at 400 S really well. No other SB stops through 900 S.

NB State from a fresh green at 900 S part of the platoon gets cut off at 600 S. Those who make it through 600 S go through 400 S at the end of green. Then I was cut off at 300 S. Green at 300 S goes into a red on 200 S. The rest of the arrivals to the north are on green through North Temple.

The SBL at South Temple is still heavy in the midday. The queue is spilling out of the pocket. It fails to clear in the protected phase.

The next SB run on State St I stopped a lot; probably 3 or 4 times north of 400 S. Also, a bunch of the platoon got cut off at 500 S.

11:21 – 900 S traffic is really light. Platoons are only 3 or 4 cars long. It should be half cycles.

300 E @ 900 S I saw that while there were ped buttons, and ped phases coming on when there were no peds. ATSPMs shows the non coord phases have ped recalls in the patterns, like a dual coordination.

12:32 – I don't think the 81 to 108 harmonic is working very well.

11:35 – I am having a lot of stops WB on 900 S: 200 E, State St, and a hesitation at 200 W.

11:38 – 800 S has heavier traffic. There is a 10-veh long WB platoon. EB from a fresh green at 300 W into a fresh red at 200 W. Then a fresh green at 200 W into a fresh red at West Temple.

West Temple is coord north/south which is how is should be. The reason I stopped at West Temple above is that is gapped out before the platoon arrived. We'll want to set offsets so the platoon arrives a little sooner if possible.

11:51 – WB on 800 S the 3/4$^{th}$ harmonic is working pretty good.

11:56 – EB on 700 S I actually had good arrivals. Maybe just lucky. Stopped at 200 E and am waiting a long time for no one. N/S is just resting in green for no one. Might be coord N/S. Checked later and it is coord N/S.

500 E @ 700 S there is more N/S traffic than E/W. Seems to be coord N/S.

12:09 – NB West Temple progression is pretty good. A hesitation stop at 600 S. Arrived on green at 500 S and 400 S.

12:15 – SB West Temple from a fresh green at 400 S I stopped at 500 S and again at 600 S.

SB from a fresh green at 600 S I made it through 700 S but stopped at 800 S.

*Group Discussion:*

For 700 S SLC is re-examining the priority preemption on 700 S in the future. Sounds like fill-in work.

The 3/4ths harmonic seems to be working okay. You stop once then arrive well after that. Shawn sometimes had double stops.

Talked about reducing the cycle lengths on 800 S and 900 S from 81CL to a 72CL. The city is considering bulb outs to reduce the ped clr times

Early in the peak the 108CL is too large on State St and West Temple. Later in the period it looked better.

200 S WB backed into State St but it looks like there was construction but we didn't check the cause.

Otherwise, we didn't see any split failures anywhere.

**PM**

The WB left turn at 800 S and 700 E is fairly heavy.

The WB left turn at 800 S and West Temple is heavy.

NB progression on State St have a stop at both 600 S and 500 S.

The NB at North Temple backs almost to 100 S; a large number of these vehicles are going thru to go up around the Capitol.

The SB thru at 400 S and State St backs up to 300 S

16:00 – State St NB – Appears that the concern with coordination at 500 S and 600 S is reversed from the AM, once I cleared from 500 S, did not stop again until I ran into the back of queue from North Temple, (this was at the intersection of S. Temple) Traffic does not seem to as heavy as the AM peak just yet.

SB run was clean until running into the choke point at 400 S. Backing from 400 S spilled to 300 S on State St.

NB run starting @ 900 S – same stops at 600 S and 500 S again. @ 16:22 the NB thru queue reaches through South Temple still.

General Thoughts - NB needs to go green sooner at North Temple, 500 S and 600 S are also needing to come on sooner. The NB backing from N. Temple extends down the hill significantly.

E/W Corridors – 800 S @ State St, experiencing some WB thru movement failure (cycle may have had additional WB traffic – Matt observed a similar concern up near Sunnyside.) At 17:02, observed split fail for the WBLT movement W. Temple @ 800 S. On 700 S, observing some good N/S volumes at the intersection with 500 E. and 200 E.

15:47 – had some stops SB on West Temple. Leaving from 400 S on green I stopped at 500 S, 400 S. Also, EB on 800 S I had some stops 200 E and 300 E. Looks like it was favoring WB progression.

15:53 – We're already seeing the heaviest traffic of the day on 800 S. Both directions are pretty heavy. 10-veh platoons both directions.

Leaving WB from 700 E I didn't stop until State St. EB from State St has the back of the platoon cut off at 200 E. A fresh green at 200 E EB goes into a fresh red at 300 E. I later had a long wait at West Temple.

16:08 – WB from 900 S you arrive a little early. A fresh green at 700 E arrives a little early at 600 E but then well at 500 E. Then a hesitation stop at 400 E. WB from a fresh green at State St into a red at Main St which was holding N/S green for no one. I might be coord N/S. Right now E/W is heavier than N/S. There are a lot of stops WB on 900 S.

16:21 – NB progression on State St is pretty good. However, I arrived at North Temple and the queue hadn't got moving yet. It would be nice if It could go green a little sooner.

NB State is failing to clear at North Temple and South Temple. There is also quite a queue WB at South Temple. However, it essentially clears.

Later the NB issue between North Temple and South Temple is gone. Must be some sort of traffic peak.

16:36 – SB State St progression stops at 200 S, 300 S, ped flashers. However, from a fresh green at 400 S I don't stop through 900 S.

16:37 – 700 S @ 500 E E/W is waiting a long time for no one. Its pretty inefficient. This should be a small cycle length.

16:44 – The WBL at West Temple is heavy on 800 S. They are accessing the freeway here. It's a 13–veh queue. We need to make sure this left turn has enough time. Existing splits didn't clear the queue in the protected phase.

16:53 – EB 800 S from a fresh green at State goes into a red at 200 E. Next you stop at 700 E just as its turning green. 800 E is green but stop at 900 E for a hesitation.

17:01 – At 200 E @ 700 S I wonder why I am waiting but then see a 10-veh long platoon. Not sure it needs a 120CL but tying it to 600 S is important.

17:06 – I feel like we can improve NB State St progression North Temple needs to turn green sooner, maybe 10 or 15 seconds. But I'm not sure what the existing strategy is. Part of the issue is the north leg of State @ North Temple is backing down into the intersection. You just can shove too much into there.

WB 200 S is backing into State St from the construction.

SB 400 S is queueing into 300 S just before 400 S turn green. The offset at 400 S should be green a little sooner. Then we arrive just as 600 S turns green; might need more of a reverse progression type strategy.

17:16 – The space between 400 S and 500 S SB gets filled in by left turners. Then the SB platoon arrives before the queue has gotten moving. Then we arrive at 600 S, and the front of the platoon gets stopped before it turns green.

17:19 – SB platoon are arriving too early at 400 S and 500 S and failing to clear. It's designed for forward progression.

*Group Discussion:*

800 S @ State St WBT fails to clear.

Flows pretty good on 800 S.

Biggest concern on State St is 500 S and 600 S.

Later around 17:30 NB back from North Temple to 100 S. Might be good to watch on camera.

Lots of stops on 700 S. 500 E and 200 E have a good amount of N/S traffic. They might work better at half cycles.

It might be good to ride the train with Devin to get a feel for how it feels to ride the train.

On 800 S the WBL is heavy at 700 E, State St, and West Temple. Thinking about harmonic or half cycle on 800 S and 900 S but would want 600 S and 500 S as well.

600 E @ 900 S we'll want to develop and fine tune coord plans but return it to free until it gets comm.

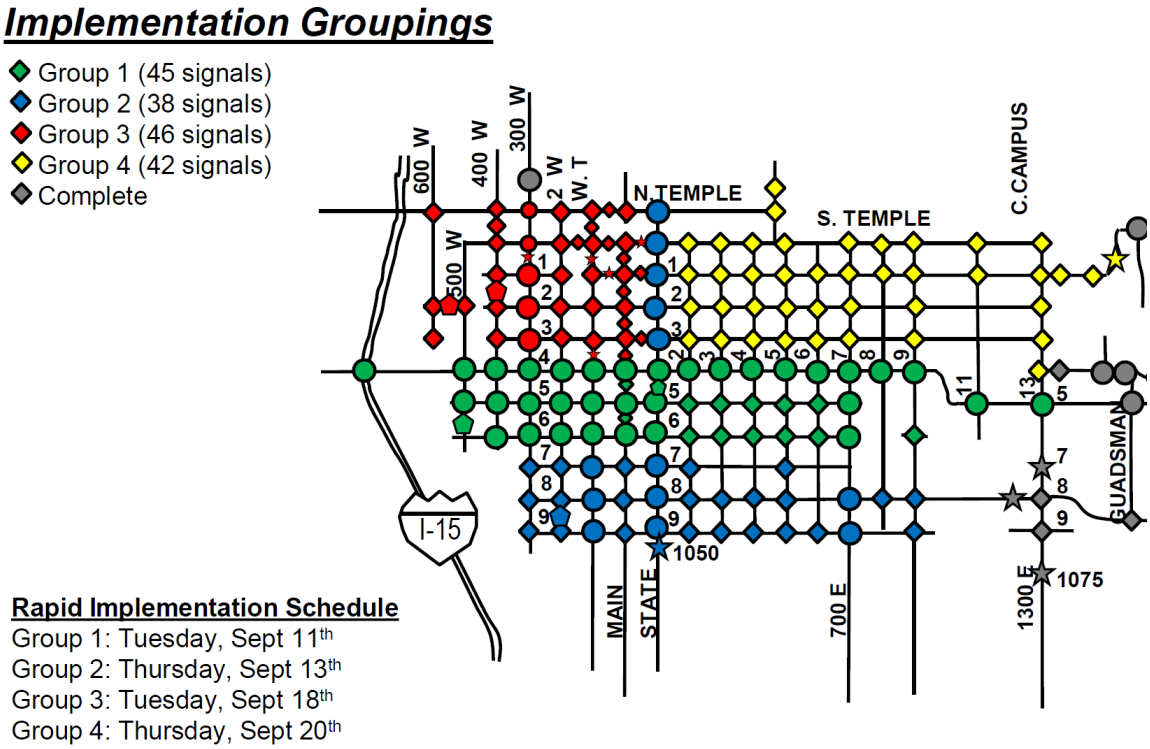
WBR at South Temple very heavy movement.

# IMPLEMENTATION

## Process

Several implementation options were discussed but we and the stakeholders decided on the following:

- All the proposed timings and day plan changes for the *entire* Downtown Area (DA) were entered on Sunday, September 9, 2018. This was done in place of entering them in groups to eliminate issues with the old timings in one area interacting poorly with the new timings in another. However, one drawback to this approach was that some portions of the DA would run the new timings un-fine-tuned for nearly two weeks. Even so, entering them all at once was the better option.
- We changed the AM to Midday (MD) transition from 9:00 to 9:30 because traffic remains heavy in the late morning.
- The new timings were placed in the permanent pattern locations (AM:1, MD:7, and PM:13) with the MD running on Saturday and Sunday. The existing patterns were moved to alternative locations to be available as a fallback (AM Pattern 1 to Pattern 2, MD Pattern 10 to stay where it was, and PM Pattern 13 to Pattern 14). We discussed making action sets to call the existing timings in their new locations, but decided that the "rubber band" manual control feature in MaxView would work without having to invest the time creating three large action sets.
- Fine tuning of the proposed timings were done by splitting up the DA into four groups (see figure below). The intent was to fine-tune the groups in rapid succession to minimize the time potential problems ran before they were addressed (see also the implementation schedule of the groups below). There were follow-up items addressed by a reduced staff on other days as well discussed further in the following section.



- Weekend day plans 1 (Sunday) and 7 (Saturday) were initially programed to run the weekday MD Pattern 7 as was done historically. These plans were fine-tuned on Saturday, September 22, 2018 and Sunday, September 23, 2018. While this worked well for Saturday traffic, unique patterns were created for Sunday running in Pattern 19 in the southwest DA. The MD 108-second cycle length (CL) was too large for the light Sunday traffic. These changes were further fine-tuned on following Sundays.

## Issues addressed

The following are the major issues observed during implementation and how they were addressed. Some of the minor offset and split adjustments are not included. They are grouped by time period below. Those affecting all times of day are under a general section. Remaining outstanding items, primarily to be completed by UDOT or SLC, are also included at the end of each section.

### General

- The East/West lead lag sequence at State St and 700 E on 400 S wasn't giving the trains enough time. The progression was reworked to make the East/West left turns leading during all times of the day.
- Main St @ 400 S runs peer to peer logic to mimic coordination. We were able to set this in the logic to work well with the coordination strategies of each coordination plan.
- Since 400 W @ 300 S couldn't run the 60CL due to long ped times it was set free during the AM and PM, the 120CL is too long. The MD and overnight coordination plans works continued to well.
- To get West Temple @ 100 S to a 60CL in the AM and PM the exclusive ped was removed and put to run with phase 4. Matthew Hyer (SLC) looked at putting in logic to turn on the exclusive ped when there were back to back ped actuations. However, he found that the larger issue is the WBL phase 4 motorists that can't proceed because they now have to yield to the pedestrians. Event plans were also made for the Salt Palace that run full cycle plans with the exclusive ped. Salt Lake City will continue to monitor the situation.
- E Street north of South Temple was checked at all times of day. The recalls on the side street were removed because these are not part of the grid and don't need to cross-coordinate. The north/south progression was working well.
- The Friday MD to PM transition time was checked to evaluate if it need to be sooner than a typical weekday (e.g. 15:00 instead of 15:30). PeMS data indicates that this may be the case. However, field observations showed that it's not different enough to warrant a unique day plan. Day plan 2 works okay on Fridays.
- Updated event patterns to work with changes we've made to the day plan patterns. Many of these call Pattern 1s or 13s at most signals with unique patterns at only a few signals. These were modeled and updated with the new timings. This consisted of the LDS Conference Center and Vivint Smart Home Arena plans.
- *Outstanding Items:*
    - Follow up after signal head/phasing changes to 100 S (Flashing Yellow Arrow (FYA) NBL and SBL) and South Temple (dual SBL by TOD & EBR overlap) on State St.
    - Evaluate PeMS data to determine the viability of placing a portable Variable Message Sign (VMS) on Victory Rd with travel times showing benefit of entering the DA via 300 W, to encourage motorists to go that way instead.
    - Look at changes at 300 W @ North Temple once the North/South FYA's are installed and alternate sequences are safe. In particular, in the PM there is a NB double stop, if not in the main platoon, at South Temple and again at North Temple. We also need to ensure

the WBR overlap is programed correctly pursue moving the Utah Transit Authority (UTA) bus stop to the west side of the intersection once the building construction is complete.

**AM**

- NB State St progression is sluggish. Looks like we can increase the offset at 600 S from 10 to 22. This will make the existing stop at 600 S longer but then the platoon will progress better through 500 S and 400 S However, the EB platoon arrives right at the beginning of green, increasing the offset will negatively affect this. Progression through 600 S, 500 S, and 400 S, is not ideal but changes will hurt East/West progression on 500 S and 400 S.
- Increased the offsets at 800 S and 900 S on State St so they arrive later at 600 S. Also changed the offset at 700 S @ State.
- 300 E and 400 E on 800 S were changed from pre-timed to actuated-coordinated along with 900 S at the same cross-streets. Allowing these to return early helped progression.
- On North Temple we are changing 200 W to a full cycle length and increasing its offset along with West Temple and the 50 W ped signal to progress the SBL 300 W movement better. We stop the EB North Temple movement at West Temple but then progress everything through with that.
- SBL at 400 S @ 300 W is spilling out of the turn pocket. Gave it 2 more seconds and next time it had all cleared but one vehicle.
- Checked the relationship on 1300 E between the 500 S 150CL and the 400 S 80CL. Determined that the other relationships with 700 E and 400 S (80CL to a 120CL) are more important and left 500 S @ 1300 E running a 150CL tying to Foothill Blvd to the east but not tying 400 S @ 1300 E.
- At about 8:30 NB at 900 S @ West Temple fails to clear, causing it to take multiple cycles to get through. Moved 9 seconds from East/West to North/South. Reduced the WBL from 24s seconds to 15. The WBL doesn't all clear on the protected phase but does permissively after that because there isn't much opposing traffic. This doesn't totally resolve the NB issue but it is the most we can do.

**MD**

- Arrival WB 500 S at State is intermittent due to the harmonic. On the "good arrival" the remaining queueing from the bad arrival is able to clear
- WB on 400 S during the hour of the lunch peak is not working well. The progression was revisited and is now working well after some significant changes. The initial progression strategy tried too hard to not have anyone stop and was cutting off the end of platoons. The new progression has planned stops but then the entire platoon progresses well after that.
- The 600 S progression east of State St wasn't as good as the other periods with multiple early arrivals or hesitation stops. The relative offsets of the AM and PM plans were put in the MD patterns.
- Adjustments to help NB West Temple progression from 900 S resulted in East/West 900 S progression problems. This was mitigated by enabling actuated coordinated with a split extension, allowing the coordinated phases to gap out, which helps the East/West progression when it can.
- The offsets were increased at 400 S and 200 S on 900 W by 10 seconds to better work with the I-15 interchange.

- There were 100 S EB hesitation stops at 400 E and 500 E. Found that removing the North/South recalls allowed EB to benefit from early returns. It is now working as good as possible.

**PM**

- We had trouble with the 800 S progression east of State St with the 60CL and wonder if the cycle length was just too small. However, Bryan Meenen revisited it another day and was able to get it working with some offset changes.
- We reduced offsets on North Temple from State St to 200 W by 5 seconds to improve progression.
- We took another look at 300 W North/South progression using lead-lag at 400 S which worked much better.
- We tested reverse progression plans on 500 S from Main St to 500 W. These plans focused on getting the queue moving before the upstream platoon arrives. While it results in more stops, it shortened the length of the overall queue and uses the green time more efficiently. We later narrowed the time the reverse progression is running from 16:45 to 17:45 to 16:50 to 17:40. We reduced the number of signals using reverse progression to just at 400 W and 500 W. This preserves North/South progression on West Temple 300 W.
- We also tested a slight reverse progression plan on 700 E at 800 S and 900 S which was the regular PM plans with the offsets reduced by 15 seconds. This didn't remove the problem but helps reduce its duration and severity. This was needed from 17:00 and 18:00.
- At 700 E @ South Temple the WBL was failing to clear. We moved 5 seconds from phase 2 to phase 1. Checked ATSPMs to see if phases 3 or 4 had extra time to give. Found that phase 4 forces off more than phase 1 even though it gets extra time from phase 3 when it gaps. Phase 1 also gets more time when Ø4 gaps. Decided to leave the splits as they were.
- Removed the North/South recalls at 200 S @ 400 E and 300 E and improve progression by benefiting from early returns.

**Overnight**

- Added max recall on the East/West phases at 300 S @ 500 E for cross-coordination.
- Adjusted the offset at South Temple @ 500 E offset which improved the progression.
- At 200 S @ State St we added East/West max recalls for cross-coordination. It was gapping out before the platoon arrived.
- We removed North/South recalls 800 S @ 400 E for better progression, benefiting from early returns.

**Saturday**

- At 500 S @ 300 W we reduced the offset by 6 seconds to remove a WB hesitation stop. Leading the NBL with the same offset change helps North/South progression. We later found that this change also works well in the weekday MD as well.
- A weekend 108CL coordination plan was added at 400 W @ North Temple on Saturday and Sunday when there are fewer trains. Coordination here on weekdays is not feasible due to frequent trains.

**Sunday**

- Offset changes on North Temple at 200 W and Main St removed a long EB stop at Main St.
- Found the 108CL to be generally too large. We need more 72CLs on Sunday. These were installed and fine-tuned on 500 S and 600 S and State St south of 400 S in Pattern 19. There are

still a large number of peds on Sunday which prevented us from testing 72CL plans on North Temple, 400 S, 700 E , and State St north of 500 S. These continue to run the MD 108CL.

- We initially had trouble with the Train Signal Priority (TSP) signals at Main St on 500 S and 600 S and at 700 S @ West Temple but were able to get these to work at the 72CL and still provide train priority by turning off the left turn re-service logic and lagging the associated left turns.