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16. Abstract

In Texas Department of Transportation (TxDOT) Project 0-5507, Texas Transportation Institute (TTI) researchers developed and field-tested an enhanced version of a platoon identification and accommodation (PIA) system developed in an earlier research project. A key feature of the PIA-2 system developed in Project 0-5507 was its ability to detect and progress platoons in both arterial directions. The objective of this implementation project was to install the PIA-2 system at two additional locations in Texas. This report documents the work performed in this implementation project.

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PLATOON IDENTIFICATION AND ACCOMMODATION SYSTEM IMPLEMENTATION IN BROWNWOOD AND CALDWELL, TEXAS

by

Nadeem A. Chaudhary, Ph.D., P.E.
Senior Research Engineer
Texas Transportation Institute

Hassan A. Charara
Research Scientist
Texas Transportation Institute

Ryan R. Longmire
Assistant Research Specialist
Texas Transportation Institute

and

Jeremy Johnson
Associate Research Specialist
Texas Transportation Institute

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

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INTRODUCTION

In TxDOT Project 0-5507, TTI researchers enhanced the platoon identification and accommodation (PIA) system developed in TxDOT Project 0-4304. These enhancements included:

- the ability to provide platoon detection and progression in both arterial directions,
- an expansion of real-time controller and detection monitoring capability,
- the ability to adapt to changing traffic conditions on minor phases, and
- a refined controller override functionality using phase hold inputs.

In Project 0-5507, researchers also installed and tested the enhanced PIA-2 system at two locations. The objective of this implementation project was to install the PIA-2 system at two additional locations in Texas. This report documents work performed under this contract.

PREPARATIONS FOR PIA SYSTEM INSTALLATION

Site Selection

One key consideration was the ability and willingness of district staff to provide support. After consulting with several TxDOT districts, researchers selected the Brownwood and Bryan Districts for PIA-2 implementation. Researchers travelled to Brownwood on June 3, 2008. After observing several locations there, they selected an intersection located a few miles south of downtown Brownwood as the first implementation site. The second site is located in Caldwell and was one of three candidate sites in Project 0-5507. The following subsections describe the two sites.

Brownwood Site

This site, a T-intersection, is located at the intersection of US 377 and Coggin Avenue, less than 2.5 miles south of downtown in Brownwood, Texas. US 377 is a major north-south route that connects to US 84 in the heart of Brownwood. As a result, it experiences unpredictable traffic demand, including significant truck traffic. In addition, local traffic generators creating demand at this site include:

- small businesses along US 377,
- a rock quarry on the west side,
- a private university located less than one mile on the north side, and
- commercial establishments, a hospital, and a 3M industrial plant on the south side within two miles of the site.

Furthermore, a signalized intersection located about 2000 ft to the south of Coggin Avenue is a source of significant vehicular platoons in the northbound direction. Even though the nearest signalized intersection on the north side is about two miles away, significant southbound platoons form naturally due to vehicular interactions. There is a railway track between the two intersections. It is located about a quarter mile south of Coggin Avenue but has insignificant train traffic. The speed limit in both arterial directions is 50 mph.

Beginnings and ends of different work shifts at the hospital and the 3M plant generate short bursts of traffic demand at the selected site. Coggin Avenue primarily serves as a backdoor route for local traffic to and from facilities on the south side. Even though southbound traffic demand from Coggin Avenue is light most of the time, there is a constant trickle of traffic throughout the day, frequently disrupting flow of platoons. These characteristics, combined with out-of-town traffic, make this site an ideal location for the implementation of the PIA system.

Figure 1 shows a sketch of this site and identifies the four signal phases being used for intersection control. This intersection uses video cameras for stopbar detection and setback detection on the two main approaches. Traffic control is provided using a Naztec Version 50 traffic controller along with a Naztec cabinet meeting Brownwood specifications. There is negligible left- and right-turn traffic to and from Coggin Avenue. Phases (Φ) 1 and Φ3, respectively, serve these movements.

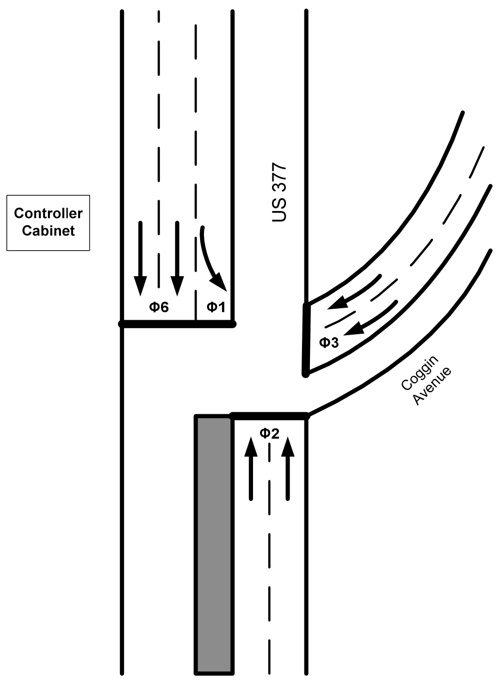

Figure 1. Layout of Brownwood Site.

Caldwell Site

This site is located at the intersection of SH 21 and one of the two access roads to Caldwell High School. This is the first signalized intersection on the east side of Caldwell. A major signalized intersection (SH 21 and SH 36) is located approximately 4000 ft to the west. The speed limit is 55 mph in both directions. This site experiences demand from three sources of traffic, described below:

1. significant unpredictable out-of-town traffic demand (including trucks) exists on this major east-west highway throughout the day,
2. morning and evening peak traffic generated by people living in the area and employed by The Texas A&M University System located approximately 30 miles to the northeast, and
3. local traffic, which includes school-related traffic.

Figure 2 provides a layout of this site. Traffic control is provided with a Naztec controller using five phases. Here, Φ1 provides protected right of way to U-turn traffic. During a normal school year, Φ1, Φ3, and Φ5 cause significant disruption to platooned flow on the major approaches. Unpredictability of demand at these phases makes it infeasible to provide time-of-day coordination with the adjacent traffic signal at the intersection of SH 21 and SH 36. Thus, this site is well suited for a PIA system.

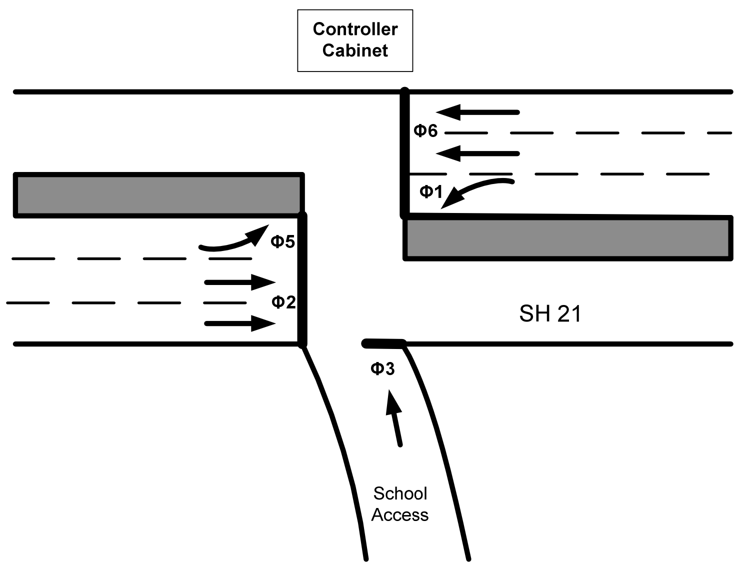

Figure 2. Layout of Caldwell Site.

Software Modifications

For each priority approach, the PIA system requires accurate detection of individual vehicles and their speeds approximately 1000 ft upstream of the intersection stopbar. All previous implementations of the PIA system used either inductive loops or video-based sensors for this purpose. In the case of inductive loops, a pair of loops (called a speed trap) is required in each approach lane to provide data needed to calculate vehicles' speeds. Video detection emulates a speed trap by using either a pair of adjacent detection zones or a single detection zone. These detection systems communicate detections to the controller cabinet via contact-closure signals.

Inductive loop detectors (ILDs) work well, but most TxDOT districts have now switched to video-based systems because they can be installed and maintained without disrupting traffic flow. Video detection is acceptable for stopbar detection, which constitutes a majority of intersection applications. However, these systems do not have the accuracy or reliability needed by the PIA system for advance detection. An alternate detection technology providing the benefits of both ILDs and video detection was desired.

Based on recent experience in other research projects, TTI researchers selected the Wavetronix SmartSensor HD Sidefire radar sensor for use in this project. This sensor uses dual radar beams to create a speed trap. As such, it provides accurate vehicle detections and speed measurements across multiple lanes. As in the case of video cameras, this sensor can be installed using a bucket truck, without any lane closures in most cases. In addition, it is much easier to configure than video detection. As opposed to ILDs and video detection, this specific sensor transmits detection data to other applications via messages. Thus, the use of this technology required minor modifications to the PIA software to allow receipt and interpretation of messages from these sensors. Therefore, TTI researchers made appropriate modifications to the vehicle detection and classification routine. This change also required a minor modification to one of the screens used to specify configuration data. Taking advantage of this opportunity, TTI researchers also made minor refinements to the platoon progression routine in the PIA software. In the process, researchers also restructured some of the program code.

Site Assessment and Preparation

At the Brownwood site, right-of-way restrictions by the utility company made the planned erection of new poles infeasible. These poles were needed for installing advance detection approximately 1000 ft upstream on both arterial approaches. The only other alternative was to use the existing utility poles. District staff requested and received permission from the utility company to use its existing wooden poles as long as installation of TTI equipment was achieved in a manner that did not cause any damage to these poles. All these poles are located on the east side of US 377. However, this restriction did not pose any problems because the radar-based sensor selected for this project is capable of handling wide roadways.

In Caldwell, there was no right-of-way restriction. However, a large tree located on the near side (north of roadway) in the westbound direction created an obstruction for wireless communication from the desired location of the pole to the cabinet. Again, this issue was resolved by installing both new poles on the south side of the roadway.

Equipment Purchase Plan

The contract provided sufficient budget for purchasing and installing the following equipment at each site:

- two 20-ft aluminum breakaway poles with screw-in anchors;
- two sensors, complete with associated electronics and cables;
- a pair of solar panels (including installation brackets and solar charge controllers);
- six backup batteries (three for each approach);
- three wireless radios for providing communication between the cabinet and advance sensors;
- two pole-mount cabinets to house batteries, radios, and other electronics;

- five timer relays; and
- an industrial personal computer (PC) for running the PIA system and digital input/output (I/O) card for communicating with the cabinet.

Because TTI does not have a facility to store large/heavy items (i.e., poles, cabinets, and batteries), researchers planned to order the equipment as needed and have it delivered directly to the appropriate TxDOT district. Thus, site selection and assessment dictated when the equipment could be ordered. Given that the proposed project start date of March 2008 provided only six months to get the first fiscal year (FY) work done, researchers had planned to purchase the equipment for the first implementation site from the FY 2008 budget and for the second implementation site from the FY 2009 budget.

PIA SYSTEM INSTALLATION AND CONFIGURATION

Brownwood Site

Researchers ordered sensors, wireless radios, pole-mount cabinets, solar panels, and batteries by the end of July 2008, with instructions to the vendor to deliver these items directly to the Brownwood District. Researchers ordered the PC, digital I/O card, and timer relays separately for delivery to TTI facilities.

The delivery date supplied by the vendor made it clear that the researchers would not be able to start the equipment installation process before the end of August 2008. Therefore, they asked the vendor to delay delivery until the district staff was ready to receive the items. The delay in the initiation of work, combined with the savings in equipment cost (mainly poles), made available a significant portion of FY 2008 funds that could not be spent during FY 2008. Furthermore, the shift of labor to the following year meant that more funds for labor hours and travel would be required during FY 2009. The easiest way to manage this shift was to use the slack funds in the FY 2008 budget to purchase a portion of equipment for the second site. This would free up a portion of the FY 2009 equipment budget for reallocation to cover the needed labor and travel expenses. Thus, the researchers purchased an extra pair of Wavetronics Smart Sensors and had these delivered to TTI for storage until they were needed at the second implementation site.

With the assistance of equipment vendor and TxDOT staff, TTI researchers installed the equipment in Brownwood on October 21, 2008. Figure 3 illustrates solar panel installation in progress, installed cabinet with batteries and electronics, and installed sensor and antenna on one approach. Installation at the other approach was similar.

During this trip, TTI researchers conducted the following additional tasks:

- installed a computer in the traffic signal cabinet and connected it to receive phase and detector status; these inputs are used by the PIA system in its operation;
- installed the master radio and an antenna; and
- configured the sensors, and tested communications link between the master radio and the two sensors.

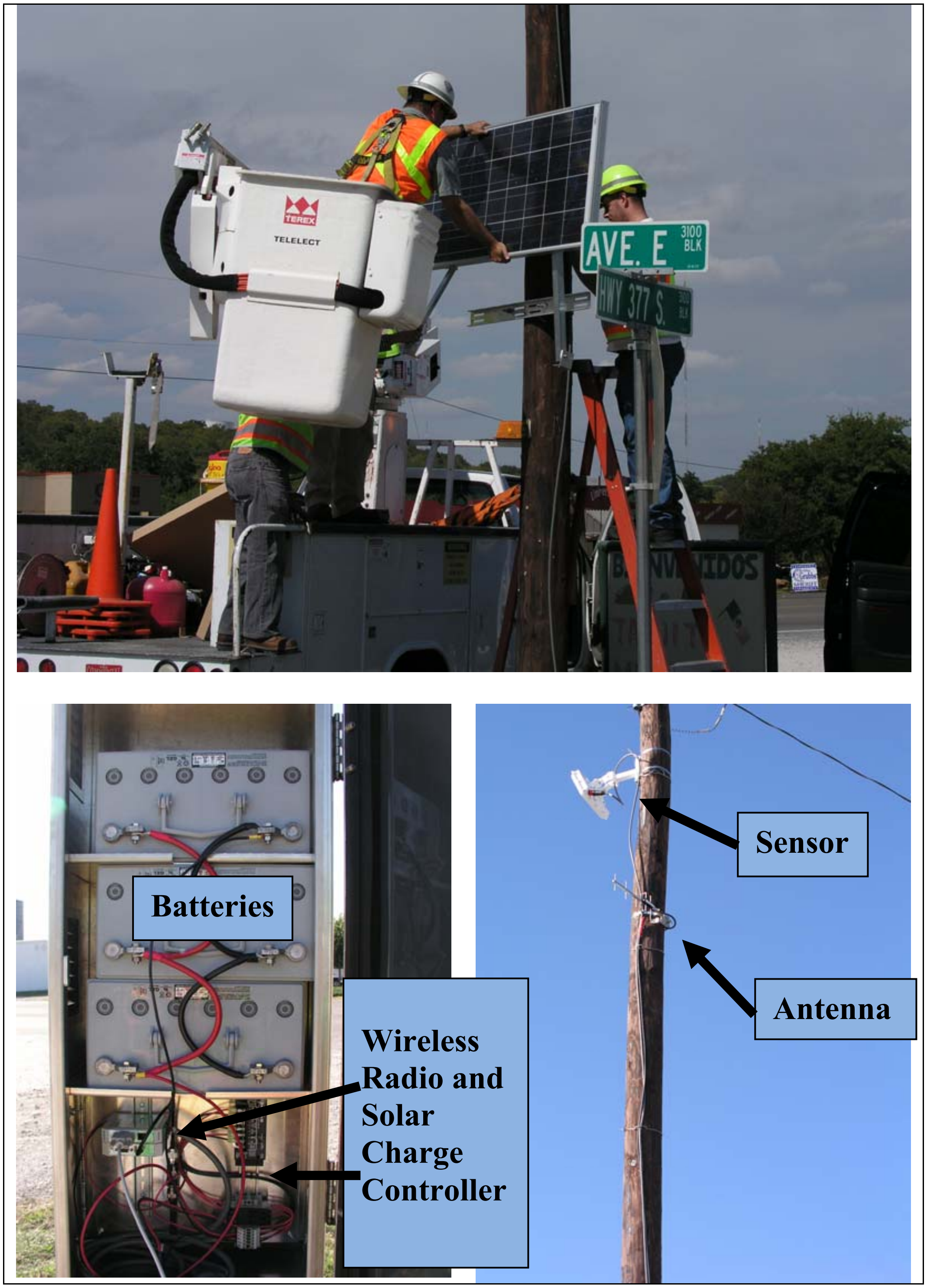

Figure 3. Installation of Equipment at the Brownwood Site.

TTI researchers made several subsequent trips to deal with two unexpected issues that had to be resolved to complete the installations. During these visits, researchers installed a wireless router to remotely monitor the PIA system operation and an additional device to remotely restart the PC when needed. These two main problems and how they were resolved are described next:

1. Researchers discovered that an electrical problem was causing the radio in one of the pole-mount cabinets to burn. It took two trips and several destroyed radios before discovery of the problem, which was caused by the cabinet latch touching one of the battery terminals. However, because the vendor took the lead in installing the batteries, these radios were replaced by the vendor at no cost. While researchers were investigating the source of problem, they ordered and installed another brand of radios they had experience with. Researchers took this step to rule out any design problems with the brand of radios originally ordered.
2. The Brownwood District uses a custom controller cabinet manufactured by Naztec, Inc. By default, this cabinet is wired to provide preempt inputs, but no access to phase holds, via the back panel. PIA systems can use both these inputs. However, if only one type is available, researchers prefer to have access to phase holds. After several tries, researchers had to contact the vendor for help. The vendor informed the researchers that this cabinet can be configured to provide either phase holds or preempts, but not both, via the back panel. Furthermore, phase holds can be accessed only through the back panel, and changing the configuration to provide this capability:
    a. requires that any needed preempts be accessed through the D-connector, and
    b. limits the number of detector inputs to the first eight detectors.

    The first constraint is insignificant. The second one is more limiting. The number of channels being used at this site required detectors 1 through 10. To get around this constraint, researchers had to disable stopbar detection for Φ2. This required some minor changes to the setting for setback detector feeding to this phase.

The final step was to connect outputs from the PC to the cabinet/controller via timer relays. Researchers turned on the PIA system at this site on July 24, 2009. After observing the system, researchers determined that using preempt is not beneficial at this site because of low traffic demand on Φ3. Therefore, researchers configured the PIA software to use only phase holds to progress detected platoons. Researchers made some additional adjustments to PIA parameters and left the system running. Figure 4 shows a view of the controller cabinet with the PC and the wireless radio installed in it.

Caldwell Site

Signal shop staff from TxDOT's Bryan District installed the poles and other equipment at this site during the week of July 6, 2009.

On July 20, 2009, a severe thunderstorm (with some reports of a localized tornado) in Caldwell somehow unscrewed and knocked down one of the two poles. This incident damaged the threads on the pole, broke the antenna, shattered the solar panel, twisted the brackets holding the solar panel, and unfastened the sensor and hurled it into a ditch full of water. Researchers sent the sensor to the manufacturer for possible repairs. In the meantime, the district staff fixed the pole and installed it again along with a solar panel supplied by the Bryan District. To avoid any delays in turning on the system, they also installed another antenna and a smart sensor that TTI staff had available from another project. Figure 5 shows the reinstalled equipment at this location.

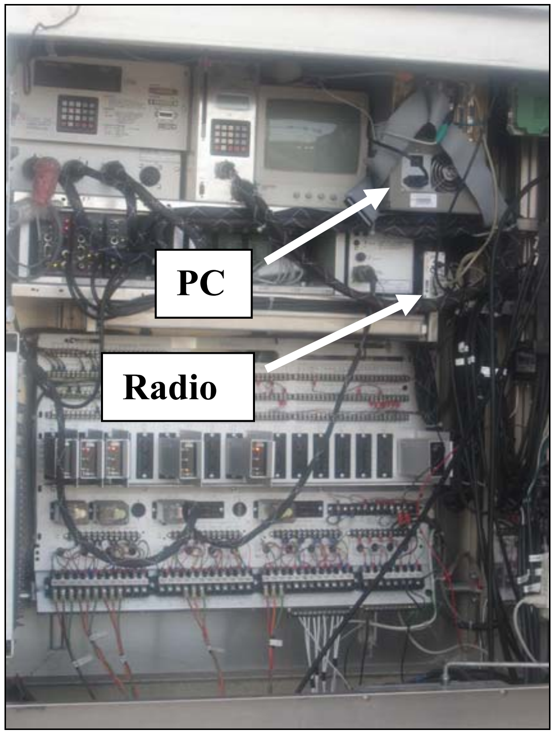

Figure 4. A View of Brownwood Cabinet.

Figure 5. Reinstalled Equipment at the Caldwell Site.

Luckily, the manufacturer was able to repair the damaged sensor for less than one sixth of the cost ($500) for a new one. TTI has received the repaired sensor, which will be swapped with the loaner unit as soon as possible.

TTI researchers installed and wired the remaining equipment (PC, radio, and wiring panel) in the signal controller cabinet on August 20, 2009. Figure 6 shows installed equipment in this cabinet.

Figure 6. Equipment Installed in Caldwell Controller Cabinet.

Final checking of the system components that day revealed that there was a lack of communications in the outbound (to Bryan) direction due to a failed solar charge controller (SCC). TTI researchers decided to go ahead and turn on the system, even though the PIA system was receiving data from only one advance sensor (westbound direction). The researchers watched the operation for a few hours, tweaked PIA parameters, and left the system running. Upon returning, researchers ordered a replacement SCC.

Researchers made another trip to the site on August 24, 2009, to observe the system operation. This was the first day of the new school year. Researchers made some changes to timings in the traffic controller to improve operation of Φ3, which experienced heavy car and bus demand when the school let out.

Researchers received the replacement SCC on the afternoon of August 24, 2009. On the afternoon of August 25, 2009, researchers installed the new part to restore communication between the cabinet and the advance sensor in the outbound direction. They also observed the PIA system operation for a few hours to ensure that it was operating as desired.

BEFORE AND AFTER EVALUATIONS

As reported above, researchers were not able to make the Caldwell system fully operational until August 25, 2009. Six remaining days until project termination did not permit before data collection. However, researchers had sufficient time to collect before and after data at the Brownwood site using the computer installed in the cabinet.

For this report, researchers used data for weeks of July 13, 2009, and November 16, 2009, for before and after comparisons. Figure 7 and Figure 8 show daily counts for the major through phases at this site for two representative days (July 15 and November 18). Note that the basic trends for before and after conditions are similar, with minor variations in the 15-minute counts. Researchers selected 12:00 noon to 5:00 p.m. time slot for further comparisons.

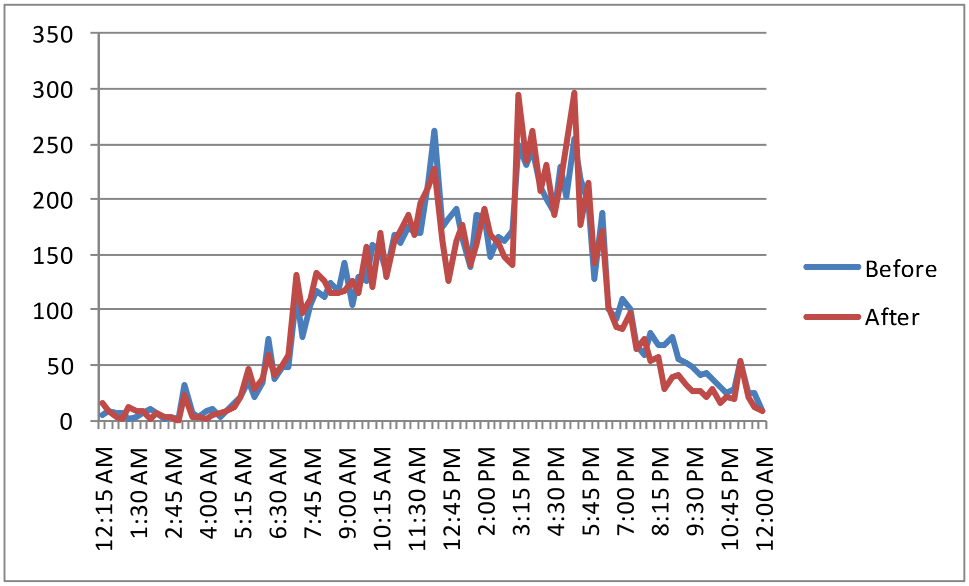

Figure 7. Twenty-Four Hour 15-Minute Counts for Phase 2.

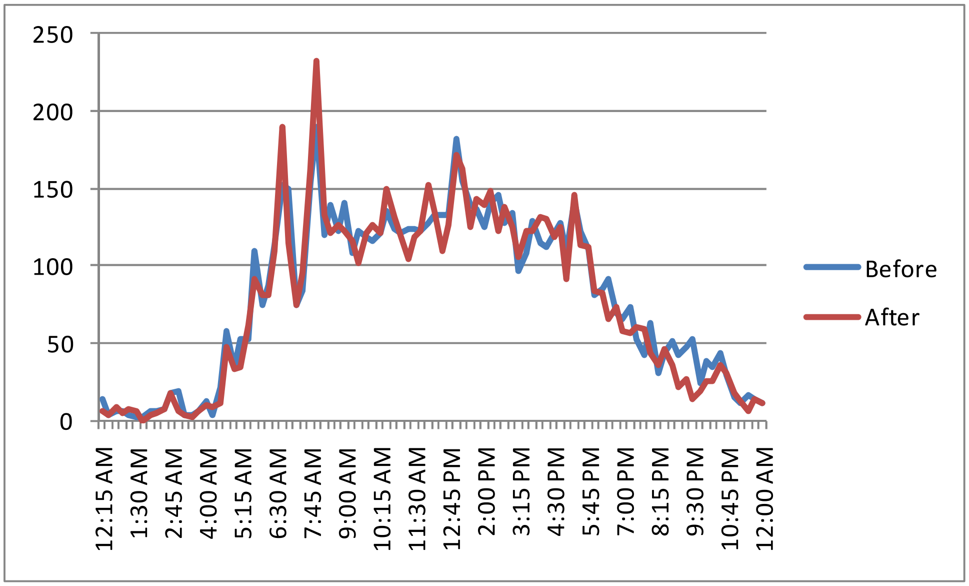

Figure 8. Twenty-Four Hour 15-Minute Counts for Phase 6.

Approximately 50 percent of the total progressed platoons occurred during the selected 5-hour period. Table 1 provides platoon statistics for Phases 2 and 6 during this period for the before and after weekdays. As can be seen in this table, both directions had significant progressed platoons. For phase 2, the smaller platoons required 8–11 seconds to progress, and the largest platoons required 58 to 62 seconds, with an average of about 20 seconds. For Phase 6, the range of platoon lengths (in seconds) was slightly wider from 7 to 69 seconds. Given that the max times for these phases were equal to 30 second each, platoon lengths in the neighborhood of 60 seconds show that in some cases the system extended the green significantly to progress detected platoons. For Phase 2, also note that the average platoon length was larger than Phase 6 during this time.

Table 1. Platoon Statistics for Phases 2 and 6.

	Monday	Tuesday	Wednesday	Thursday	Friday
Phase 2					
Platoons progressed	264	279	246	287	278
Average Platoon Length (seconds)	21	20	20	22	20
Minimum Platoon Length (seconds)	11	9	11	8	10
Maximum Platoon Length (seconds)	59	58	61	58	62
Phase 6					
Platoons progressed	245	242	233	260	270
Average Platoon Length (seconds)	16	15	15	15	15
Minimum Platoon Length (seconds)	7	9	9	8	9
Maximum Platoon Length (seconds)	68	61	55	50	69

From Tables 2 through 4, notice that the number of phase terminations (proxies for number of cycles) reduced. These data are consistent with the fact that extension of through greens to progressing platoons increases the cycle length, resulting in fewer cycle in the same time period.

Table 2. Phase 2 Terminations.

	Monday	Tuesday	Wednesday	Thursday	Friday
Before	257	251	242	227	226
After	220	215	226	214	218
Change (%)	-14%	-14%	-7%	-6%	-4%

Table 3. Phase 6 Terminations.

	Monday	Tuesday	Wednesday	Thursday	Friday
Before	252	248	240	225	210
After	217	210	225	211	216
Change (%)	-14%	-15%	-6%	-6%	3%

Table 4. Phase 3 Terminations.

	Monday	Tuesday	Wednesday	Thursday	Friday
Before	252	248	240	224	210
After	215	210	224	212	213
Change (%)	-15%	-15%	-7%	-5%	1%

Also consistent with this observation is the fact that the average green lengths for the two main street phases increase (see Tables 5 and 6).

Table 5. Phase 2 Average Green per Cycle.

	Monday	Tuesday	Wednesday	Thursday	Friday
Before	45	47	49	54	49
After	57	58	55	58	58
Change (%)	27%	23%	12%	7%	18%

Table 6. Phase 6 Average Green per Cycle.

	Monday	Tuesday	Wednesday	Thursday	Friday
Before	47	48	50	55	50
After	47	48	50	55	50
Change (%)	26%	27%	12%	9%	20%

However, except a minor difference on one of the five days, researchers did not see any change in the average lengths of greens for cross street Phase 3. These data confirmed field observations showing that there were a significant number of cycles with only one or two vehicles, clearing the approach before minimum time of 5 seconds elapsed. Therefore, reductions in number of cycles did not adversely affect this phase. Southbound left-turn phase experienced occasional demand. As a result, a significant size sample did not exist to allow any meaningful comparison of before and after data.