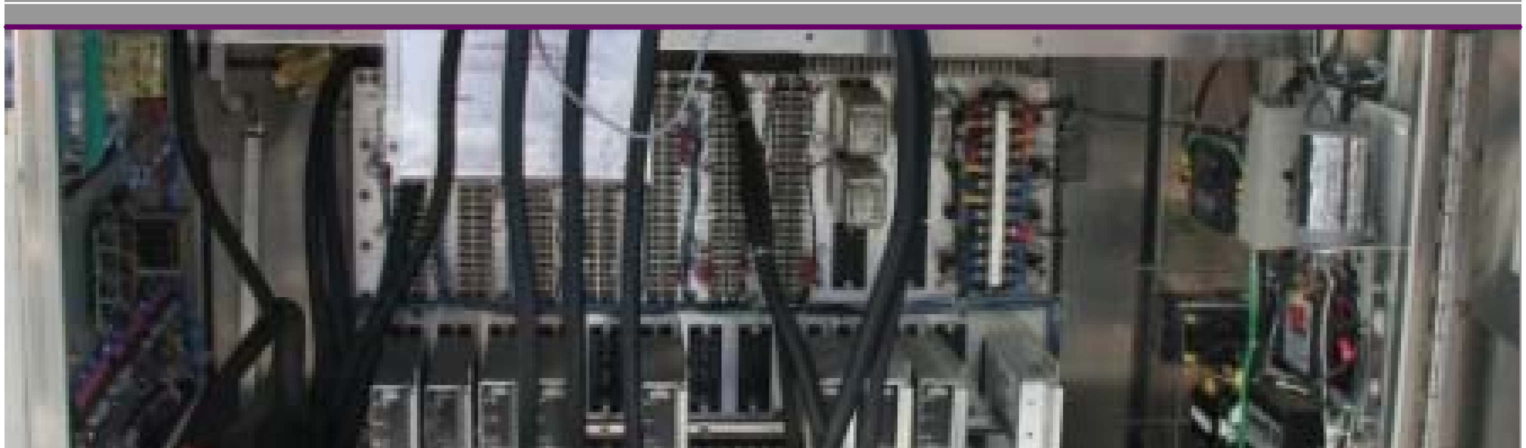
Development of Intersection Performance Measures for Timing Plan Maintenance Using an Actuated Controller: Phase 1

Final Report 663
November 2012



Arizona Department of Transportation
Research Center

Development of Intersection Performance Measures for Timing Plan Maintenance Using an Actuated Controller: Phase 1

Final Report 663
November 2012

Prepared by:
AZ*Trans*: The Arizona Laboratory for Applied Transportation Research
Northern Arizona University
Department of Civil and Environmental Engineering
Flagstaff, Arizona 86004-5600

Prepared for:
Arizona Department of Transportation
206 South 17th Avenue
Phoenix, Arizona 85007
In cooperation with
U.S. Department of Transportation
Federal Highway Administration

This report was funded in part through grants from the Federal Highway Administration, U.S. Department of Transportation. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data, and for the use or adaptation of previously published material, presented herein. The contents do not necessarily reflect the official views or policies of the Arizona Department of Transportation or the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, or regulation. Trade or manufacturers' names that may appear herein are cited only because they are considered essential to the objectives of the report. The U.S. government and the State of Arizona do not endorse products or manufacturers.

.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-AZ-09-663		

4. Title and Subtitle

Development of Intersection Performance Measures for Timing Plan Maintenance Using an Actuated Controller: Phase 1

5. Report Date

November 2012

6. Performing Organization Code

7. Author

Edward J. Smaglik, Craig A. Roberts

8. Performing Organization Report No.

9. Performing Organization Name and Address

AZTrans: The Arizona Laboratory for Applied Transportation Research
Northern Arizona University
Department of Civil and Environmental Engineering
Flagstaff, AZ 86004-5600

10. Work Unit No.

11. Contract or Grant No.

SPR-PL1 (173) 663

12. Sponsoring Agency Name and Address

Research Center
Arizona Department of Transportation
206 S. 17th Ave. MD075R
Phoenix, AZ 85007

13.Type of Report & Period Covered

Final Report

14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Federal Highway Administration.

16. Abstract

This proof-of-concept study is to develop an automated data collection module for collection and management of traffic data at signalized intersections controlled by the Arizona Department of Transportation (ADOT). The objective of this proof-of-concept phase of the work was to determine the feasibility and cost of modifying an existing ADOT traffic control cabinet to collect operational data using the video equipment installed for presence detection to capture vehicle flow rate information. The goal was to use this data to develop event-based performance measures, leveraging existing infrastructure to its fullest extent.

An intersection in Flagstaff, Arizona, was chosen as the test location. Researchers used the intersection's existing video detection cameras, installing additional video detector interface cards to produce contact-closure vehicle flow rate information. Researchers calculated performance measures (volume-to-capacity [V/C] ratio, equivalent hourly volume [EHV], and cumulative counts) from the video-generated data and compared them with measures generated from concurrent manually counted data over a 24-hour analysis period. The V/C values generated from the video data were shown to be statistically different than those calculated with manual-count data; however, on all but one phase, the difference was not operationally significant. An analysis of cumulative count data did show operationally significant differences.

While the data had some inaccuracies, the proof of concept was successful in that the research team was able to generate traffic volume performance measures using existing video detection equipment. During the next phase of the project, the data inaccuracies can be investigated and possibly addressed with measures such as camera placement, choice of technology, etc.

A cost analysis determined that the cost of equipping a similar intersection for this type of vehicle count capability is approximately $16,700 using the equipment specified for this project if the installation is performed as part of the initial construction or rehabilitation of the intersection. The researchers recommend that Phase 2 of this project be undertaken. Ultimately, assuming successful completion of all phased milestones, the investigators recommend that ADOT consider equipping future intersections as described in this report to improve the quality of future signal-timing plans while reducing costs over the long term.

17. Key Words	18. Distribution Statement	23. Registrant's Seal
Traffic actuated controllers, traffic signal controllers, traffic signal timing, traffic signal control systems, traffic signal phases, traffic signal cycle, traffic signals, video imaging detectors, intelligent transportation systems.	This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.	

19. Security Classification	20. Security Classification	21. No. of Pages	22. Price
Unclassified	Unclassified	54	

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This proof-of-concept study is to develop an automated data collection module for collection and management of traffic data at signalized intersections controlled by the Arizona Department of Transportation (ADOT). The objective of this proof-of-concept phase of the work was to determine the feasibility and cost of modifying an existing ADOT traffic control cabinet to collect operational data using the video equipment installed for presence detection to capture vehicle flow rate information. The goal was to use this data to develop event-based performance measures, leveraging existing infrastructure to its fullest extent. The work was phased to document a successful outcome for each milestone before proceeding with the next one.

An intersection in Flagstaff, Arizona, was chosen as the test location. Researchers used the intersection's existing video detection cameras, installing additional video detector interface cards to produce contact-closure vehicle flow rate information. These individual vehicle counts were communicated via a TS2 data bus to an event-based data logger embedded within the traffic controller.

Researchers calculated performance measures (volume-to-capacity [V/C] ratio, equivalent hourly volume [EHV], and cumulative counts) from the video-generated data and compared them with measures generated from concurrent manually counted data over a 24-hour analysis period. The V/C values generated from the video data were shown to be statistically different than those calculated with manual-count data; however, on all but one phase, the difference was not operationally significant. An analysis of cumulative count data did show operationally significant differences.

While the data had some inaccuracies, the proof of concept was successful in that the research team was able to generate traffic volume performance measures using existing video detection equipment. During the next phase of the project, the data inaccuracies can be investigated and possibly addressed with measures such as camera placement, choice of technology, etc.

A cost analysis determined that the cost of equipping a similar intersection for this type of vehicle count capability is approximately $16,700 using the equipment specified for this project if the installation is performed as part of the initial construction or rehabilitation of the intersection. Ultimately, assuming successful completion of all phased milestones, the investigators recommend that ADOT consider equipping future intersections as described in this report to improve the quality of future signal-timing plans while reducing costs over the long term.

CHAPTER 1. INTRODUCTION

BACKGROUND

Limited resources are available for maintenance of traffic signal timing plans. As such, it is important to ensure that resources are allocated to those signals and corridors in need of retiming. The *Highway Capacity Manual* (Transportation Research Board [TRB] 2000) provides methodologies that departments of transportation (DOTs) can use to develop quantitative measures of signal timing performance, such as arrival type, V/C ratio, and delay, which can aid engineers in identifying intersections where improvements are needed. However, generating these measures through traditional methods requires labor-intensive data collection and analysis (turning movement counts, travel time studies), and it may be challenging to collect the data needed to gauge signal performance during times outside the typical workday (such as for special events, Saturday at the mall, etc.). Because of these issues, it would be valuable to have an *automated* method for tabulating data at signalized intersections.

Current traffic signal controllers have the ability to collect data, but they bin that data in 5-, 15-, or 60-minute intervals. Research has shown that because phase split, green interval, and, in some cases, cycle length may change from cycle to cycle, binning data in these intervals does not allow the data to be tabulated on a cycle-by-cycle basis, which results in a loss of fidelity as measures of effectiveness (MOEs) are averaged over a time period (Abbas et al. 2001). For example, the average percentage of vehicles arriving on green in Figure 1 is 53 percent; however, this overlooks the fact that values across the three cycles ranged from 20 to 80 percent (a black dot represents an arriving vehicle). Using data averaged across multiple cycles limits the traffic flow efficiencies that can be achieved through a signal retiming (Smaglik, Sharma, et al. 2007).

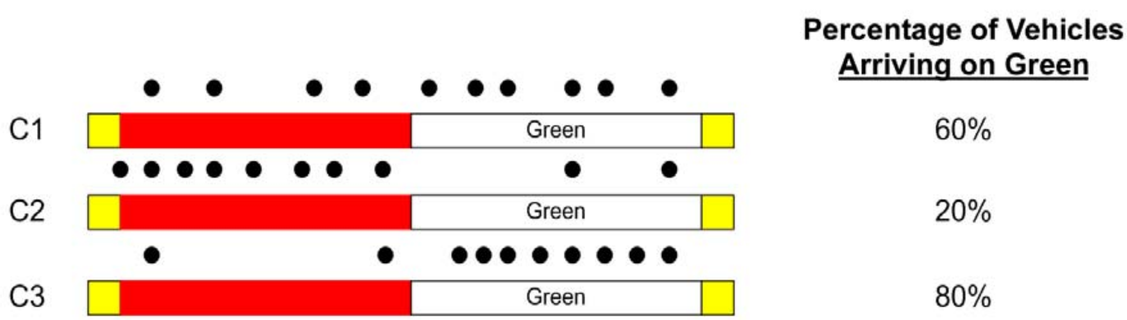


Figure 1. Sample Data for Percentage of Vehicles Arriving on Green.

Recent research has resulted in the development of an event-based data collection module integrated within a traffic controller (the Econolite ASC/3), and research has shown that meaningful MOEs (such as V/C ratio, arrival type, delay, and EHV) can be developed from phase on/off times and vehicle flow rate information (provided by inductive loop count detectors) recorded by the module (Smaglik, Sharma, et al. 2007). A sample 24-hour plot of V/C ratios developed from this data is shown in Figure 2.

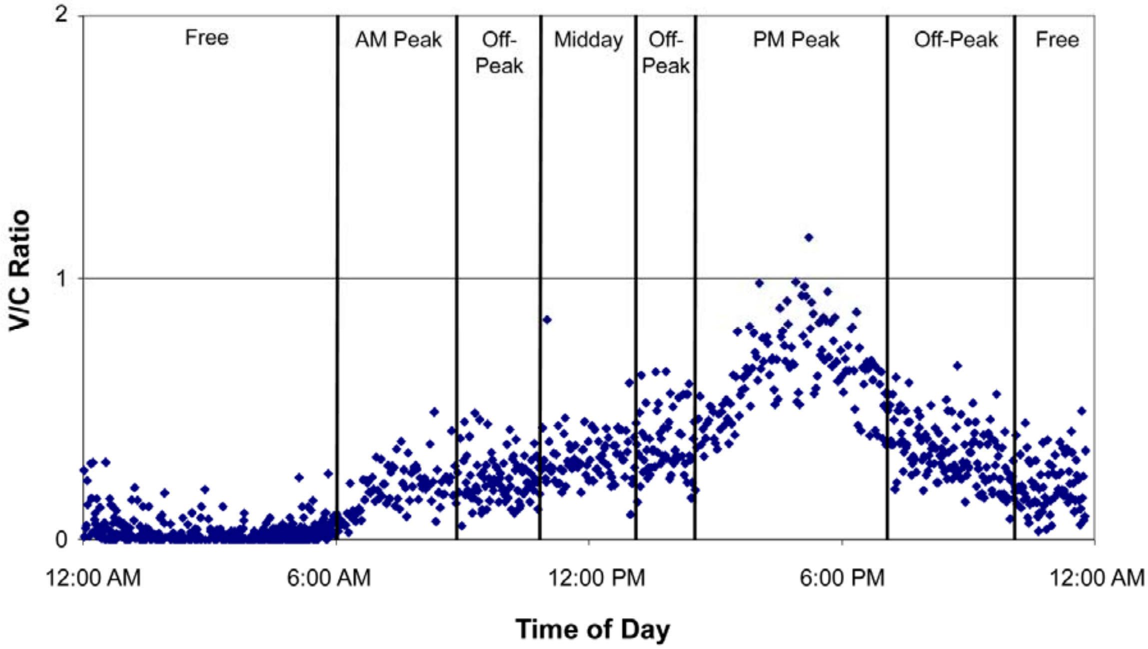


Figure 2. Sample Plot of V/C Ratios over 24 Hours.

This type of information can be used to fine-tune operations, providing a significantly more robust basis for operational decisions than traditional data collection has allowed (Smaglik et al. 2005). Collection of this data over a longer period of time would provide information on historical trends and would demonstrate the impacts of any signal retimings that are undertaken, which is essential for justification of funding for future retiming work.

PROJECT SCOPE

ADOT does not currently use automated methods for collecting vehicle flow data at its signalized intersections. This project's goal was to determine the feasibility and cost of modifying an existing ADOT traffic control cabinet to collect operational data, using video detection to capture vehicle flow rate information while leveraging existing infrastructure as much as possible. This study is the first step in providing important operational information to regional traffic engineers, as well as long-term turning movement information to planning and maintenance staff. The results of this project will serve as the proof-of-concept.

PROJECT APPROACH

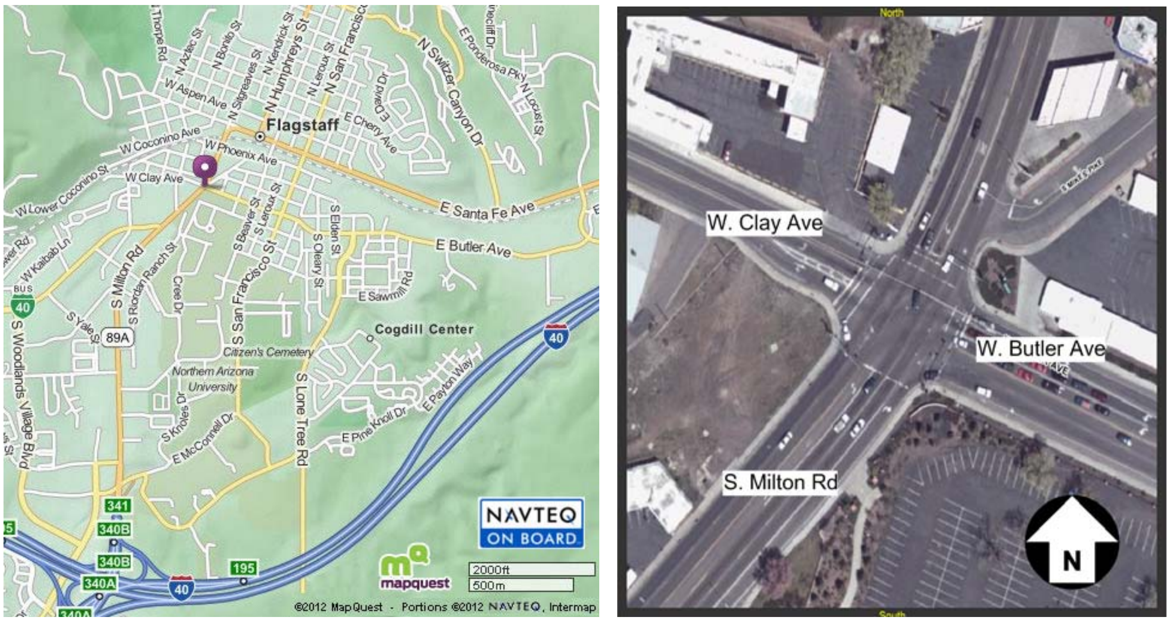
Investigators developed an initial research work plan consisting of the following major tasks:

- **Task 1:** Procure, install, and configure the additional equipment required to provide vehicle flow rate information from the existing vehicle detection units in the traffic control cabinet at the study location.
- **Task 2:** Transcribe the traffic control settings from the current controller at the study location and program the settings into the Econolite ASC/3 controller to be used during the study.
- **Task 3:** Implement the ASC/3 controller.
- **Task 4:** Install and configure a cellular modem at the study location for remote access to collected data.
- **Task 5:** Generate MOEs from the collected data.
- **Task 6:** Corroborate the automatically collected data with manual turning-movement count data.
- **Task 7:** Determine the approximate additional cost of equipping a new intersection (or rehabilitating an existing intersection) with equipment for vehicle flow rate collection.
- **Task 8:** Make a final presentation to ADOT and partner agency senior management. Be available to assist in other presentations to interested parties as requested.
- **Task 9:** Draft the final report.

CHAPTER 2. SITE SELECTION AND ENHANCEMENTS

SITE SELECTION

The site chosen for the proof-of-concept installation was the intersection of South Milton Road with West Butler Avenue and West Clay Avenue in Flagstaff, Arizona, shown in Figure 3.



a) Study location (map created with MapQuest).

b) Aerial view of the intersection.

Figure 3. Study Location.

The site was chosen primarily because of its high traffic volumes, which result in the intersection operating at close to saturation for many hours of the day. Prior to this study, the traffic control cabinet at this intersection was a TS1 installation, using Traficon video detection equipment to provide presence detection on a phase basis. A photo of the traffic cabinet is shown in Figure 4.

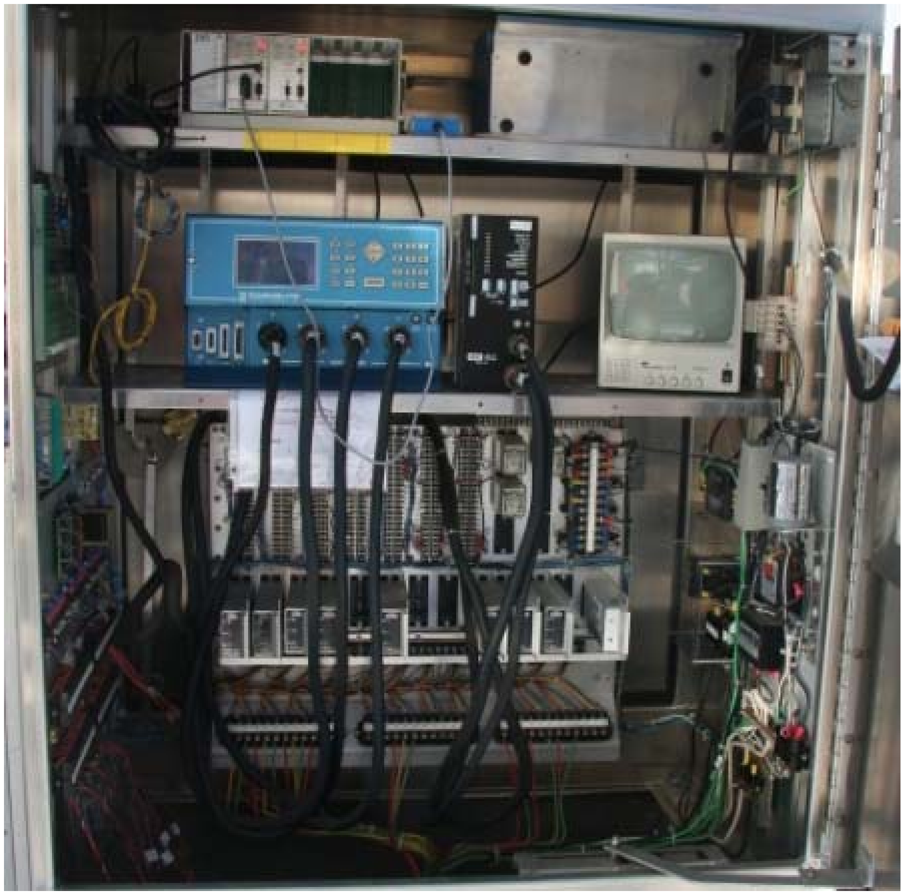


Figure 4. Traffic Control Cabinet Prior to Study Enhancements.

Figure 5 shows the conceptual ring structure in place at the site.

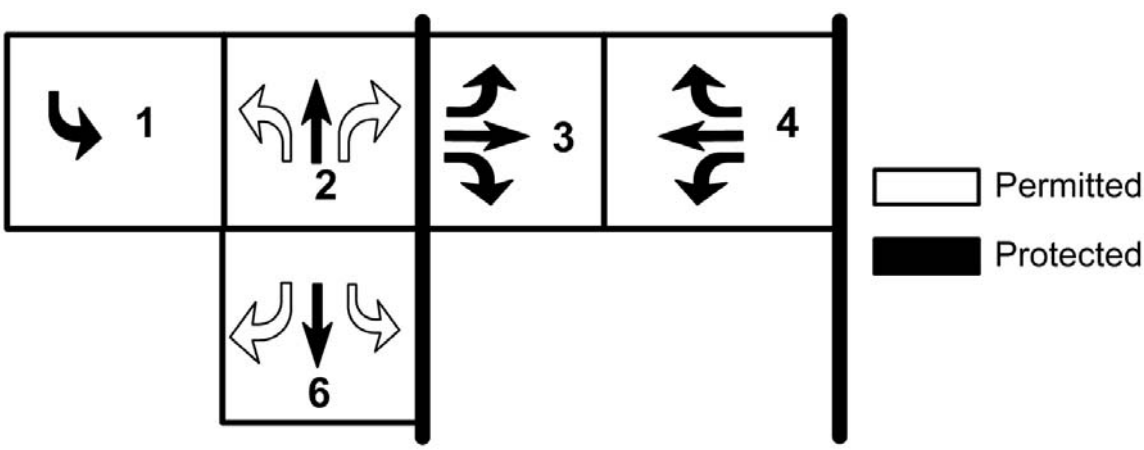


Figure 5. Ring Diagram of Intersection Phases.

Figure 6 shows an overlay of the phases on an aerial photograph. The arrow icons in Figure 6 are conceptual, corresponding to the ring diagram in Figure 5, and do not represent lane configurations.

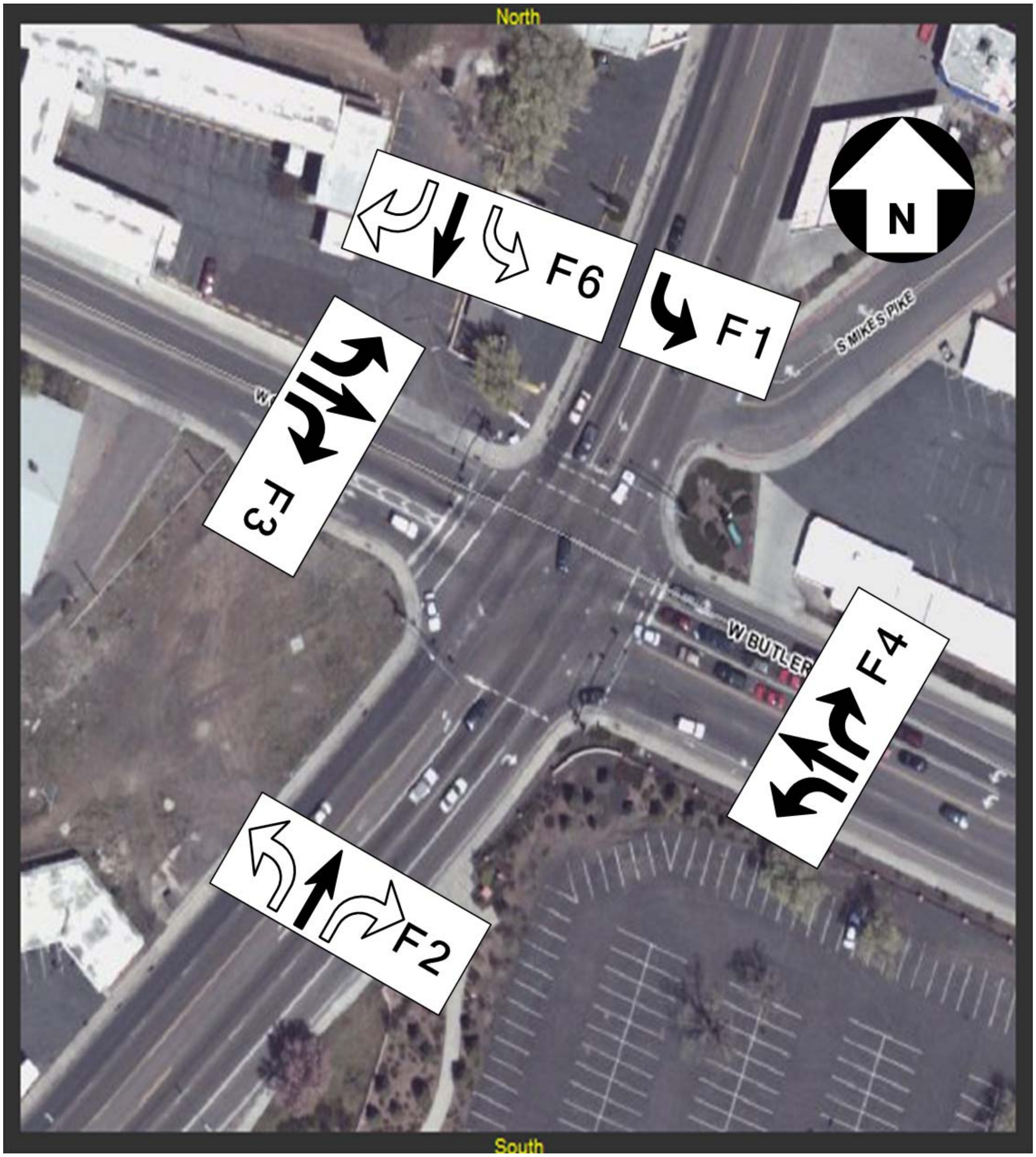


Figure 6. Aerial View of Intersection Phases.

Lane usage at the intersection, as well as the location of the existing video cameras, is shown in Figure 7. A camera is mounted on the arm of the luminaire positioned at the far right corner of each approach. The centerline of each camera's view is shown as a line from the camera to the appropriate stop bar.

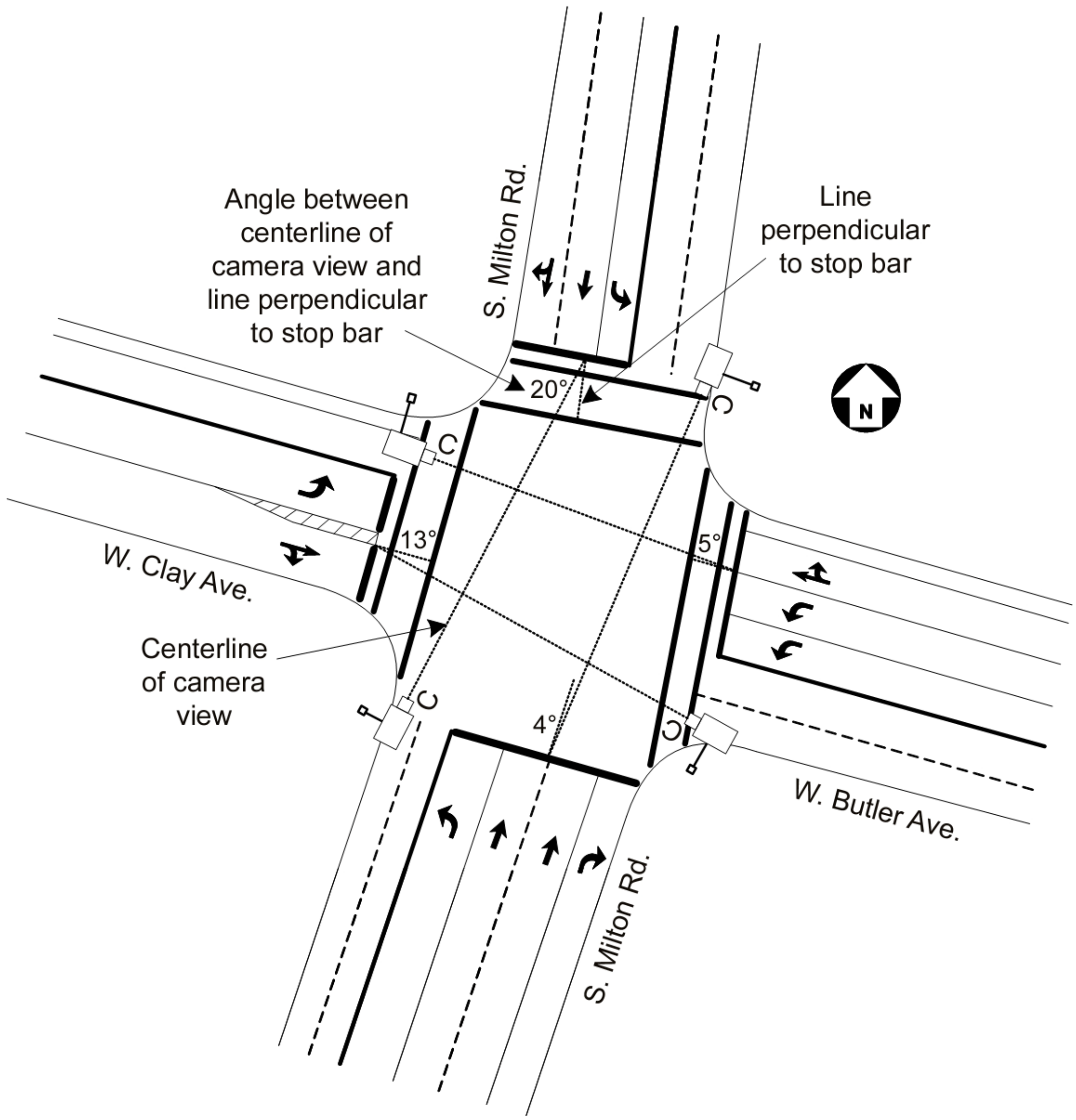


Figure 7. Lane Usage and Video Camera Locations.

Figure 7 also shows the angle between the centerline of the camera view and a line perpendicular to the stop bar.

TRAFFIC CABINET ENHANCEMENTS

The Econolite ASC/3 controller was the device used for data logging in this project. An event-based data logger within the controller allows data to be stored on board and then accessed through an Ethernet port. This data logger is supplied with every ASC/3 controller sold by Econolite.

In order for the controller to log a stream of data, it must be able to access it through a detector input. The existing traffic cabinet at this site was a TS1 cabinet, limited to 16 detector inputs (8 standard plus 8 from the auxiliary panel, which was not present at this location). To provide the most versatile data, vehicle count data should be captured separately for each lane of the intersection—12 in this case. Therefore, 12 detector inputs needed to be added to the cabinet. The cabinet required 5 inputs (1 per phase) for presence detection, for a total of 17 inputs.

To accomplish this, the cabinet was operated in TS2 Type 2 mode, using contact-closure communication for phase outputs, the conflict monitor, and presence detection. A TS2 detector rack provided an additional 16 detector inputs; a Synchronous Data Link Control (SDLC) bus was used to communicate with this detector rack. If necessary, two additional detector racks could have been added, for a total of three TS2 detector racks providing 48 detection channels. Only one was needed at this site.

EQUIPMENT ENHANCEMENTS

One objective of this work was to leverage existing infrastructure for collecting performance measurement data. As such, this project used the existing Traficon video detection units to generate vehicle counts. To capture and log this information, equipment had to be added or replaced. Figure 8 shows the cabinet after these equipment enhancements; Table 1 lists the equipment and explains its role in the project.

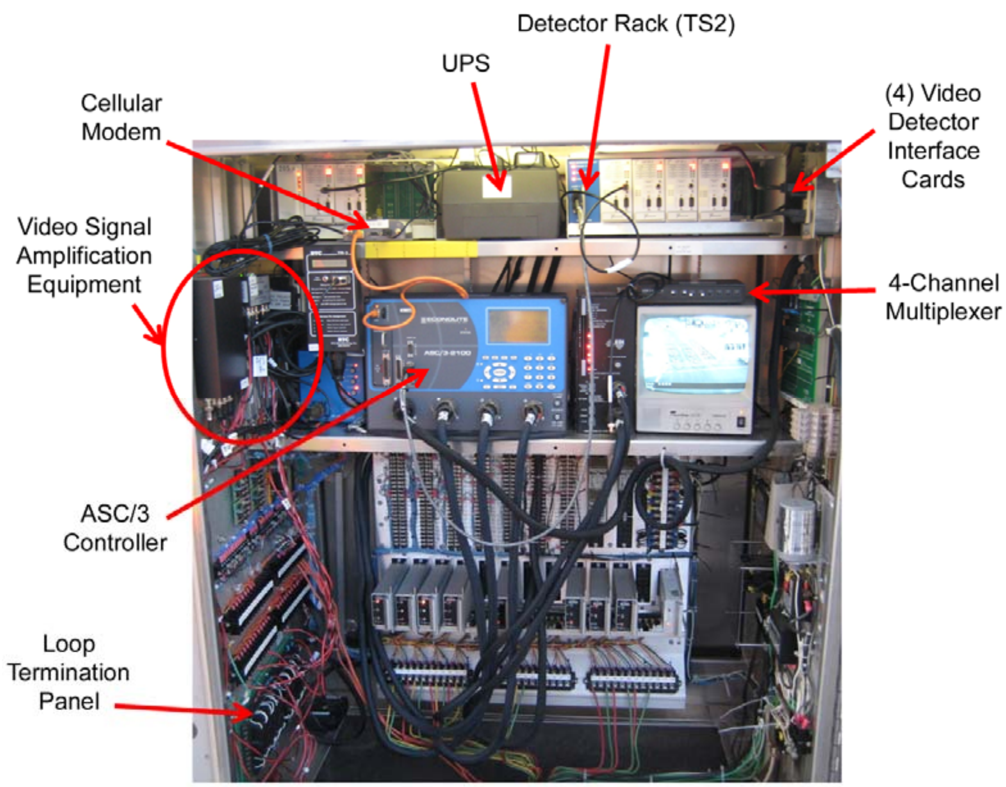


Figure 8. Traffic Cabinet with Enhancements.

Table 1. Traffic Cabinet Enhancements.

Fig. 9 Ref.	Item	Description
A	ASC/3 Controller	Off-the-shelf Econolite traffic controller that contains an event-based data logger, enabling each phase state change and each detector actuation to be logged with an individual time stamp, allowing for the creation of cycle-by-cycle performance measures. The controller was operated in TS2 Type 2 mode. Data are stored on board and retrieved through an Ethernet port.
B	Video Detector Interface Cards (VIP/P 3D.2)	Traficon video detector interface cards are limited to a certain number of detection outputs. The outputs on the existing cards were already used for presence detection. Twelve additional detector outputs were required to provide vehicle counts on a lane-by-lane basis for the entire intersection. Each card has four outputs, but due to the distribution of lanes among the approaches, four cards were added.
C	Loop Termination Panel	This panel provided a necessary communication link between the video signal amplification equipment and the TS2 detector rack. The video signals were terminated here and communicated to the video detector interface cards housed in the TS2 detector rack.
D	TS2 Detector Rack	The added video detector interface cards were housed in this detector rack. The additional detector inputs were provided to the controller via an SDLC bus.
E	Uninterruptible Power Supply (UPS)	Additional power points were needed due to the addition of the video signal amplification equipment, cellular modem, and four-channel multiplexer, as well as the laptop that would be used for video recording. The UPS served this purpose.
F	Cellular Modem (Airlink Raven X)	The cellular modem provided remote access to the data stored on the traffic controller. No access was available to traffic signal timing data or controller operation.
G	Video Signal Amplification Equipment	The video signal from each Traficon camera had to be split several times to provide a signal for each device that required it. To avoid problems due to a loss of resolution from the splitting, the signal was amplified as it was split.
H	Power Supply (PS150)	To provide enough power for the additional detector rack and video detector interface cards, an additional cabinet power supply was added.
I	Four-Channel Multiplexer	To verify the count data provided by the video detection units, all four video feeds (one from each direction) were recorded simultaneously. The four-channel multiplexer combined these four feeds into one for easy digital recording.

Figure 9 diagrams the project’s data flow.

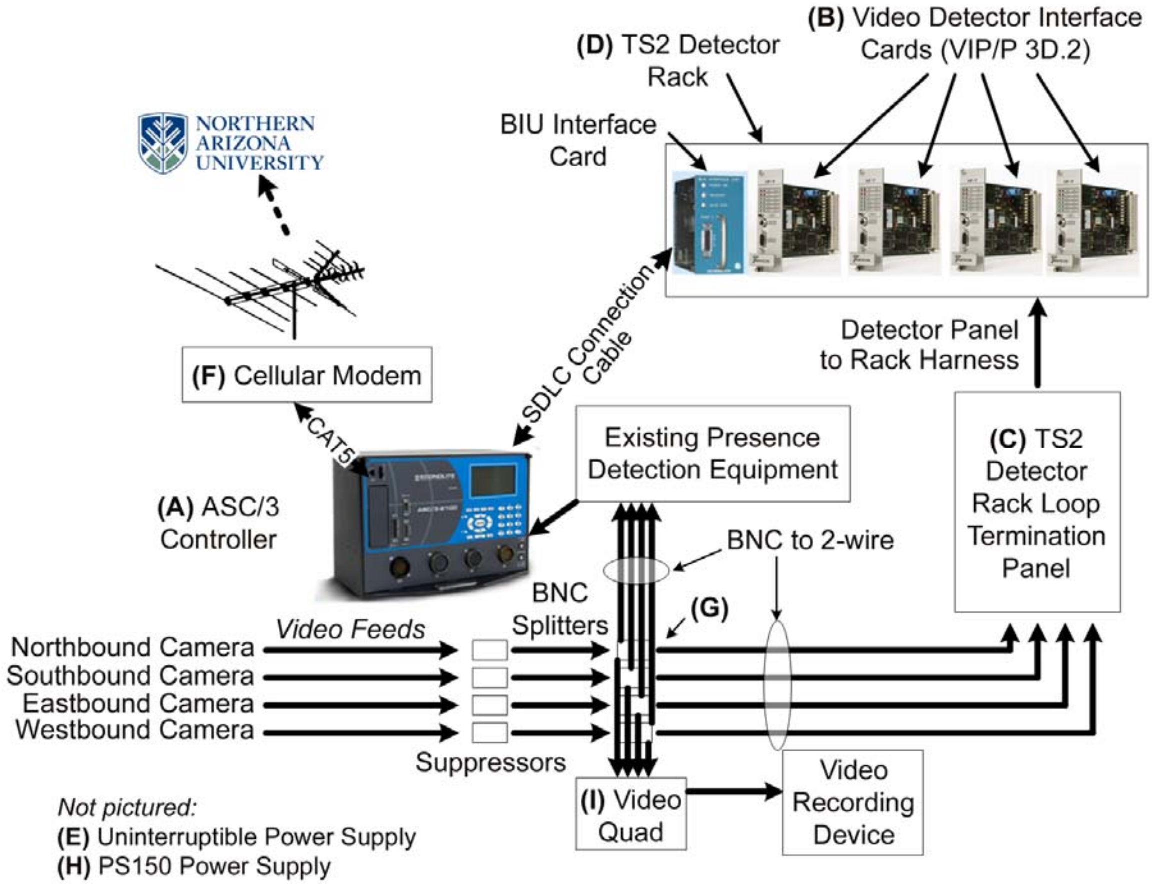


Figure 9. Project Information Flow.

As shown in Figure 9, the video stream enters the cabinet from the four existing video feeds, passing through suppressors on the way to Bayonet Nut Coupling (BNC) splitters. Here each video feed is split, supplying the existing presence detection cards, the new count cards, and the video recording device. The vehicle count cards communicate with the traffic controller via an SDLC bus. Data are then downloaded remotely from the controller through the cellular modem.

EQUIPMENT COST

Not all of the equipment listed in Table 1 is necessary for data collection; some was installed specifically for this study, for the purpose of comparing vehicle count data collected automatically with manually counted data. The equipment necessary for data collection, and its associated costs, are listed in Table 2. The cost given for cables and connectors represents the cost of the SDLC cable ($40) and other connectors used (BNC-2 wire).

Table 2. Equipment Cost.

Item	Cost	Quantity	Extension
ASC/3 Controller	$3,000	1	$3,000
VIP/P 3D.2 Video Detector Interface Card	$4,450	4	$17,800
TS2 Detector Rack	$1,040	1	$1,040
Bus Interface Unit (BIU) Card	$211	1	$211
TS2 Loop Termination Panel	$200	1	$200
PS150 Power Supply	$390	1	$390
Cellular Modem	$600	1	$600
Cables and Connectors	$100	1	$100
		TOTAL	**$23,341**

The total cost listed in Table 2 represents a worst-case scenario, as some of the equipment is redundant with what was already in the cabinet. If the equipment were installed during the construction or rehabilitation of an intersection, the costs would be lower. For example, the study intersection has a total of 12 lanes serving five phases. To provide presence detection for each phase, as well as a vehicle count output for each lane, 17 detector outputs are required, broken down as follows:

- Northbound (five outputs):
  - One presence detection output (Phase 2).
  - Four vehicle count outputs.
- Southbound (five outputs):
  - Two presence detection outputs (Phases 1 and 6).
  - Three vehicle count outputs.
- Eastbound (three outputs):
  - One presence detection output (Phase 3).
  - Two vehicle count outputs.
- Westbound (four outputs):
  - One presence detection output (Phase 4).
  - Three vehicle count outputs.

Five VIP/P 3D.2 video detector interface cards are required to provide these 17 presence and count outputs to the traffic controller. Prior to this project, the study intersection required two VIP/P 3D.2 cards to provide presence detection. If the presence and count detection were integrated on the same cards, only three additional cards would be necessary (as opposed to the four required by this project). Also, the traffic controller would already be included in the cost of the intersection, and all detection cards would be mounted in TS2 detector racks using TS2 termination panels. Table 3 presents an estimate of costs if the equipment were installed as part of a new or rehabilitated intersection.

Table 3. Estimated Equipment Cost if Part of New Installation or Rehabilitation.

Item	Cost	Quantity	Extension
ASC/3 Controller*	$3,000	included	$0
VIP/P 3D.2 Video Detector Interface Card	$4,450	3	$13,350
TS2 Detector Rack	$1,040	2	$2,080
TS1 Detector Rack**	($300)	1	($300)
Bus Interface Unit (BIU) Card	$211	2	$422
TS2 Loop Termination Panel	$200	2	$400
TS1 Loop Termination Panel***	($90)	1	($90)
Cellular Modem	$600	1	$600
Cables & Connectors	$100	2	$200
		TOTAL	**$16,662**

* Cost of ASC/3 controller included in intersection build.

** TS1 detector rack (normally installed) not required.

*** TS1 loop termination panel (normally installed) not required.

These costs are based on an installation using Traficon video detection units; costs may vary for equipment from other manufacturers. If inductive detection is used, the cost to cut additional loops and install additional or replacement detector cards should be accounted for, as it is imperative to have vehicle counts available for all lanes. In addition, overhead costs should be considered, such as the cost of cellular data service or office computers. These expenses are not easily quantifiable, and therefore they are not included in Tables 2 and 3.

CHAPTER 3. EQUIPMENT IMPLEMENTATION

This chapter describes the implementation of the equipment installed to enhance the traffic cabinet, as shown in Figure 8 and described in Table 1. Several items were straightforward hardware installations and required little or no configuration:

- Loop termination panel.
- TS2 detector rack.
- Uninterruptible power supply.
- Four-channel multiplexer.

ECONOLITE ASC/3 CONTROLLER

All traffic control settings in the ASC/3 controller were programmed by ADOT personnel through database transcription from the previous controller (an Econolite ASC/2). The following configuration steps are directly related to data collection, and were performed by research personnel under the guidance of ADOT personnel. Investigators:

- Configured the Internet protocol (IP) address and associated Ethernet settings.
    - IP address: 192.168.13.100
    - Subnet mask: 255.255.0.0
    - Gateway: 192.168.13.1
- Enabled detector channels for vehicle counting (channels are listed in Table 4).
- Enabled TS2 operation for detector rack communication.
- Enabled and configured the event data logger. Instructions for configuration are included as Appendix A of this report.

VIDEO DETECTOR INTERFACE CARDS

The configuration of the video detector interface cards (model VIP/P 3D.2) used for the vehicle counts was completed by a representative from AM Signal, a regional Traficon vendor. ADOT and research personnel were present for observation during the configuration.

CELLULAR MODEM

The cellular modem used was an Airlink Raven X. To communicate with the data logger from a remote location, the cellular modem was configured to pass data to the ASC/3 controller. The modem was accessible through a static IP address assigned by Verizon (166.154.120.97), which in turn accessed the ASC/3 controller through an internal IP address. IP settings for the ASC/3 are listed above.

Table 4. Detector Channel Mapping for Vehicle Counts.

Channel	Lane
17	WB Outside Left
18	WB Inside Left
19	WB Through/Right
21	NB Outside Through
22	NB Inside Through
23	NB Right
24	NB Left
25	EB Left
26	EB Through/Right
29	SB Through/Right
30	SB Through
31	SB Left

VIDEO SIGNAL AMPLIFICATION EQUIPMENT

Two separate power amplifiers were used to provide four separate video streams for each approach. These streams provided:

- Presence detection.
- Video recording.
- Count detection (two streams).

As noted previously, each additional VIP/P 3D.2 card has four outputs; however, the card is designed to accept two separate video feeds and provide two outputs per feed. (Note: Cards are available that accept one feed and provide four outputs. However, this model was chosen because it is preferred by ADOT, and it will be useful in the future when the cards are returned to ADOT stock.) As such, two identical video feeds were sent to each VIP/P 3D.2 card.

CHAPTER 4. DATA COLLECTION AND DATA PROCESSING

The data from which to calculate the performance measures were collected continuously for 24 hours, yielding a 24-hour set of logged data from the ASC/3 controller concurrent with video. Cycle-by-cycle counts were developed from the logged data, and then combined with phase-duration data to produce performance measures.

DATA COLLECTION

Collected data are accessible through the Ethernet port on the ASC/3 controller. The connection can be made at the controller with a crossover cable or remotely via a file transfer protocol (FTP) client. Figure 10 is a screen capture showing the data files accessed through CuteFTP, an FTP client.

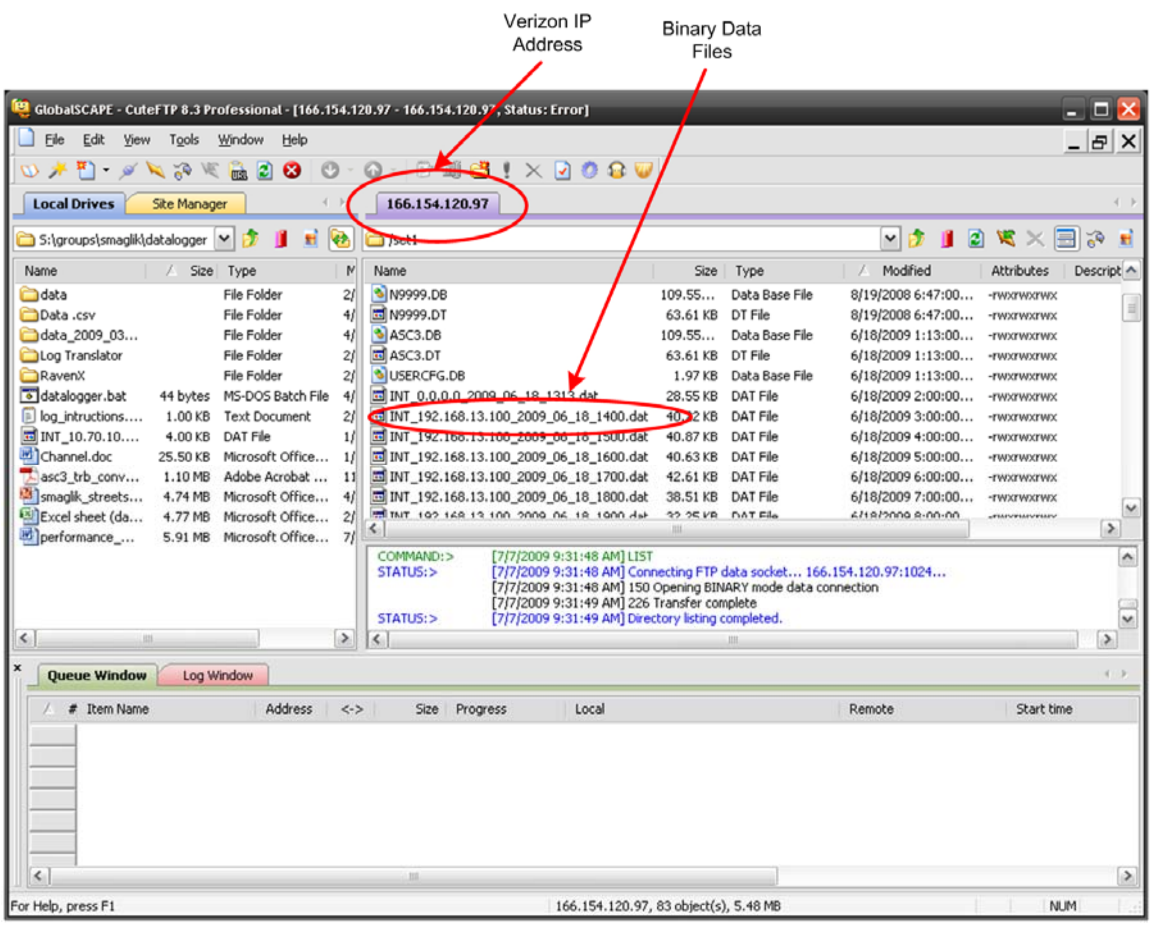


Figure 10. FTP Data Access.

The IP address used to access the data is assigned by Verizon; it is circled in Figure 10. The controller logs the data into hourly files (one is circled in Figure 10) using a standard naming convention:

INT_XXX.XXX.XXX.XXX_YYYY_MM_DD_HHHH.DAT

where XXX.XXX.XXX.XXX = IP address of controller
YYYY_MM_DD = date (e.g., 2009_07_04 = July 4, 2009)
HHHH = hour at start of data file

The data files are in binary format. Econolite provides a utility for converting the binary files to several different formats. Details are provided in Appendix B.

DATA PROCESSING

Using the provided Econolite utility, the data are converted from binary format into a comma-separated values (CSV) file, which is then imported into a Microsoft Access database. Once the data are in the database, a query is developed to pull the desired data set from Access and export it into a Microsoft Excel spreadsheet, where it can be used to generate performance measures. The database contains all the on and off times for every detector and for every phase and pedestrian signal. However, the query extracts only the few items necessary to develop a performance measure for a certain movement over a certain duration.

Volume-to-Capacity Ratio

The volume-to-capacity (V/C) ratio (TRB 2000) is a measure of what portion of the green signal interval is utilized. A V/C ratio close to 1.0 shows that vehicles are using most if not all of the green signal time. Previous research has used historical V/C data for a variety of analyses (Ngan et al. 2004, Chang et al. 2000, Frantzeskakis and Iordanis 1987, Berry and Pfefer 1986). While typically applied to 15- or 60-minute intervals as part of a *Highway Capacity Manual* analysis or a macroscopic, computer-aided analysis using Synchro or similar tools, V/C ratios can be applied to individual green signal intervals, allowing for intersection analysis on a microscopic basis. The formula for the V/C ratio is shown in Eq. 1:

$$\left(\frac{v}{c}\right)_l = \frac{q_g}{\left[s_l * \left(\frac{g_l}{C}\right)\right]} = \frac{(v_l * C)}{(s_l * g_l)} \quad \text{(Eq. 1)}$$

where v_l = served flow rate for lane group
c_l = capacity of lane group
q_g = flow rate observed for a green signal phase
s_l = observed lane saturation flow rate

C = cycle length

g_l = length of green signal indication for movement

Researchers obtained the values for v_l, C, and g_l directly from the logged data. The value for s_l was derived from procedures set forth in the *Highway Capacity Manual* (TRB 2000). Saturation flow values for the following lanes were determined through a field study using data from the northbound through lanes, southbound through and through/right lanes, and westbound left-turn lanes. Saturation flow values for the remaining lanes were calculated, as there was not enough traffic to determine them through the field study. Though counterintuitive, it is possible to calculate a V/C ratio above 1.0 from real-time data, as the value for saturation flow given in Eq. 1 is static, while the actual value will vary from interval to interval. V/C ratios were calculated for the dominant lane group within each phase.

Equivalent Hourly Volume

The equivalent hourly volume (EHV) measure scales the served volume from an individual cycle up to an hourly flow rate. This metric provides data that can be easily compared from intersection to intersection and between movements at an intersection. The formula for EHV is shown in Eq. 2.

$$EHV = \left(\frac{3600}{C}\right) * v \qquad \text{(Eq. 2)}$$

where EHV = equivalent hourly volume

C = cycle length

v = served volume

Both values used to calculate this metric, v and C, were obtained from the logged data. EHV was calculated for each approach.

Cumulative Volume

A cumulative volume count provides the total number of vehicles observed during a specified time. In this project, cumulative volume counts were used to compare the total number of vehicles counted through the video-generated and manual counts. This allowed the researchers to evaluate the accuracy of the automated counts.

CHAPTER 5. RESULTS

Researchers collected 24 hours of data starting at 7:00 a.m. Thursday, March 27, 2009, and ending at 7:00 a.m. Friday, March 28, 2009. Weather during this period was mostly clear with moderate wind, with a short period of rain in the late afternoon. While weather conditions can impact the quality of video detection performance, it is not believed that weather had a significant impact on the results of this study. From this automated data, V/C ratio values were calculated for the major lane group for each green signal interval of each phase during the 24-hour period. EHV values were computed for each approach. Cumulative counts were developed for the entire period on an approach basis as well as for individual lanes.

During the 24-hour automated data collection, video was recorded concurrently for all four approaches (video feeds from the four approaches were multiplexed together to form a quad view of the intersection) for the duration of the study. Then, in a controlled laboratory environment, research assistants watched the video feed and manually tabulated the vehicle counts for each lane. The process was similar to conducting a turning movement count in the field. However, conducting the manual counts in the laboratory rather than in the field allowed the researchers to pause the video if necessary to ensure accuracy, and eliminated the need to staff the intersection for a continuous 24-hour period.

The following sections present the results of the manual and automated data collection and discuss inconsistencies between the two data sets. To interpret these results, it is important to discuss the meaning of the term “operationally significant.”

In a perfect world, data collected and processed from automated units would be 100 percent accurate. However, this is not the case, which raises the question “How much error is too much error?” Little guidance is available in the literature, and practitioners may vary in what they consider acceptable. In addition, the acceptable amount of error varies depending on the conditions being analyzed. For example, when considering error in V/C ratio values, the following questions must be asked[1]:

- Is the movement typically under- or oversaturated?
- Are two phases that share green time both operating close to saturation?
- Is the entire intersection oversaturated, such that there is no phase from which to obtain additional green signal time?
- Is the intersection running in coordination?

---

[1] Telephone interview with Jim Sturdevant, traffic systems engineer with Indiana DOT and member of TRB Committee AHB25: Traffic Signal Systems, July 27, 2009.

While the determination of what level of error is operationally significant in this project is ultimately up to the project's Technical Advisory Committee and ADOT personnel, the researchers propose the following criteria:

- For V/C ratio values:
  - From 0.00 to 0.50, a difference larger than 0.10 is unacceptable.
  - From 0.51 to 1.20, a difference larger than 0.05 is unacceptable.
- For cumulative count values:
  - A difference larger than 10 percent is unacceptable.

The threshold value for V/C data is incremented due to the nature of the measure. At lower V/C ratio values, greater error is tolerable because the V/C ratio is far from reaching the capacity of the movement. Less error should be allowed as the V/C ratio values increase, because green signal time becomes more valuable as the V/C ratio value gets closer to the capacity of the movement. For cumulative count values, a value of 10 percent was selected because a smaller error is not likely to have a large impact on signal timing. In addition, that value has been proposed in previous research (Smaglik, Vanjari, et al. 2007).

PHASE-BY-PHASE V/C RATIO DATA

For each signal phase, researchers calculated V/C ratio values using the traffic volume data logged by the traffic controller (provided by the video detection unit), as well as for the data counted manually. Each V/C plot contains four series:

- Individual V/C ratio data points, generated from data collected by video detection.
- 20-cycle moving average of V/C ratio, generated from data collected by video detection.
- Individual V/C ratio data points, generated from manually counted data.
- 20-cycle moving average of V/C ratio, generated from manually counted data.

The 20-cycle moving average trace lines aid in identifying differing trends between the data generated by video detection and the manually counted data (Smaglik, Sharma, et al. 2007). The upper right corner of each plot shows an aerial image of the intersection and indicates which camera was used to develop the data (the camera's field of view is indicated with a triangle). The V/C ratio plot for Phase 1 is shown in Figure 11.

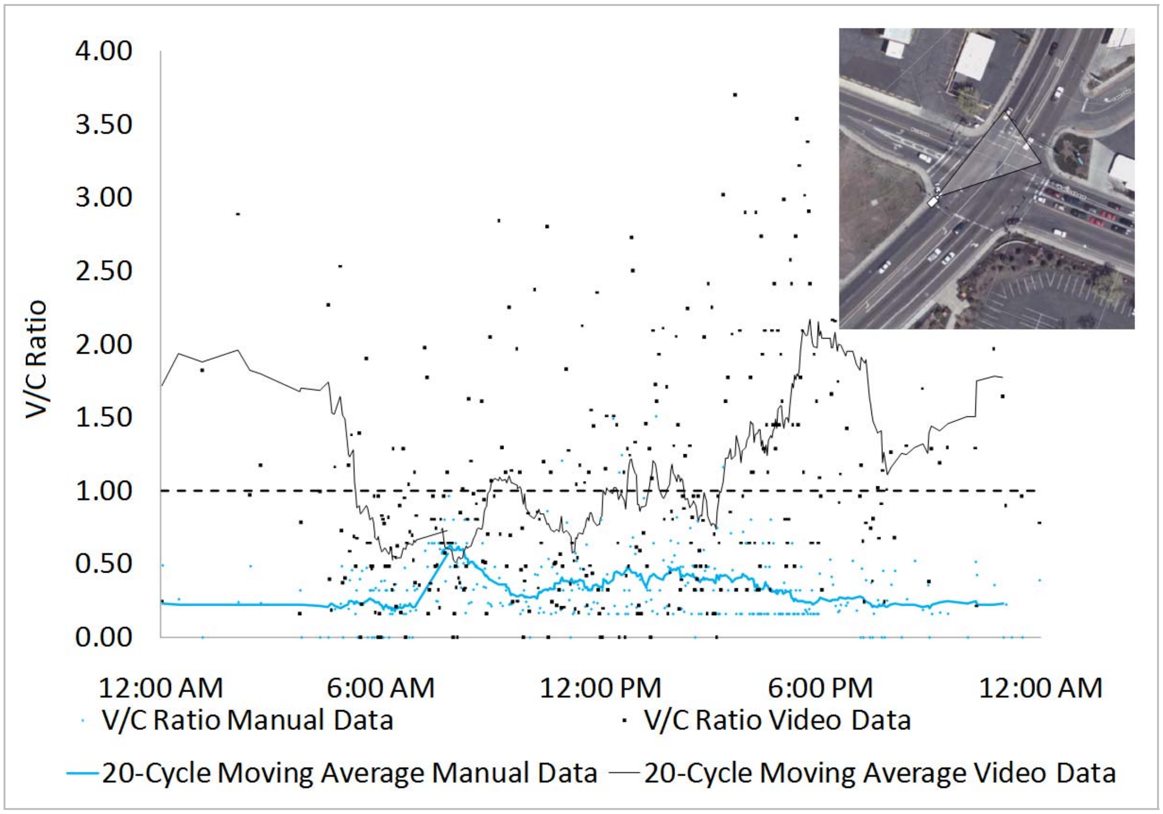


Figure 11. Phase 1 V/C Ratio Data.

Phase 1 is a single-lane protected/permitted southbound left-turn movement at the study intersection. It is a lightly used movement due to the structure of the local road network. The V/C values calculated from the manually counted data hovered between 0.25 and 0.50 for most the day, with a slight peak during the morning rush hour. The V/C values calculated from the video data ranged from 0 to an upper bound of 7.

Because there was no overlay of the video detector unit activity on the video to aid in investigation of these values, the researchers were not able to determine what caused the video unit to overcount so greatly. As shown in Figure 7, the camera serving this movement has the largest offset from perpendicular to the stop bar, providing an angled view of this phase. The researchers believe that camera placement contributed to the inaccuracies in the video count, as the unit may have counted through vehicles as left-turn vehicles. In addition, the volume of vehicles on this movement is relatively low (1118 vehicles during the 24-hour period), which will exacerbate the magnitude of any error.

Figure 12 shows the V/C ratio data for Phase 2.

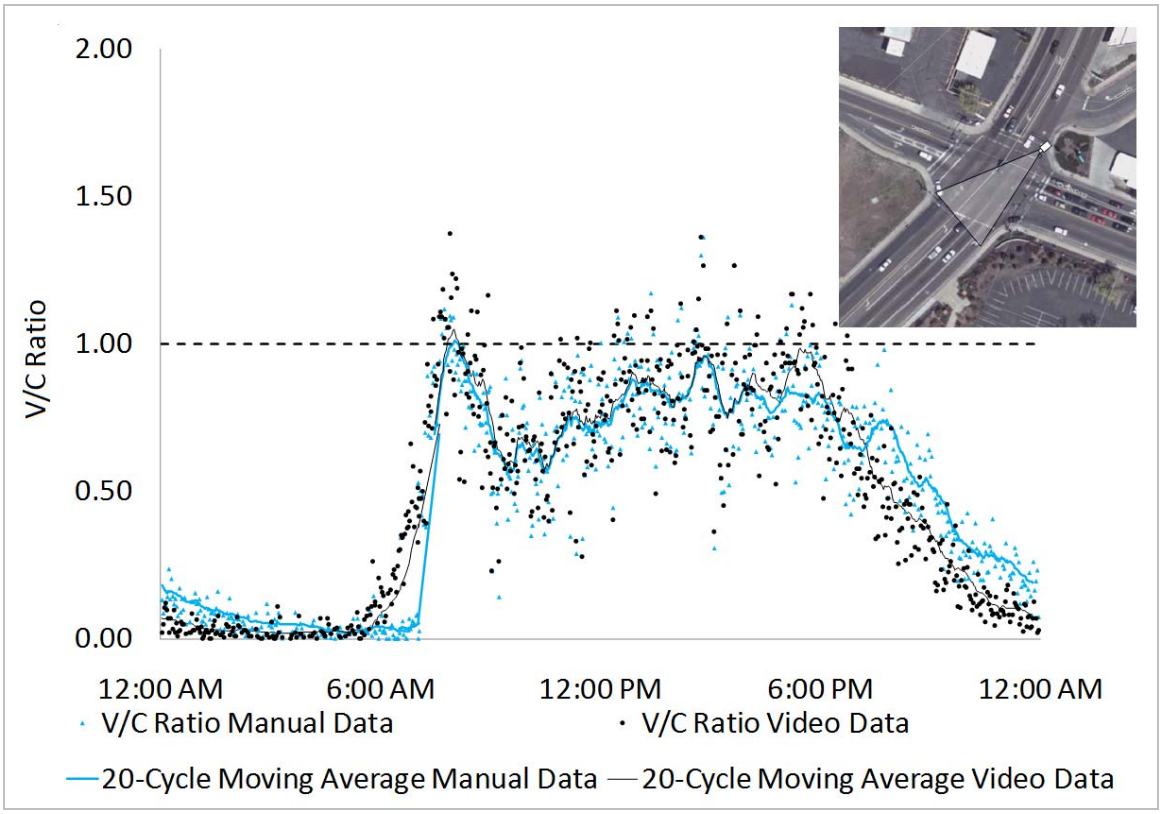


Figure 12. Phase 2 V/C Ratio Data.

Phase 2 is the northbound movement at the study intersection. V/C ratio values were calculated for the lane group consisting of the two through lanes. The V/C values for the manually counted data ranged between 0.50 and 1.10 between 6:00 a.m. and 9:00 p.m., with a peak around 8:00 a.m. This is reasonable, as downtown Flagstaff is north of this intersection, so a slight peak in the data is to be expected. The V/C values for the video data were fairly close to those for the manual data throughout the day, though there were a few differences. The most notable difference occurred after sundown, when the video V/C values were consistently a bit lower than the manual V/C values.

Figure 13 shows the V/C ratio data for Phase 3.

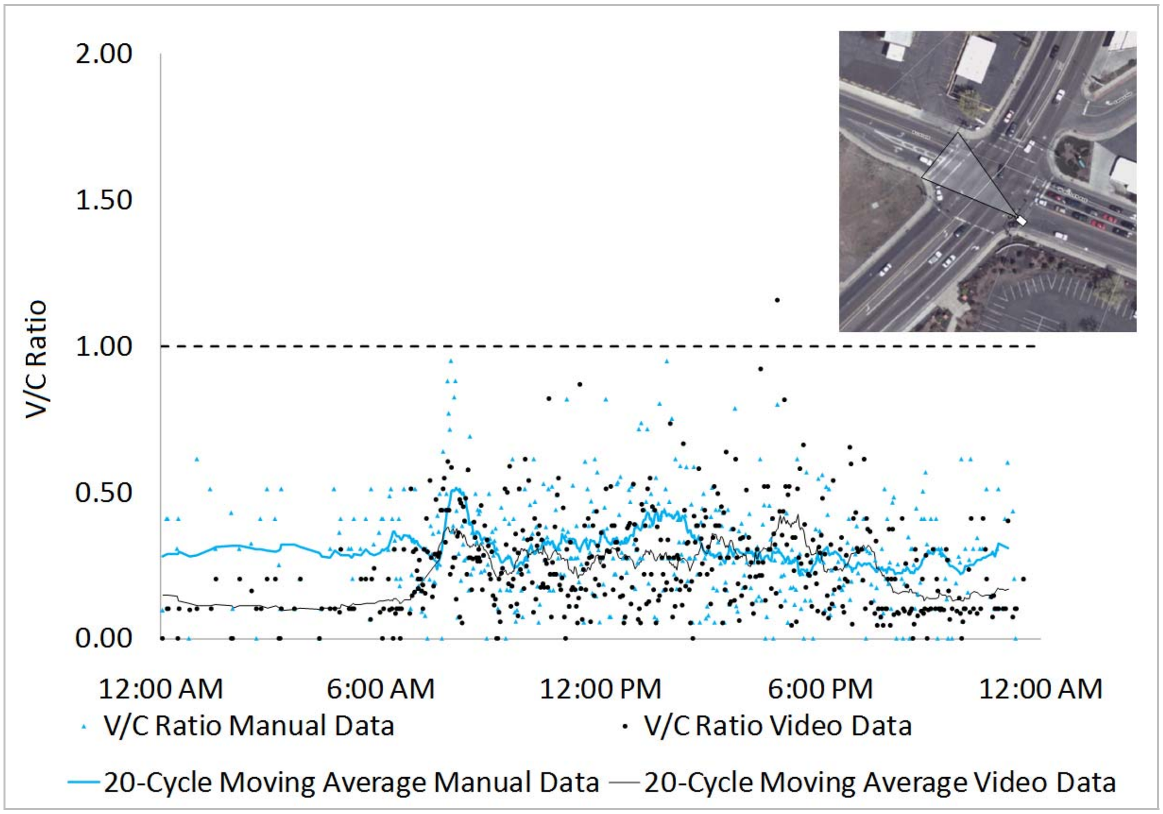


Figure 13. Phase 3 V/C Ratio Data.

Phase 3 is the eastbound movement at the study intersection. The V/C ratio values computed for Phase 3 represent traffic on both lanes of the approach (left and through/right). Traffic on Phase 3 was undersaturated throughout the day. The video V/C values were relatively close to manual V/C values, with the manual values again a bit higher throughout most of the day with the exception of 5:00 p.m. to 7:00 p.m. As with Phase 2, the manual V/C values were consistently higher during the evening and overnight hours.

Figure 14 shows the V/C ratio data for Phase 4.

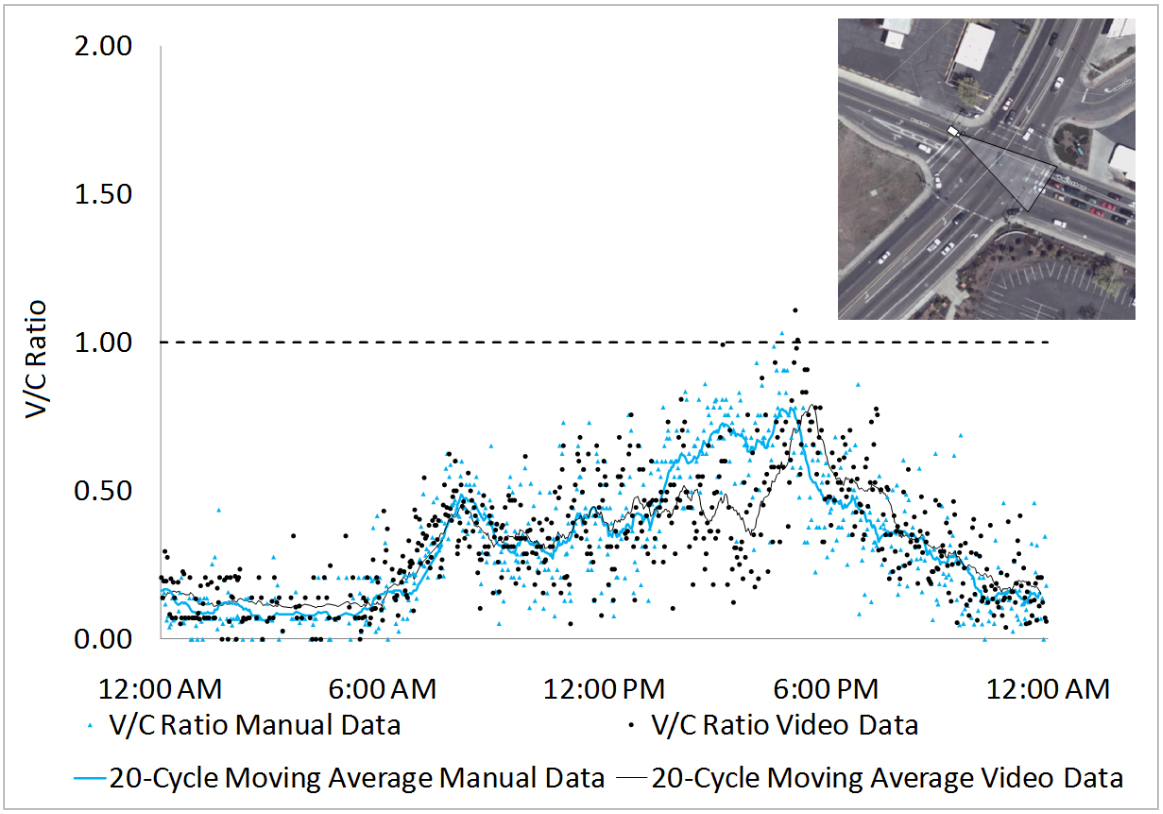


Figure 14. Phase 4 V/C Ratio Data.

Phase 4 is the westbound movement at the approach, consisting of a dual left-turn lane and a shared through/right lane. The reported V/C ratio values account for traffic in all lanes of the approach. Traffic on Phase 4 was undersaturated throughout the day, with the highest volumes during the afternoon and early evening hours. Again, video V/C values were similar to manual V/C values. However, during the hours of 1:00 p.m. to 5:30 p.m., the manual V/C values were consistently higher than the video values. Also, between 5:30 p.m. and 7:00 p.m., the manual values were consistently lower than the video values.

Figure 15 shows the V/C ratio data for Phase 6.

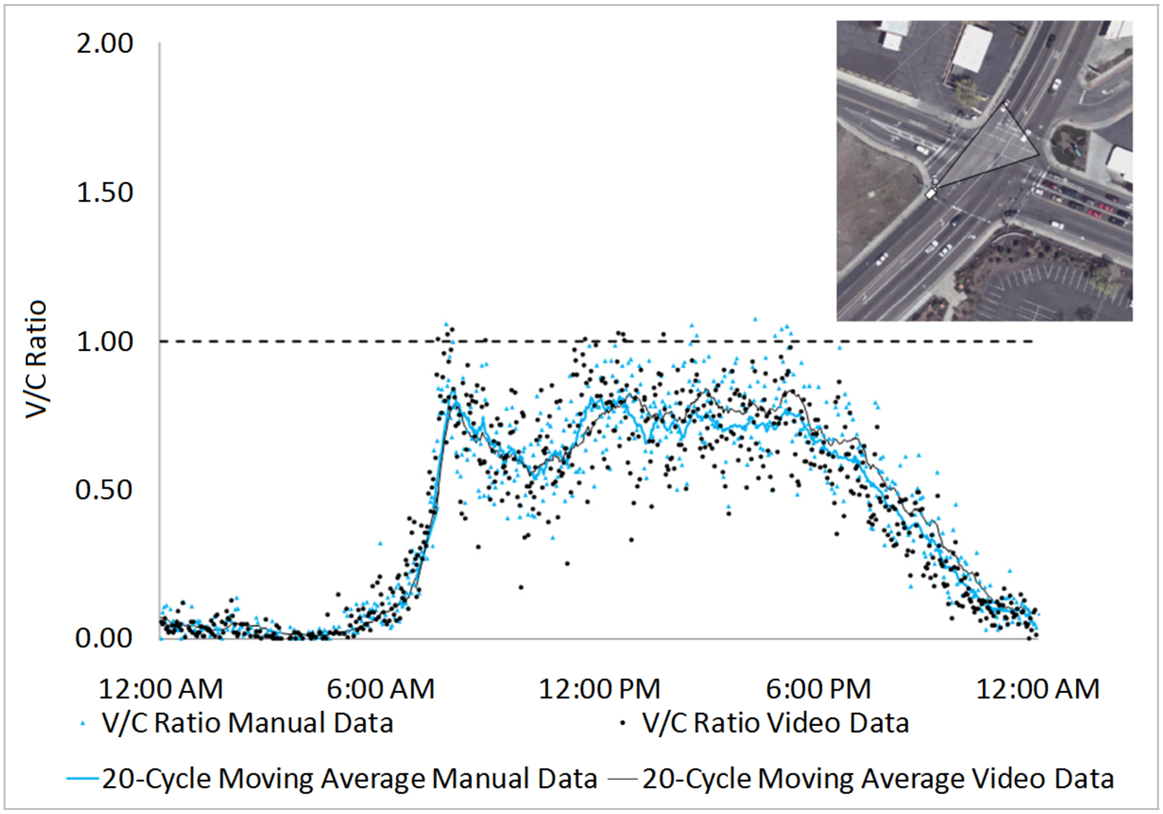


Figure 15. Phase 6 V/C Ratio Data.

Phase 6 is the southbound movement at the intersection, consisting of a through lane and a shared through/right-turn lane. Traffic on Phase 6 is fairly heavy throughout the day, with many V/C values in the 0.60 to 1.00 range. The video and manual V/C data values are fairly similar throughout the day.

STATISTICAL COMPARISON OF V/C RATIO DATA

Researchers performed a statistical comparison of the performance measures generated from the two data sources. For each phase, they compared the V/C ratio value calculated from the manually counted data with the value calculated across all lanes from the video-generated data. To compare the two sets of calculations, researchers conducted a statistical paired *t*-test rather than a regular *t*-test, as the paired *t*-test eliminates more random error in the testing. This type of test could be used because the data set contains a pair of observations for each data point (V/C ratio value). The procedure tests the null hypothesis that the true mean difference between values in a pair is equal to a hypothesized value. In this case, the hypothesized value is 0. The test is shown in Eq. 3:

$$H_0 : \mu_d = 0$$
$$H_1 : \mu_d \neq 0 \quad \text{(Eq. 3)}$$

where H_n is the name of a hypothesis and μ_d as applied here is the observed mean of the differences. The results of this test are shown in Table 5. A *p*-value of 0.05 or lower signifies that the difference between the means is statistically significant at the 95 percent confidence level. In addition, the table indicates for each phase whether the difference between the two sets of data is operationally significant according to the criteria proposed earlier in this chapter.

Table 5. Statistical Comparison Results.

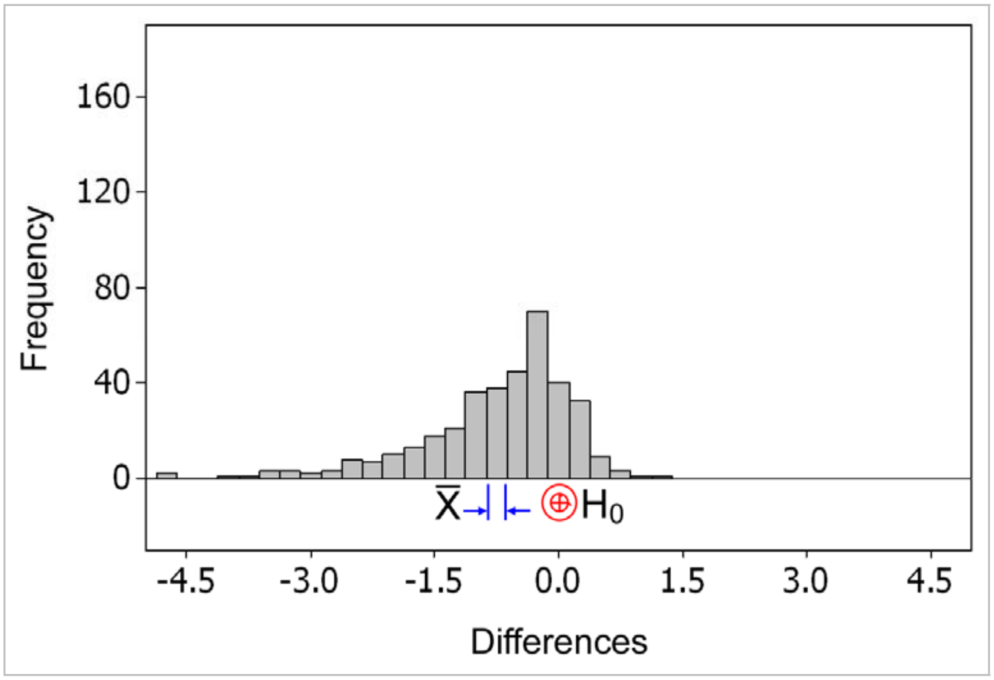
Phase	**Mean**			**95% CI[1] for Difference**	***P*-Value[2]**	**Operationally Significant?**
	Video	Manual	Difference			
1	1.0951	0.3393	–0.7558	(–0.8563, –0.6552)	0.00	Yes
2	0.5212	0.5274	0.0062	(–0.00459, 0.01699)	0.26	No
3	0.2498	0.3096	0.0597	(0.04076, 0.07870)	0.00	No
4	0.3098	0.3465	0.0367	(0.02327, 0.05016)	0.00	No
6	0.4445	0.4621	0.0176	(0.00933, 0.02581)	0.00	No

[1]Confidence interval. The range within which an observed value is likely to fall the stated percent of the time. The CI will be narrow for data that vary little.

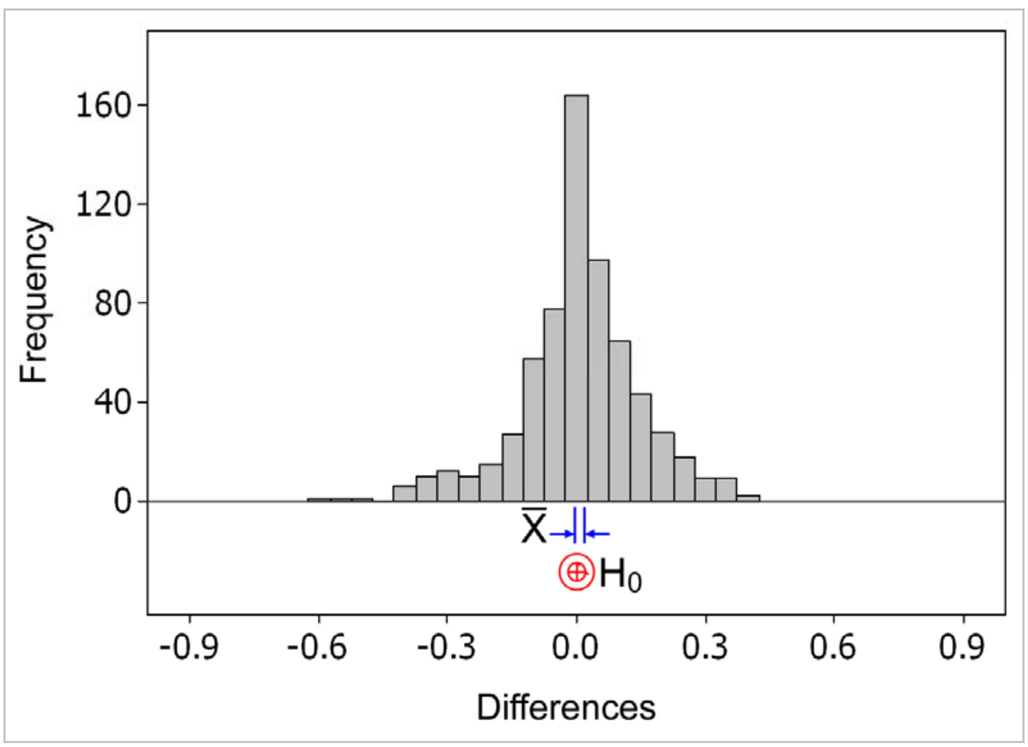
[2] The probability that a hypothetical test result (here the mean difference between observation pairs, expected to be near 0 [null hypothesis]), will equal or exceed the actual test result. If the *p*-value exceeds a level set here at 0.05 (a common value), then the actual test result is within a 95% probability curve, and the null hypothesis is said to be validated, meaning also that the deviation from $H_0 = 0$ is not statistically significant at the 5% level. A *p*-value of 0.05 or lower, however, would cause rejection of the null hypothesis and would connote statistical significance at the 5% level. *P*-value may also be viewed as the probability that the statistical parameter *t*-critical, taken from a table associated with an applicable distribution curve, is greater than or equal to the calculated *t*-statistic, which is a function of variance, the mean of the differences, and the number of trials.

Phase 2 is the only phase where the mean difference is not statistically significant at the 95 percent level. With the exception of Phase 1, the mean difference for all phases was positive, reflecting that the manual V/C value was higher than the video value. The largest positive difference was 0.0597 for Phase 3, although none of the positive differences for Phases 2, 3, 4, and 6 was operationally significant. For Phase 1, the difference of –0.7558 between the manual and video V/C values is operationally significant, and in this case the video V/C value is higher than the manual value.

Figure 16 shows a histogram of differences by phase for each of the five phases. The null hypothesis (H_0) is shown in each plot, as well as the mean ($\overline{X}$). Note that the *x*-axis scale in Figure 16a differs from that of the other plots in Figure 16. These plots show the distribution of the differences for each phase. With the exception of Phase 1, the distributions center around 0. All distributions are roughly normal. This validates the normality assumption of the paired *t*-test.

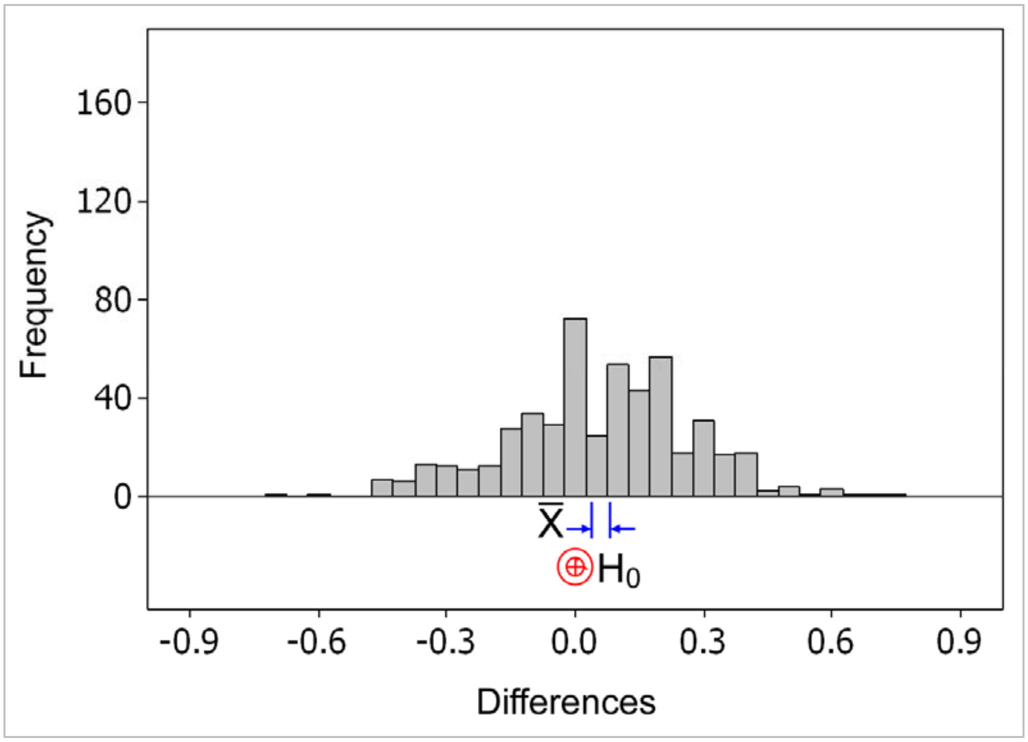


(a) Phase 1.

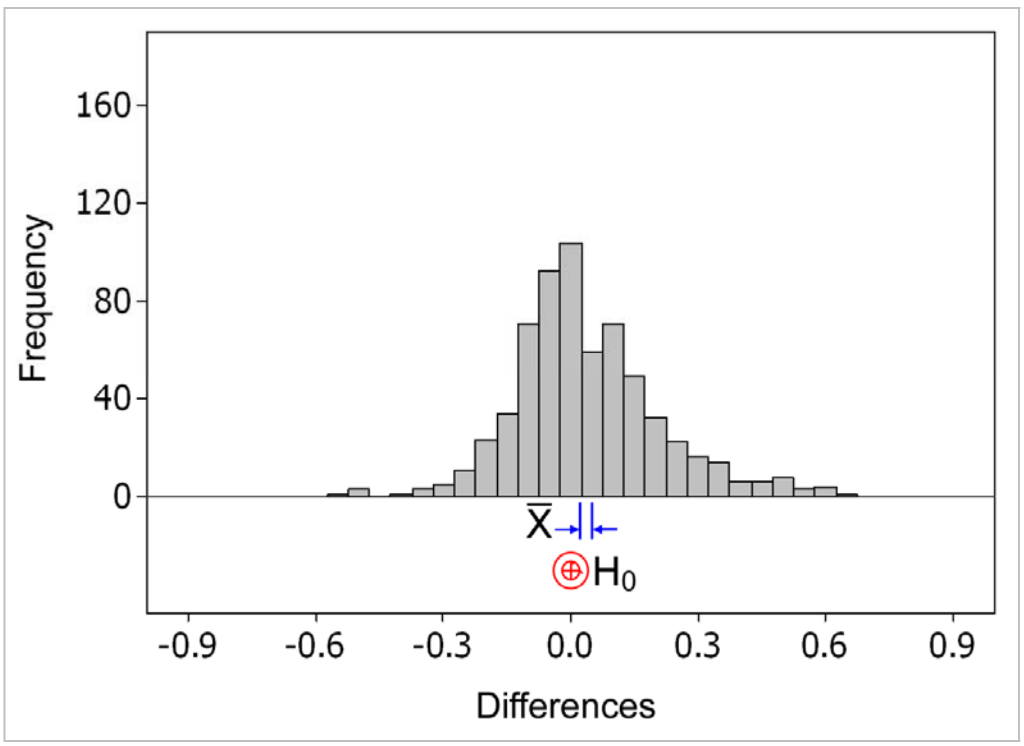


(b) Phase 2.

Figure 16. Histogram of Differences by Phase.

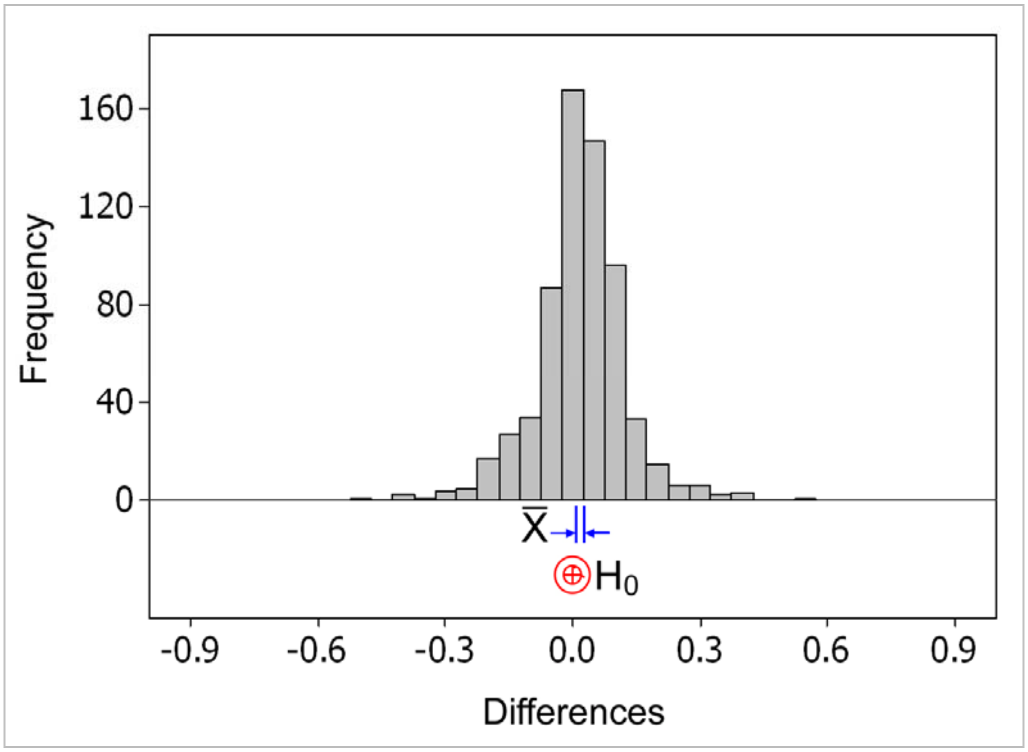


(c) Phase 3.



(d) Phase 4.

Figure 16. Histogram of Differences by Phase (continued).

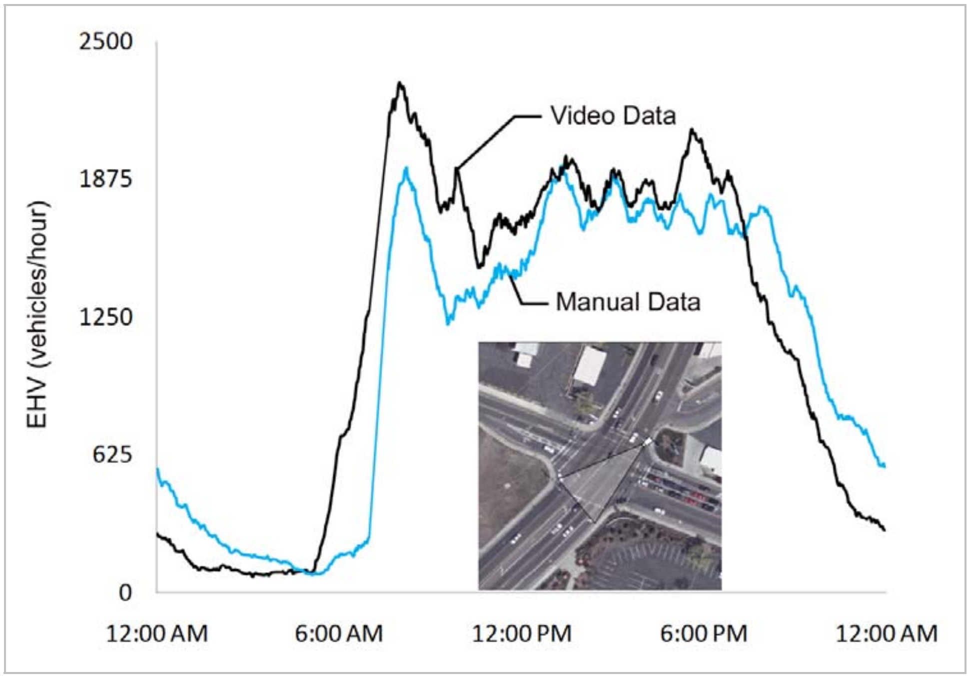


(e) Phase 6.

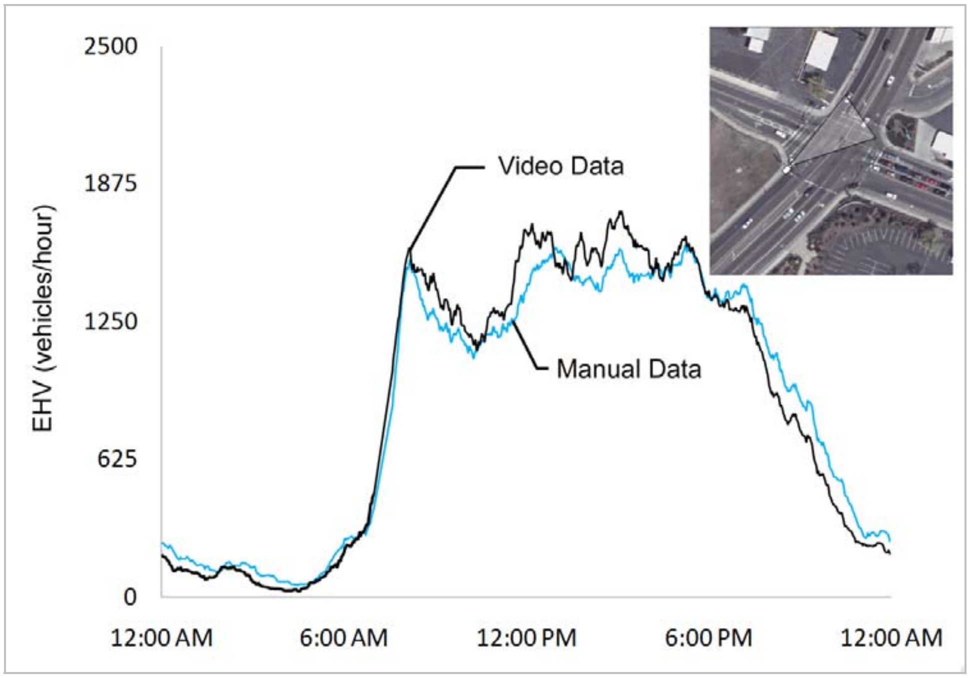
Figure 16. Histogram of Differences by Phase (continued).

APPROACH PERFORMANCE MEASURE DATA

Figure 17 shows EHV data for each approach to allow comparison of volumes across the intersection. Each EHV plot has two trace lines, one for the manually counted data and one for the video detector data. Each trace line is a 20-cycle moving average of the actual data points.

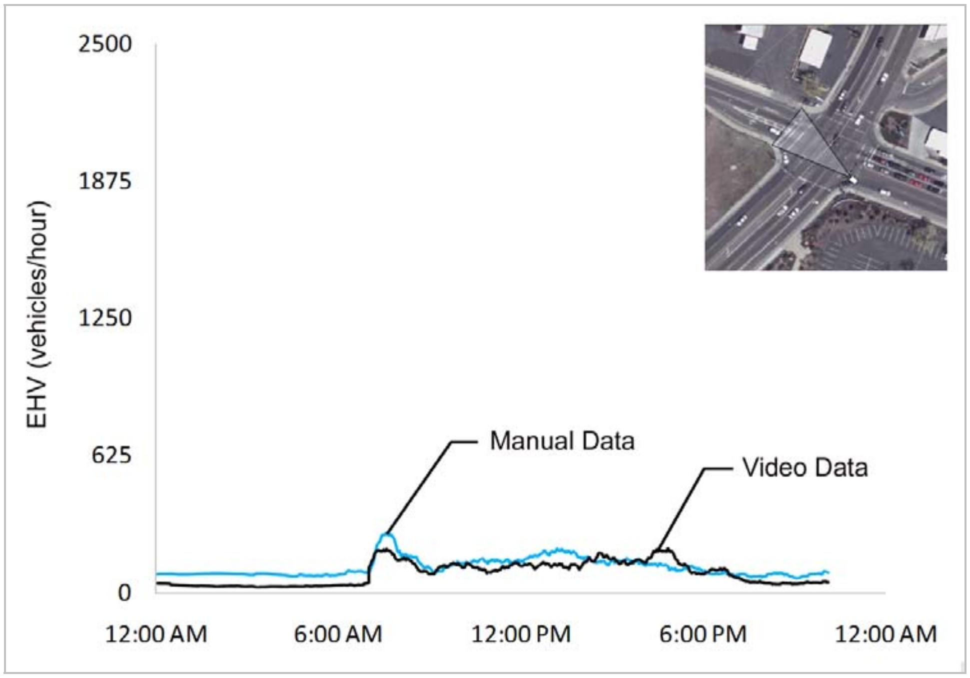


(a) Northbound.

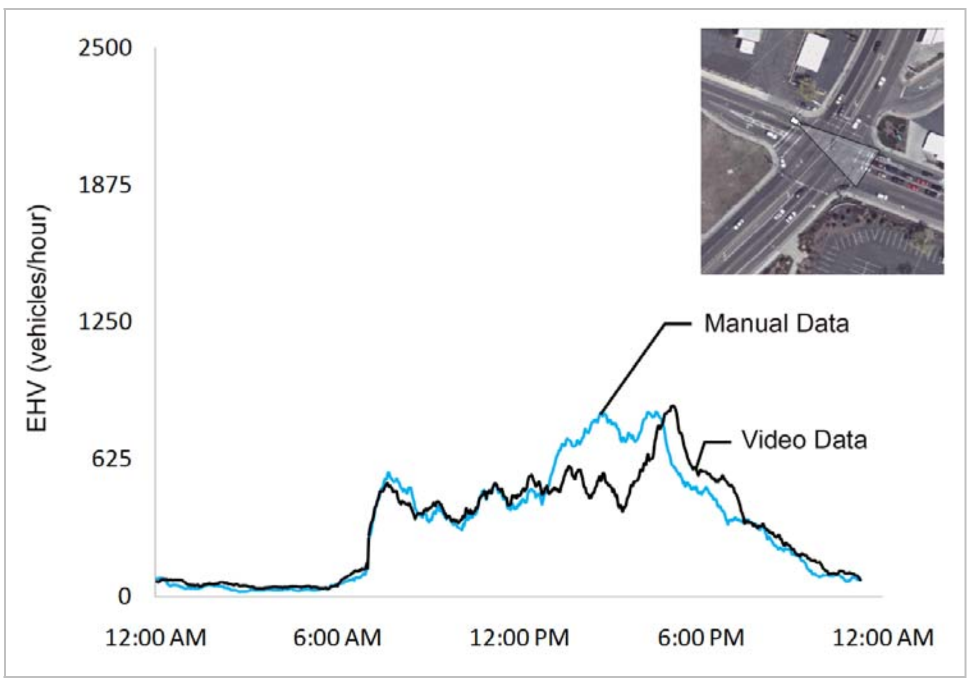


(b) Southbound.

Figure 17. EHV Plots by Approach.



(c) Eastbound.



(d) Westbound.

Figure 17. EHV Plots by Approach (continued).

The video trace lines in the EHV plots generally follow the manual trace lines, but there are some trends, similar to those seen in the V/C ratio data. On the north- and southbound approaches (Figures 17a and 17b, respectively), the video unit produced counts higher than those counted manually for most of the day. On the east- and westbound approaches (Figures 17c and 17d, respectively), the video units produced counts lower than the manual counts for most of the day.

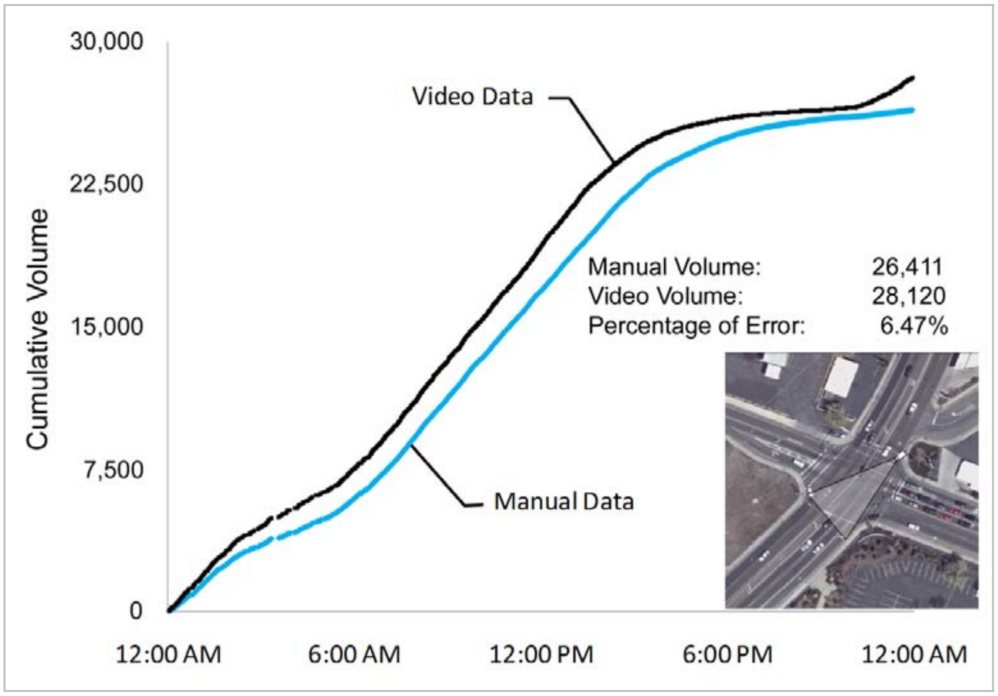
Figure 18 shows the cumulative volume plots by approach to allow for evaluation of the accuracy of the video counts. Each cumulative volume plot has two trace lines, one for the manually counted data and one for the video-generated data. The percentage of error in the video-generated data was determined by comparing the cumulative volume counts from the video data with the counts from the manual data (see Eq. 4).

$$Percentage\ of\ error = \frac{video\ volume - manual\ volume}{manual\ volume} \qquad \text{(Eq. 4)}$$

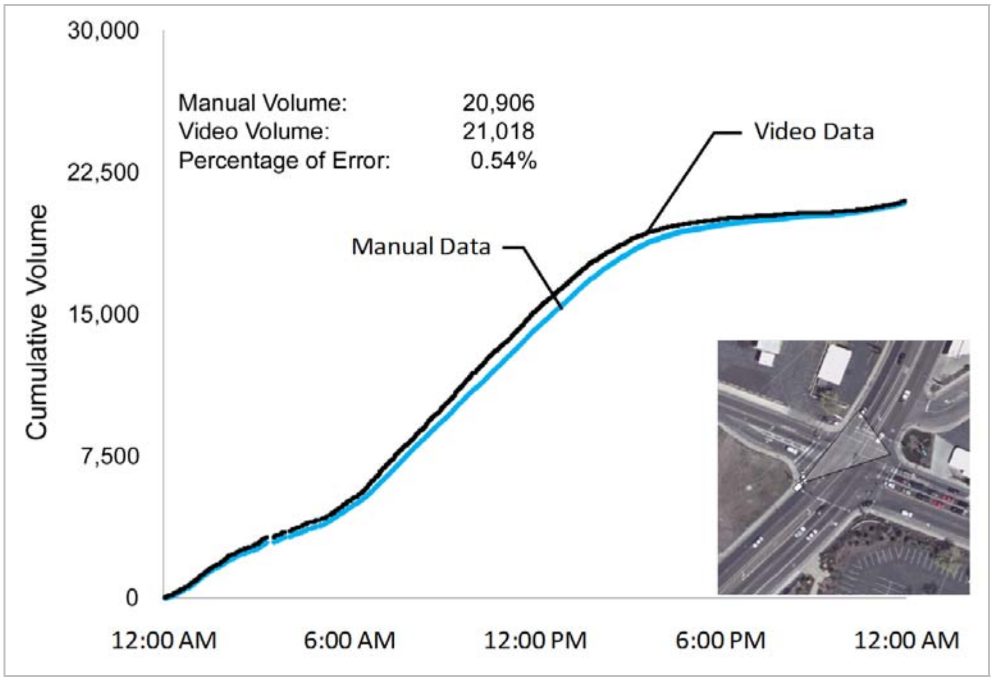
For example, for the northbound approach (Figure 18a), the calculation is as follows:

$$Percentage\ of\ error = \frac{28{,}120 - 26{,}411}{26{,}411} = 6.47\% \qquad \text{(Eq. 5)}$$

For each phase, Figure 18 gives the cumulative volume counts generated from the video and manual data and shows the percentage of error in the video data. With the exception of the eastbound approach, the cumulative volume counts generated by the video detector differed from the manual counts by less than 10 percent.

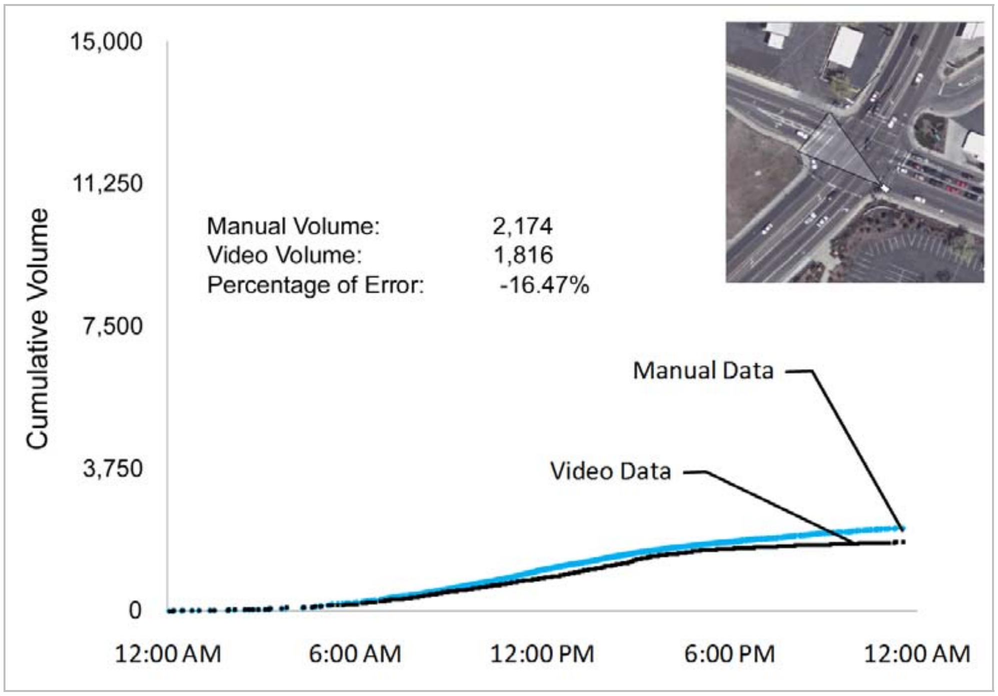


(a) Northbound.

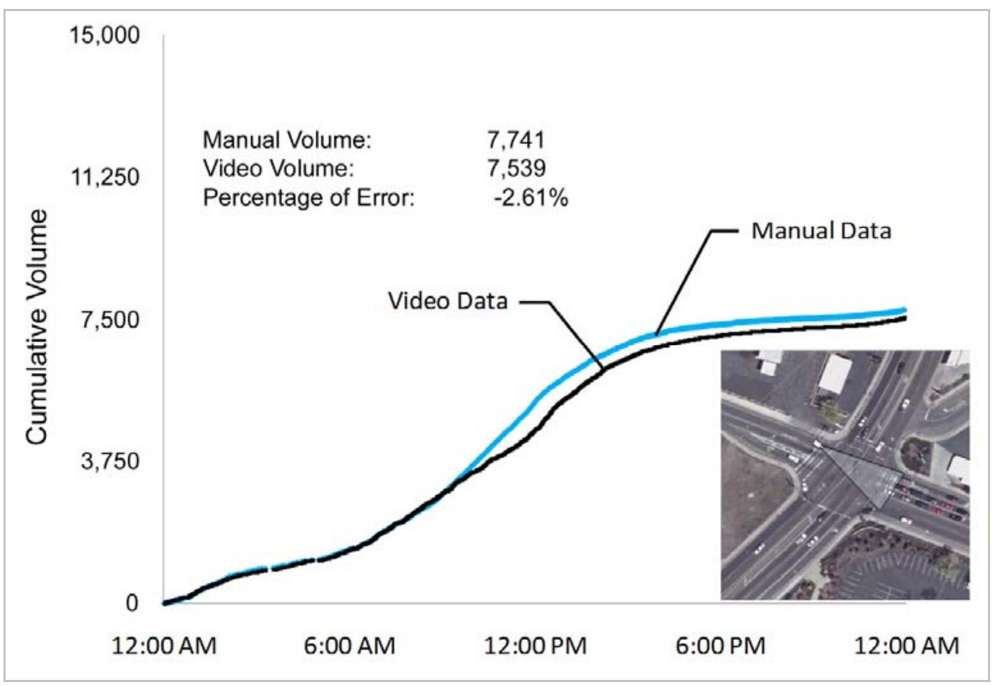


(b) Southbound.

Figure 18. Cumulative Volume Plots by Approach.



(c) Eastbound.



(d) Westbound.

Figure 18. Cumulative Volume Plots by Approach (continued).

Table 6 expands upon this data, listing also the lane-specific and time-specific volume counts and their percentages of error. The table indicates, for each direction and lane, whether the difference between the video and manual volumes is operationally significant, according to the criteria proposed earlier in this chapter: that a difference in cumulative count larger than 10 percent is unacceptable. All lane- and time-specific differences are operationally significant except those highlighted in light gray. The table similarly indicates the differences across all lanes and times in each direction. Only two such cumulative differences in the crosshatched cells are operationally significant.

Table 6. Cumulative Count Comparison, Individual Lane Basis.

		Video Volume				Manual Volume				Percentage of Error			
Approach	Lane	24-Hour Study Period	6:00–9:00 AM	3:00–6:00 PM	24-Hour Direction Cumulative	24-Hour Study Period	6:00–9:00 AM	3:00–6:00 PM	24-Hour Direction Cumulative	24-Hour Study Period	6:00–9:00 AM	3:00–6:00 PM	24-Hour Direction Cumulative
Northbound	Left Turn	1,987	1,098	30	28,124	106	3	24	26,411	1774.5%	36,500.0%	25.0%	6.5%
	Through Left	8,392	1,457	1,836		10,451	1,500	1,905		-19.7%	-2.9%	-3.6%	
	Through Right	11,468	1,913	2,238		10,158	1,465	1,918		12.9%	30.6%	16.7%	
	Right Turn	6,277	827	1,488		5,696	803	1,285		10.2%	3.0%	15.8%	
Southbound	Left Turn	2,154	294	676	21,018	1,118	262	276	20,906	92.7%	12.2%	144.9%	0.5%
	Through	7,409	1,020	235		9,775	1,749	221		-24.2%	-41.7%	6.3%	
	Through Right	11,455	1,550	1,884		10,013	1,021	1,722		14.4%	51.8%	9.4%	
Eastbound	Left Turn	1,102	213	257	1,815	1,200	198	146	2,174	-8.2%	7.6%	76.0%	-16.5%
	Through Right	713	116	208		974	218	246		-26.8%	-46.8%	-15.4%	
Westbound	Left Left	5,132	400	1,247	8,740	2,749	290	794	7,741	86.7%	37.9%	57.1%	12.9%
	Right Left	2,283	289	577		3,413	493	934		-33.1%	-41.4%	-38.2%	
	Through Right	1,325	269	337		1,579	196	494		-16.1%	37.2%	-31.8%	

Despite the operational significance of the differences in the lane- and time-specific data, some general trends did emerge. With the exception of the eastbound approach, the video units overcounted left-turn movements. As was discussed for Phase 1 V/C ratio data, it is believed that the location of the camera contributed to this overcount.

Volume in the lane adjacent to the interior left-turn lane was undercounted by the video unit on all approaches over the 24-hour analysis period. This may be tied to the overcount on the left-turn movements on the north- and southbound approaches, as well as the inside left-turn lane on the westbound approach; vehicles in these lanes may have been picked up by the count detectors in the adjacent left-turn lanes. Also, the video unit undercounted volume in both the east- and westbound through and through/right lanes over the 24-hour period, while overcounting volume for the same movements on the north- and southbound approaches, with the exception of the left-hand through lane on the northbound approach and the through lane on the southbound approach.

The authors of this report believe that much of this error could be rectified through improved camera placement, though some error is inherent in any detection technology. As shown in Figure 7, the video cameras in this study all exhibited some declination from perpendicular to the stop line, ranging from 4 to 20 degrees. Any deviation from perpendicular will increase vehicle occlusion and likely degrade the performance of the unit.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

This study demonstrated that with a reasonable amount of effort, a signalized intersection equipped with video cameras for presence detection can be retrofitted to generate flow rate information. The researchers in this study performed this retrofit, using a data logger embedded within the traffic controller to log flow rate information for each event, which allowed performance measures to be generated on a cycle-by-cycle basis. V/C ratio values calculated from the video data were shown to be statistically different from those calculated with manually counted data; however, for all but one phase, the difference was not operationally significant. Analysis of cumulative count data did show operationally significant differences. Due to the nature of the data collected (limited overlay of the vehicle count detection zones within the area recorded by the video cameras), the researchers were not able determine with certainty the cause of the inaccurate video-generated flow data; however, they propose that relocating the video camera from the luminaire arm to a location farther into the roadway, and higher in the air, might improve the accuracy. In general, this proof-of-concept study was successful.

A cost analysis showed an incremental cost of about $16,700 to equip an intersection with the ability to generate and log flow rate information if the work is completed as part of a signal construction or rehabilitation project.

Additionally, a separate track of research would be useful to ADOT and to other agencies using video detection equipment for presence detection. While much work has been done to validate the use of video detectors for presence detection (Rhodes et al. 2006; Rhodes, Jennings, et al. 2007; Rhodes, Smaglik, et al. 2007; Medina et al. 2009; Martin et al. 2004; MacCarley and Palen 2002; Middleton and Parker 2002), little research appears to have been conducted to validate using video detectors as count devices at signalized intersections (Zheng et al. 2009). Currently, there are no recommended practices, other than those provided by the manufacturer, to improve the accuracy of video detection count devices at signalized intersections. While it is theorized that much of the work relating to video presence detection would carry over, the potential benefit of improving the accuracy and reliability of vehicle counts generated by video detection units makes this type of research useful.

REFERENCES

Abbas, M., D. Bullock, and L. Head. 2001. “Real-Time Offset Transitioning Algorithm for Coordinating Traffic Signals.” *Transportation Research Record: Journal of the Transportation Research Board* 1748: 26–39.

Berry, D. S., and R. C. Pfefer. 1986. “Analysis of the Proposed Use of Delay-Based Levels of Service at Signalized Intersections.” *Transportation Research Record: Journal of the Transportation Research Board* 1091: 78–86.

Chang, J.; C. Oh, and M. Chang. 2000. “Effects of Traffic Condition (V/C) on Safety at Freeway Facility Sections.” *Transportation Research Circular E-C018: Fourth International Symposium on Highway Capacity Proceedings,* pages 200–208. Washington, D.C.: Transportation Research Board, National Research Council.

Frantzeskakis, J., and D. Iordanis. 1987. “Volume-to-Capacity Ratio and Traffic Accidents on Interurban Four-Lane Highways in Greece.” *Transportation Research Record: Journal of the Transportation Research Board* 1112: 29–38.

MacCarley, C. A., and J. Palen. 2002. “Evaluation of Video Traffic Sensors for Intersection Signal Actuation: Methods and Metrics.” Presented at the 81st Annual Meeting of the Transportation Research Board, Washington, D.C., paper 02-3920.

Martin, P. T., G. Dharmavaram, and A. Stevanovic. 2004. *Evaluation of UDOT’s Video Detection Systems: System’s Performance in Various Test Conditions.* Publication UT-04.14. Salt Lake City, Utah: Utah Department of Transportation.

Medina, J. C., R. Benekohal, and M. Chitturi. 2009. “Changes in Video Detection Performance at Signalized Intersections under Different Illumination Conditions.” *Transportation Research Record: Journal of the Transportation Research Board* 2129: 111-120.

Middleton, D., and R. Parker. 2002. *Vehicle Detector Evaluation.* Publication FHWA/TX-03/2119-1. Austin, Texas: Texas Department of Transportation.

Ngan, V., T. Sayed, and A. Abdelfatah. 2004. “Impacts of Various Parameters on Transit Signal Priority Effectiveness.” *Journal of Public Transportation* 7(3): 71-93.

Rhodes, A., D. Bullock, J. Sturdevant, and Z. Clark. 2006. *Evaluation of Stop Bar Video Detection Accuracy at Signalized Intersections.* Publication FHWA/IN/JTRP-2005/28. Indianapolis, Indiana: Indiana Department of Transportation.

Rhodes, A., K. Jennings, and D. Bullock. 2007. “Consistency of Video Detection Activation and Deactivation Times between Day and Night Periods.” *Journal of Transportation Engineering* 133(9): 505–512.

Rhodes, A., E. J. Smaglik, D. M. Bullock, and J. Sturdevant. 2007. "Operational Performance Comparison of Video Detection Systems." *ITE 2007 Annual Meeting and Exhibit Compendium of Technical Papers,* Washington, D.C.: Institute of Transportation.

Smaglik, E. J., D. M. Bullock, and T. Urbanik II. 2005. "Adaptive Split Control Using Enhanced Detector Data." *ITE 2005 Annual Meeting and Exhibit Compendium of Technical Papers,* paper AB05H-11. Washington, D.C.: Institute of Transportation.

Smaglik, E., S. Vanjari, V. Totten, E. Rusli, M. Ndoye, A. Jacobs, D. M. Bullock, and J. V. Krogmeier. 2007. "Performance of Modern Stop Bar Loop Count Detectors over Various Traffic Regimes." Presented at the 86th Annual Meeting of the Transportation Research Board, Washington, D.C., paper 07-1090.

Smaglik, E. J., A. Sharma, D. M. Bullock, J. R. Sturdevant, and G. Duncan. 2007. "Event-Based Data Collection for Generating Actuated Controller Performance Measures." *Transportation Research Record: Journal of the Transportation Research Board* 2035: 97–106.

Transportation Research Board (TRB). 2000. *Highway Capacity Manual.* Washington, D.C.: National Research Council.

Zheng, J., X. Ma, Y. Wang, and P. Yi. 2009. "Measuring Signalized Intersection Performance in Real Time with Traffic Sensors." Presented at the 86th Annual Meeting of the Transportation Research Board, Washington, D.C., paper 09-3119.

APPENDIX A. DATA LOGGER CONFIGURATION

The configuration details provided below were obtained from Econolite technical support.

Table 7. ASC/3 Data Collection Feature Notes.

SNMP Object ID	Mnemonic	Data Type	Value
1.3.6.1.4.1.1206.3.5.2.9.17.1	asc3DataLogEnable	Boolean	1 = Enable Logging. 2 = Disable Logging.
1.3.6.1.4.1.1206.3.5.2.9.17.2	asc3DataLogCircularBufferEnable	Boolean	1 = Enable Circular Logging. Oldest files are deleted to make room for new files. ftp delete does not work in this mode. 2 = Disable Circular Logging. No more files can be created after Flash is full. ftp delete works in this mode.

Note: For NTCIP Boolean objects, a 1 means "ON" and a 2 means "OFF." Any other value will return an error.

- On a new ASC/3 controller, the default value of asc3DataLogEnable is OFF and the default value of asc3DataLogCircularBufferEnable is ON. Upon power-up, the controller will not be logging any data.
- To log data, asc3DataLogEnable must be **set** to 1 using the ASC3_SNMP_Util.
- To disable circular buffer data, asc3DataLogCircularBufferEnable must be **set** to 2 using the ASC3_SNMP_Util.
- To get the current setting, press the **get** button on the Utility.
- You can download the data files via FTP. If circular buffering is enabled, you don't need to delete the old data files that you have downloaded. This will be taken care of automatically. If circular buffering is disabled, then you will need to use FTP to delete data files after you download them.
- Place the asc3Aries.ini file in the same folder as the utility program. When you start it up, it will display the above OIDs as the first two items. Do "set" or "get" operations as described above.

APPENDIX B. DATA TRANSLATOR INSTRUCTIONS/OUTPUT

The software provided to manage the binary controller data has additional options that were not utilized in this project. The research staff converted the binary data into CSV files only, though utilities are provided to parse the data into either an SQL database or simply provide more useful information. Below is the “Readme” file provided with the software; it is available through Econolite technical support.

CONTENTS SUMMARY

LogTrans.exe: This is a utility for translating DAT log files to CSV files or to a SQL database

EventParser.exe: Sample program that reads events from a database and consolidates them into more meaningful cycle information. The program is run from the command line as follows:

```
EventParser <database signal ID> <start data and time> <end date
and time> <connection string>

EventParser 4 "1/1/1970 00:00:00" "1/1/1970 23:59:59" "Data
Source=csdb1;Initial Catalog=PurdueLogs;User ID=sa;Password=pass"
```

EventParserSample.txt: Test output from the EventParser for demo purposes

EventParser (folder): C# source code for the EventParser

Database (folder): SQL scripts for installing a database for storing controller events

OVERALL USAGE/DATA LIFE CYCLE

```
                            ---> CSV files
                           /
ASC/3 .dat Logs-> LogTrans
                          \
                           ---> Database ---> EventParser ---> Cycle-Based Data
```

Instructions for converting to CSV data are below:

logtrans /dir:c:\temp\ /outdir:c:\temp

/dir:_____ = folder where the raw DAT files are located.

/outdir:______ = folder where it will put the translated CSV file.

The CSV file will contain data from all the DAT files in the input folder (rather than one for each hour as before).

Each line of CSV data includes a time stamp, event code, and a data column. The data column provides information pertaining to the specific nature of the event code (detector number, phase number, etc.). The list of event codes appears in Table 8.

Table 8. ASC/3 Data Logger Event Codes.

Event Code	Description
0	Phase Off
1	Phase Green
2	Phase Yellow
3	Phase Red Clear
4	Ped Off
5	Ped Walk
6	Ped Clear
8	Detector Off
9	Detector On
12	Overlap Off
13	Overlap Green
14	Overlap Green Extension
15	Overlap Yellow
16	Overlap Red Clear
20	Preempt Active
21	Preempt Off
24	Phase Hold Active
25	Phase Hold Released
26	Ped Call on Phase
27	Ped Call Cleared
32	Phase Min Complete
33	Phase Term Gap Out
34	Phase Term Max Out
35	Phase Term Force Off
40	Coord Pattern Change
41	Cycle Length Change
42	Offset Length Change

Table 8. ASC/3 Data Logger Event Codes (continued).

Event Code	Description
43	Split 1 Change
44	Split 2 Change
45	Split 3 Change
46	Split 4 Change
47	Split 5 Change
48	Split 6 Change
49	Split 7 Change
50	Split 8 Change
51	Split 9 Change
52	Split 10 Change
53	Split 11 Change
54	Split 12 Change
55	Split 13 Change
56	Split 14 Change
57	Split 15 Change
58	Split 16 Change
62	Coord cycle state change
63	Coord phase yield point
Coord Cycle State Code	**Description**
0	Free
1	In Step
2	Transition - Adding
3	Transition - Subtracting
4	Transition - Dwell
5	Local Zero
6	Pickup

Each converted file contains one hour of data. A few sample lines of data are shown below:

00:21.8	8	30
00:22.9	9	30
00:22.9	8	31
00:23.0	2	1

This example shows that at 00:21.8, Detector 30 turned off. Detector 30 then turned on again at 00:22.9. Phase 2 green turned on at 00:23.0.