FHWA/IN/JTRP-2005/28

Evaluation of Stop Bar Video Detection Accuracy at Signalized Intersections

By

Avery Rhodes, EIT
Graduate Research Assistant

Darcy Bullock, Ph.D., PE
Professor of Civil Engineering

James Sturdevant, PE
Traffic Management / Systems Operations Engineer
Federal Highway Administration

and

Zachary Clark
Undergraduate Research Assistant

School of Civil Engineering
Purdue University

Joint Transportation Research Program
Project Number: C-36-17QQQ
File Number: 8-4-69
SPR-2869

Prepared in Cooperation with the
Indiana Department of Transportation and the
U. S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views and policies of the Indiana Department of Transportation or Federal Highway Administration at the time of publication. The report does not constitute a standard, specification or regulation.

Purdue University
West Lafayette, IN 47907
May 2006

INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

TRB Subject Code: 54-5 Traffic Control Devices
Publication No. FHWA/IN/JTRP-2005/28, SPR-2869

May 2006
Final Report

Evaluation of Stop Bar Video Detection at Signalized Intersections

Introduction

Video detection has become a popular replacement for traditional loop detectors at signalized intersections. While loop detectors are a relatively mature device, the experience with video detection is much more limited. The Indiana Department of Transportation suspended the deployment of video detection subsequent to a 2001 JTRP report detailing several problems with the technology. These included missed calls at night at intersections with limited lighting and the tendency for video detectors to extend detection zones significantly at night due to headlight reflection off of the pavement.

In 2002, suggestions to improve the performance of video detection were posed by video detection manufacturers. They were primarily concerned with the placement of cameras, and suggested a preferred lateral offset and camera height.

In late 2003 and the summer of 2004, two test beds were constructed at signalized intersections in Noblesville, Indiana and West Lafayette, Indiana respectively. A camera was located at the vendor preferred location and several other cameras were located at slightly less optimal locations.

This report details the procedures used to evaluate three separate video detection systems at one of the test sites with respect to missed presence calls and false presence calls. A procedure to evaluate the consistency of detection zones between day and night lighting conditions is also presented. The conclusions of this report provide the Indiana Department of Transportation with important considerations when choosing detection technology at signalized intersections.

Findings

Autoscope (version 8.10), Peek UniTrak (version 2), and Iteris Vantage (Camera CAM-RZ3) were evaluated on the same traffic conditions at the Noblesville test site. All video detection systems were observed to fail to detect a large number of

vehicles. Such performance is unacceptable and justifies INDOT's moratorium on video detection at signalized intersections. Furthermore, the high number of false calls is unacceptable due to the resulting motorist delay.

Implementation

This report provides a comprehensive evaluation of the Autoscope (version 8.10), Peek UniTrak (version 2), and Iteris Vantage (Camera CAM-RZ3) stop bar video detection systems at signalized intersections. The deployment of video detections systems at signalized intersections is not recommended due to the following:

- Each video detection system showed a moderate to high number of missed and false calls over the two test periods.
- The loop detector showed only one missed call and 1 false call over both 48 hour test periods. The missed call was due to a wild vehicle path, while the false call was due to an unexplained eight-second extension.

- None of the three systems appeared to provide superior performance over the other three. The most accurate and reliable technology was the traditional loop detectors.
- The accuracy of all three systems appears to degrade with time and it appeared that a re-calibration was necessary only four months after the initial installation by factory representatives.

Contacts

For more information:

Prof. Darcy Bullock

Principal Investigator
School of Civil Engineering
Purdue University
West Lafayette IN 47907
Phone: (765) 494-2226
Fax: (765) 496-7996
E-mail: darcy@purdue.edu

Indiana Department of Transportation

Division of Research
1205 Montgomery Street
P.O. Box 2279
West Lafayette, IN 47906
Phone: (765) 463-1521
Fax: (765) 497-1665

Purdue University

Joint Transportation Research Program
School of Civil Engineering
West Lafayette, IN 47907-1284
Phone: (765) 494-9310
Fax: (765) 496-7996
E-mail: jtrp@ecn.purdue.edu
<http://www.purdue.edu/jtrp>

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA/IN/JTRP-2005/28	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Evaluation of Stop Bar Video Detection Accuracy at Signalized Intersections		5. Report Date May 2006	
		6. Performing Organization Code	
7. Author(s) Avery Rhodes, Darcy Bullock, James Sturdevant, Zachary Clark		8. Performing Organization Report No. FHWA/IN/JTRP-2005/28	
9. Performing Organization Name and Address Joint Transportation Research Program 1284 Civil Engineering Building Purdue University West Lafayette, IN 47907-1284		10. Work Unit No.	
		11. Contract or Grant No. SPR-2869	
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration.			
16. Abstract <p>Many agencies nationwide have adopted video vehicle detection technology as an alternative to inductive loops. While many product evaluations have been performed, the majority of these evaluations have concentrated on freeway applications where speed and volume were the primary evaluation criteria. At an actuated intersection, the metrics of speed and volume do not necessarily represent how well a device will operate as a presence detector.</p> <p>Video detection was evaluated at two signalized intersections in West Lafayette, Indiana and Noblesville, Indiana. A camera on each approach was located at the vendor recommended position, at a height of 40 feet and offset so that the camera was approximately inline with the lane line dividing the left-turn lane and through lane. Two additional cameras were located on each approach at less optimal horizontal and vertical locations. Additionally at the West Lafayette site, a fourth camera was located directly above the stop bar so that it looked down onto the detection zone.</p> <p>Inductive loops were used as baseline data to screen for discrepancies. Each time the loop detectors were not in agreement with a specific video detector, a discrepancy was noted. A digital video recording was later observed to determine whether the video detector or the loop detector was in error. An analysis of the data showed video detection was found to produce statistically significantly more false detections and missed detections than the loop detectors on most phases. Generally, only very small variations in video detector performance were observed at the different camera locations.</p> <p>The video detection was also evaluated in terms of its' consistency of detector turn-on and turn-off times. The video detection displays an undesirable inconsistency between night periods and day periods where it tends to activate 1 to 3 seconds earlier during the night period due to headlight reflections on the pavement. However, the camera at West Lafayette located directly above the stop bar displayed very consistent behavior between the night and day periods.</p> <p>.</p>			
17. Key Words Traffic engineering, traffic signals, traffic surveillance, traffic management, traffic control devices, loops, intelligent transportation systems, statistical analysis, statistics, video detection, vehicle detector performance		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 418	22. Price

INTRODUCTION

Video detection has become a popular replacement for traditional loop detectors at signalized intersections. While loop detectors are a relatively mature device, the experience with video detection is much more limited. The Indiana Department of Transportation suspended the deployment of video detection subsequent to a 2001 JTRP report detailing several problems with the technology. These included missed calls at night at intersections with limited lighting and the tendency for video detectors to extend detection zones significantly at night due to headlight reflection off of the pavement.

In 2002, suggestions to improve the performance of video detection were posed by video detection manufacturers. They were primarily concerned with the placement of cameras, and suggested a preferred lateral offset and camera height.

In late 2003 and the summer of 2004, two test beds were constructed at signalized intersections in Noblesville, Indiana and West Lafayette, Indiana respectively. A camera was located at the vendor preferred location and several other cameras were located at slightly less optimal locations.

This report details the procedures used to evaluate the video detection systems at varying locations with respect to missed presence calls and false presence calls. A procedure to evaluate the consistency of detection zones between day and night lighting conditions is also presented. The conclusions of this report provide the Indiana Department of Transportation with important considerations when choosing detection technology at signalized intersections.

FINDINGS

This study documented that in almost all conditions, loop detectors perform statistically significantly better than video detection in the number of missed presence calls and false presence calls that are produced. Video detection was found to produce a large number of false presence calls, which would adversely impact the operation of a signalized intersection that is accommodating vehicles that are not actually there. Video detection produced far fewer missed calls, but a significant enough number that they should be of concern, particularly because missed calls pose a safety problem if a motorist is not detected indefinitely. In this case, the motorist may choose to violate the red signal rather than continue to wait.

A change in operational performance was also documented between day and night lighting conditions. During night conditions, video detection tends to activate several seconds earlier due to headlights reflecting off of the pavement. This change in detection performance would need to be addressed in signal timing parameters, in order to provide efficient and consistent control over different lighting periods. The video detection deactivation times were found to be fairly consistent between day and night.

In West Lafayette, Indiana, a near side camera was located directly above the stop bar looking down onto the detection zone. This was the only camera position that demonstrated dramatically different performance than the cameras at all of the other positions. From a presence detection perspective, the performance of this camera was very similar to the other camera positions. However, from a consistency of activation times between day and night, this camera was much less susceptible to headlight reflections activating the camera early.

During the course of this research project, it was necessary to replace one of the cameras at each location after the hardware failed. Additionally, several times the units would have to be recovered manually by a technician through the software after the unit stopped responding. At the Noblesville site, one loop splice had to be replaced after false calls were discovered during wet weather conditions. The additional maintenance requirements for video detection should be considered when choosing technologies.

TABLE OF CONTENTS

	Page
LIST OF TABLES	iii
LIST OF FIGURES	x
IMPLEMENTATION REPORT	xxiii
ACKNOWLEDGMENTS	xxv
CHAPTER 1. Introduction	1
CHAPTER 2. Literature Review	4
2.1. Introduction	4
2.2. Early Evaluations	8
2.3. Aggregated Data Evaluations	9
2.4. Texas Transportation Institute Evaluations	12
2.5. Integration of CCTV and video detection	16
2.6. Parallax Error	17
2.7. Intersection Impacts Evaluations	18
2.8. Design Guidelines	19
2.9. Stop Bar Evaluations	20
2.10. State of Indiana Experiments	23
2.11. Approach for this Research	24
CHAPTER 3. Test Methodology	29
3.1. Discrepancies between Video Detectors and Loop Detectors	29
3.2. Impacts of Detection Errors	30
3.3. Graphical Presentations of Data	33
3.3.1. L1V0 and L0V1 Graphs	33
3.3.2. On-Time and Off-Time Histograms	33
3.4. Example Analyses	35
3.4.1. L1V0 Discrepancies – (Loop Active, Video Inactive)	35
3.4.2. L0V1 Discrepancies – (Loop Inactive, Video Active)	36
3.4.3. On-Time Histogram	36
3.4.4. Off-Time Histogram	37
3.5. Statistical Analysis	38
3.5.1. Analysis of L0V1 and L1V0 Results	38
3.5.2. Analysis of Difference of On-Time and Off-Time Histograms	41
CHAPTER 4. Testing Site	58
4.1. Introduction	58
4.2. Noblesville, Indiana	58
4.3. West Lafayette, Indiana	62

	Page
4.4. Traffic Cabinets	65
4.5. Software	69
4.6. Data Collection Example	77
CHAPTER 5. Data Management and Processing	100
5.1. Introduction.....	100
5.2. Database	101
5.3. Query.....	104
5.4. L0V1/L1V0 Graphs	105
5.4.1. Spreadsheet	105
5.4.2. Example Calculations	108
5.5. On-Time and Off-Time Histograms.....	111
5.5.1. Spreadsheet	111
5.5.2. Example Calculations	113
5.6. Advantages of Procedure	117
CHAPTER 6. Results	129
6.1. Introduction.....	129
6.2. Noblesville, Indiana, March 2004, Econolite Autoscope software v7.03.	132
6.3. Noblesville, Indiana, April 5, 2005, Econolite Autoscope software v8.10	133
6.4. West Lafayette, Indiana, January 25, 2005, Econolite Autoscope software v8.00 (Clear Weather)	134
6.5. West Lafayette, Indiana, January 20, 2005, Econolite Autoscope software v8.00 (Snow)	135
CHAPTER 7. Conclusions	154
7.1. Introduction.....	154
7.2. Evaluation Procedure	154
7.3. Comparison of Traditional Inductive Loops to Video Detection	156
7.4. Consistency of Detector Turn-On and Turn-Off Times	156
7.5. Camera Position Evaluation	157
7.6. Lighting Effects on Video Detection Performance	158
7.7. Weather Effects on Video Detection.....	159
LIST OF REFERENCES	166
Appendix A. Test Bed.....	169
Appendix B. Results – Noblesville, Indiana, March 24 th – 28 th , 2004	222
Appendix C. Results – Noblesville, Indiana, April 5 th , 2005.....	270
Appendix D. Results – West Lafayette, Indiana, January 25 th , 2005.....	318
Appendix E. Results – West Lafayette, Indiana, January 20 th , 2005	371

LIST OF TABLES

Table	Page
Table 2.1 Nine Possible Vehicle Detection Event Classes as Defined by MacCarley and Palen (2003)	22
Table 2.2 Phase Actuation Events Proposed by MacCarley and Palen (2003) ..	23
Table 2.3 Increase in Video Detection Activation Distances from Day to Night Due to Headlights (Source: Grenard (2001))	24
Table 2.4 Summary of Components of Previous Research and Framework for this Research.....	28
Table 3.1: Error types	41
Table 4.1 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') in Noblesville, Indiana.....	61
Table 4.2 Pixel Coordinates for Noblesville Video Captures (December 12, 2003, July 12, 2004 and Difference).....	62
Table 4.3 Autoscope Camera views for Cam4, Cam3, Cam2 and Cam1 in West Lafayette, Indiana	65
Table 4.4 Data Collection Cabinet Item Legend for Noblesville (Figure 4.12) and West Lafayette (Figure 4.13)	67
Table 4.5 Screen Overlay Legend for Noblesville (Figure 4.14) and West Lafayette (Figure 4.15)	71
Table 4.6 List of Tables Containing Poll Lists for Data Collection in Noblesville and West Lafayette.....	75
Table 4.7 Time Drift of Autoscope from the NIST Atomic Time	76
Table 4.8 Columns in Event Collector shown in Figure 4.20a.	78
Table 4.9 Autoscope Poll List for Northbound (West Lafayette, IN).....	98
Table 5.1 Data collection field names and descriptions.....	102
Table 5.2 Color legend for graphical results	107
Table 6.1 List of Tests Presented in the Results	130
Table 6.2 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (Noblesville, Indiana, March 2004)	138
Table 6.3 Difference between Loop Detector and Video Detector Turn On Times (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	139
Table 6.4 Difference between Loop Detector and Video Detector Turn Off Times (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	140

Table	Page
Table 6.5 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (Noblesville, Indiana, April 5, 2005).....	142
Table 6.6 Difference between Loop Detector and Video Detector Turn On Times (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	143
Table 6.7 Difference between Loop Detector and Video Detector Turn Off Times (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	144
Table 6.8 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (West Lafayette, Indiana, January 25, 2005).....	146
Table 6.9 Difference between Loop Detector and Video Detector Turn On Times (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	147
Table 6.10 Difference between Loop Detector and Video Detector Turn Off Times (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	148
Table 6.11 Chi-Squared Goodness of Fit Test between Day and Night On-Time Histograms (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	149
Table 6.12 Chi-Squared Goodness of Fit Test between Day and Night Off-Time Histograms (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	149
Table 6.13 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (West Lafayette, Indiana, January 20, 2005).....	151
Table 6.14 Difference between Loop Detector and Video Detector Turn On Times (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	152
Table 6.15 Difference between Loop Detector and Video Detector Turn Off Times (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	153
Table 7.1 Summary of statistical significance for false detections greater than 10 seconds in duration for three test periods.....	158
Table 7.2 Summary of statistical significance for missed detections greater than 10 seconds in duration for three test periods.....	159
Table A.3 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') in Noblesville, Indiana.....	180
Table A.4 Pixel Coordinates for Noblesville Video Captures (December 12, 2003, July 12, 2004 and Difference).....	186
Table A.5 Autoscope Camera views for Cam4, Cam3, Cam2 and Cam1 in West Lafayette, Indiana.....	191

Table	Page
Table A.6 Data Collection Cabinet Item Legend for Noblesville (Figure A.28) and West Lafayette (Figure A.29).....	200
Table A.7 Screen Overlay Legend for Noblesville (Figure A.30) and West Lafayette (Figure A.31).....	203
Table A.8 Columns in Event Collector shown in Figure A.37a.....	210
Table A.9 Time Drift of Autoscope from the NIST Atomic Time.....	211
Table A.10 Autoscope Poll List for Northbound (Noblesville, IN).....	213
Table A.11 Autoscope Poll List for Northbound (Noblesville, IN).....	214
Table A.12 Autoscope Poll List for Southbound (Noblesville, IN).....	215
Table A.13 Autoscope Poll List for Eastbound (Noblesville, IN).....	216
Table A.14 Autoscope Poll List for Westbound (Noblesville, IN).....	217
Table A.15 Autoscope Poll List for Northbound (West Lafayette, IN).....	218
Table A.16 Autoscope Poll List for Southbound (West Lafayette, IN).....	219
Table A.17 Autoscope Poll List for Eastbound (West Lafayette, IN).....	220
Table A.18 Autoscope Poll List for Westbound (West Lafayette, IN).....	221
Table B.1 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (Noblesville, Indiana, March 2004).....	237
Table B.2 Difference between Loop Detector and Video Detector Turn On Times During Red Through Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	248
Table B.3 Difference between Loop Detector and Video Detector Turn On Times During Green Through Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	249
Table B.4 Difference between Loop Detector and Video Detector Turn Off Times During Red Through Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	250
Table B.5 Difference between Loop Detector and Video Detector Turn Off Times During Green Through Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	251
Table B.6 Difference between Loop Detector and Video Detector Turn On Times During Red Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	262
Table B.7 Difference between Loop Detector and Video Detector Turn On Times During Protected Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	263
Table B.8 Difference between Loop Detector and Video Detector Turn On Times During Permitted Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	264
Table B.9 Difference between Loop Detector and Video Detector Turn Off Times During Red Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	265

Table	Page
Table B.10 Difference between Loop Detector and Video Detector Turn Off Times During Protected Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)....	266
Table B.11 Difference between Loop Detector and Video Detector Turn Off Times During Permitted Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)....	267
Table B.12 Difference between Loop Detector and Video Detector Turn On Times (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	268
Table B.13 Difference between Loop Detector and Video Detector Turn Off Times (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	269
Table C.1 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (Noblesville, Indiana, April 5th, 2005).....	285
Table C.2 Difference between Loop Detector and Video Detector Turn On Times During Red Through Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	296
Table C.3 Difference between Loop Detector and Video Detector Turn On Times During Green Through Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	297
Table C.4 Difference between Loop Detector and Video Detector Turn Off Times During Red Through Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	298
Table C.5 Difference between Loop Detector and Video Detector Turn Off Times During Green Through Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	299
Table C.6 Difference between Loop Detector and Video Detector Turn On Times During Red Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	310
Table C.7 Difference between Loop Detector and Video Detector Turn On Times During Protected Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	311
Table C.8 Difference between Loop Detector and Video Detector Turn On Times During Permitted Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	312
Table C.9 Difference between Loop Detector and Video Detector Turn Off Times During Red Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	313
Table C.10 Difference between Loop Detector and Video Detector Turn Off Times During Protected Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	314

Table	Page
Table C.11 Difference between Loop Detector and Video Detector Turn Off Times During Permitted Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	315
Table C.12 Difference between Loop Detector and Video Detector Turn On Times (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	316
Table C.13 Difference between Loop Detector and Video Detector Turn Off Times (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	317
Table D.1 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (West Lafayette, Indiana, January 25 th , 2005)	333
Table D.2 Difference between Loop Detector and Video Detector Turn On Times During Red Through Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	346
Table D.3 Difference between Loop Detector and Video Detector Turn On Times During Green Through Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	347
Table D.4 Difference between Loop Detector and Video Detector Turn Off Times During Red Through Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	348
Table D.5 Difference between Loop Detector and Video Detector Turn Off Times During Green Through Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	349
Table D.6 Difference between Loop Detector and Video Detector Turn On Times During Red Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	362
Table D.7 Difference between Loop Detector and Video Detector Turn On Times During Protected Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	363
Table D.8 Difference between Loop Detector and Video Detector Turn On Times During Permitted Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	364
Table D.9 Difference between Loop Detector and Video Detector Turn Off Times During Red Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	365
Table D.10 Difference between Loop Detector and Video Detector Turn Off Times During Protected Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	366

Table	Page
Table D.11 Difference between Loop Detector and Video Detector Turn Off Times During Permitted Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	367
Table D.12 Difference between Loop Detector and Video Detector Turn On Times (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	368
Table D.13 Difference between Loop Detector and Video Detector Turn Off Times (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	369
Table D.14 Chi-Squared Goodness of Fit Test between Day and Night On-Time Histograms (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	370
Table D.15 Chi-Squared Goodness of Fit Test between Day and Night Off-Time Histograms (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	370
Table E.1 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (West Lafayette, Indiana, January 20, 2005).....	386
Table E.2 Difference between Loop Detector and Video Detector Turn On Times During Red Through Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	397
Table E.3 Difference between Loop Detector and Video Detector Turn On Times During Green Through Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)....	398
Table E.4 Difference between Loop Detector and Video Detector Turn Off Times During Red Through Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	399
Table E.5 Difference between Loop Detector and Video Detector Turn Off Times During Green Through Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)....	400
Table E.6 Difference between Loop Detector and Video Detector Turn On Times During Red Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	411
Table E.7 Difference between Loop Detector and Video Detector Turn On Times During Protected Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	412
Table E.8 Difference between Loop Detector and Video Detector Turn On Times During Permitted Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	413

Table	Page
Table E.9 Difference between Loop Detector and Video Detector Turn Off Times During Red Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	414
Table E.10 Difference between Loop Detector and Video Detector Turn Off Times During Protected Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	415
Table E.11 Difference between Loop Detector and Video Detector Turn Off Times During Permitted Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	416
Table E.12 Difference between Loop Detector and Video Detector Turn On Times (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	417
Table E.13 Difference between Loop Detector and Video Detector Turn Off Times (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	418

LIST OF FIGURES

Figure	Page
Figure 2.1 Relationship of Proposed Test Methodology to Previous Research ..	27
Figure 3.1 L0V1 and L1V0 Discrepancy Concept.....	46
Figure 3.2 Effect of Headlight Reflection on Video Detection	47
Figure 3.3 Headway Effects	48
Figure 3.4 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends.....	49
Figure 3.5 Example L1V0 Errors (Noblesville, IN)	50
Figure 3.6 Example L0V1 Errors (Noblesville, IN)	51
Figure 3.7 Example On-Histogram Events for Camera 1 (Noblesville, IN)	52
Figure 3.8 Example Off-Histogram Events for Camera 1 (Noblesville, IN)	53
Figure 3.9 Example of Discrepancies between Loop Detection Zones and Video Detection Zones.	54
Figure 3.10 Example Calculations for Statistical Significance of Error Proportions between Loop Detectors and Video Detectors (West Lafayette, January 25 th , 2005, Northbound Phase 2)	55
Figure 3.11 Example Thresholds for West Lafayette Northbound Camera 3 (January 25, 2005) for Evaluation of Average Difference of On and Off Times using the Student's T-distribution	56
Figure 3.12 On Time Threshold Range for West Lafayette Northbound Camera 3 (January 25, 2005).	57
Figure 4.1 Summary of Test Bed Purpose and Output.....	80
Figure 4.2 Noblesville Intersection Layout.....	81
Figure 4.3 West Lafayette Intersection Layout	82
Figure 4.4 Sample Approach Detail (West Lafayette, IN – Northbound Approach)	83
Figure 4.5 Typical Pole Configurations.....	84
Figure 4.6 Example Camera Locations	85
Figure 4.7: Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Eastbound Approach in Noblesville during December 2003 and July 2004	86
Figure 4.8 Temperature at Noblesville, Indiana during December 2003 and July 2004 (Corresponds to Screen Captures in Figure 4.7)	87
Figure 4.9 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Eastbound Approach in Noblesville	88

Figure	Page
Figure 4.10 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Northbound Approach in West Lafayette during October 2004	89
Figure 4.11 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Northbound Approach in West Lafayette..	90
Figure 4.12 Noblesville Data Collection Cabinet.....	91
Figure 4.13 West Lafayette Data Collection Cabinet	92
Figure 4.14 Noblesville Example Screen Overlay.....	93
Figure 4.15 West Lafayette Example Screen Overlay	94
Figure 4.16 Econolite Autoscope Mini-Hub II I/O Indications	95
Figure 4.17 Autoscope Network Browser	96
Figure 4.18 Autoscope Data Collector: Creating a Poll	97
Figure 4.19 Sample Autoscope Poll List (Northbound – West Lafayette, IN)	97
Figure 4.20 Autoscope Data Collector: State Data with Example Screen Captures	99
Figure 5.1 Autoscope Data Collector: Event Data and Text File.....	118
Figure 5.2 Data Management Structure	119
Figure 5.3 Microsoft Access: Data Import Specification	119
Figure 5.4 Data Processing: Microsoft Access Database Structure	120
Figure 5.5 Data Processing: Microsoft Query used to Connect Microsoft Access Database and Microsoft Excel.....	121
Figure 5.6: Data Processing: Microsoft Query used to Connect Microsoft Access Database and Microsoft Excel: Data Range Properties.....	122
Figure 5.7: Data Processing: Microsoft Excel – L0V1/L1V0 Spreadsheet Settings	122
Figure 5.8 Data Processing: Microsoft Excel – L0V1/L1V0 Spreadsheet List of Large Errors.....	123
Figure 5.9 Data Processing Microsoft Excel: Sample Input and Output (Query Data Sheet)	124
Figure 5.10 Data Processing: Calculations Methodology	125
Figure 5.11 Data Processing: Calculations Methodology (System State - (See Column J in Figure 5.9)	126
Figure 5.12 Data Processing: Microsoft Excel – On-Time/Off-Time Spreadsheet Settings Sheet	126
Figure 5.13 Data Processing Microsoft Excel: Sample Input and Output (Query Data Sheet)	127
Figure 5.14 Data Processing: Calculations Methodology	128
Figure 6.1 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (March 2004, Noblesville, Indiana)	137
Figure 6.2 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (April 5, 2005, Noblesville, Indiana)	141
Figure 6.3 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (January 25, 2005, West Lafayette, Indiana).....	145

Figure	Page
Figure 6.4 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (January 20, 2005, West Lafayette, Indiana).....	150
Figure 7.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends.....	160
Figure 7.2 Far Side Camera Locations at Noblesville, Indiana and West Lafayette, Indiana	161
Figure 7.3 Example of Difference in Turn On Times During a Night Period between Far Side Camera Location and Above Stop Bar Camera Location	162
Figure 7.4 On-Time Histograms for two camera locations at West Lafayette, Indiana (January 25, 2005).....	163
Figure 7.5 Roadway Lighting at Noblesville, Indiana and West Lafayette, Indiana	164
Figure 7.6 Roadway Lighting and Camera 4 Position at West Lafayette, Indiana	165
Figure A.1 Summary of Test Bed Purpose and Output	170
Figure A.2 Noblesville Intersection Location.....	171
Figure A.3 West Lafayette Intersection Location	172
Figure A.4 Aerial Photograph of Noblesville Intersection.....	173
Figure A.5 Aerial Photograph of West Lafayette Intersection	174
Figure A.6 Noblesville Intersection Layout	175
Figure A.7 West Lafayette Intersection Layout	176
Figure A.8 Sample Approach Detail (West Lafayette, IN – Northbound Approach)	177
Figure A.9 Typical Pole Configurations	178
Figure A.10 Example Camera Locations	179
Figure A.11 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Northbound Approach in Noblesville during December 2003 and July 2004.	181
Figure A.12 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Southbound Approach in Noblesville during December 2003 and July 2004.	182
Figure A.13 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Eastbound Approach in Noblesville during December 2003 and July 2004.	183
Figure A.14 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Westbound Approaches in Noblesville during December 2003 and July 2004.	184
Figure A.15 Temperature at Noblesville, Indiana during December 2003 and July 2004 (Corresponds to Screen Captures in Figure 4.7).....	185
Figure A.16 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Northbound Approach in Noblesville.....	187
Figure A.17 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Southbound Approach in Noblesville.	188

Figure	Page
Figure A.18 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Eastbound Approach in Noblesville	189
Figure A.19 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Westbound Approach in Noblesville.	190
Figure A.20 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Northbound Approach in West Lafayette during October 2004	192
Figure A.21 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Southbound Approach in West Lafayette during October 2004.	193
Figure A.22 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Eastbound Approach in West Lafayette during October 2004.	194
Figure A.23 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Westbound Approach in West Lafayette during October 2004.	195
Figure A.24 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Northbound Approach in West Lafayette	196
Figure A.25 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Southbound Approach in West Lafayette.	197
Figure A.26 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Eastbound Approach in West Lafayette.	198
Figure A.27 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Westbound Approach in West Lafayette.	199
Figure A.28 Noblesville Data Collection Cabinet	201
Figure A.29 West Lafayette Data Collection Cabinet.....	202
Figure A.30 Noblesville Example Screen Overlay	204
Figure A.31 West Lafayette Example Screen Overlay.....	205
Figure A.32 Econolite Autoscope Mini-Hub II I/O Indications	206
Figure A.33 Autoscope Network Browser	207
Figure A.34 Autoscope Data Collector: Creating a Poll	208
Figure A.35 Sample Autoscope Poll List (Northbound – West Lafayette, IN) ...	208
Figure A.36 Sample Autoscope Poll List (Northbound – West Lafayette, IN) ...	209
Figure A.37 Autoscope Data Collector: State Data with Example Screen Capture	212
Figure B.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends.....	223
Figure B.2 Weather at Eagle Creek Airpark (Indianapolis, IN) During March 2004 Noblesville Testing Period	224
Figure B.3 Noblesville Northbound Through-Right Movement (Phase 2), 12:00 AM March 26th – 12:00 AM March 27th L1V0 and L0V1 Graphs for Cameras 1 through 3	226

Figure	Page
Figure B.4 Noblesville Northbound Left Turn Movement (Phase 5), 12:00 AM March 26th – 12:00 AM March 27th L1V0 and L0V1 Graphs for Cameras 1 through 3	227
Figure B.5 Noblesville Southbound Through-Right Movement (Phase 6), 6:00 PM March 24th – 6:00 PM March 25th L1V0 and L0V1 Graphs for Cameras 1 through 3	228
Figure B.6 Noblesville Southbound Left Turn Movement (Phase 1), 6:00 PM March 24th – 6:00 PM March 25th L1V0 and L0V1 Graphs for Cameras 1 through 3	229
Figure B.7 Noblesville Eastbound Through-Right Movement (Phase 4), 12:30 AM March 27th – 12:30 AM March 28th L1V0 and L0V1 Graphs for Cameras 1 through 3	230
Figure B.8 Noblesville Eastbound Left-Turn Movement (Phase 7), 12:30 AM March 27th – 12:30 AM March 28th L1V0 and L0V1 Graphs for Cameras 1 through 3	231
Figure B.9 Noblesville Westbound Through-Right Movement (Phase 8), 1:00 AM March 28th – 1:00 AM March 29th L1V0 and L0V1 Graphs for Cameras 1 through 3	232
Figure B.10 Noblesville Westbound Left-Turn Movement (Phase 3), 1:00 AM March 28th – 1:00 AM March 29th L1V0 and L0V1 Graphs for Cameras 1 through 3	233
Figure B.11 Tabulation of Discrepancies Longer than 5 Seconds for All Approaches (March 2004, Noblesville, Indiana)	234
Figure B.12 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (March 2004, Noblesville, Indiana)	235
Figure B.13 Tabulation of Discrepancies Longer than 20 Seconds for All Approaches (March 2004, Noblesville, Indiana)	236
Figure B.14 On Time Histograms for Three Cameras. Noblesville Northbound Through-Right Movement (Phase 2), (March 26th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	238
Figure B.15 Off Time Histograms for Three Cameras. Noblesville Northbound Through-Right Movement (Phase 2), (March 26th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	239
Figure B.16 On Time Histograms for Three Cameras. Noblesville Southbound Through-Right Movement (Phase 6), (Day Period: March 25th, 2004, 12:00 PM to 4:00 PM, Night Period: March 24th, 2004, 8:00 PM to 12:00 AM)....	240
Figure B.17 Off Time Histograms for Three Cameras. Noblesville Southbound Through-Right Movement (Phase 6), (Day Period: March 25th, 2004, 12:00 PM to 4:00 PM, Night Period: March 24th, 2004, 8:00 PM to 12:00 AM)....	241
Figure B.18 On Time Histograms for Three Cameras. Noblesville Eastbound Through-Right Movement (Phase 4), (March 27th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	242

Figure	Page
Figure B.19 Off Time Histograms for Three Cameras. Noblesville Eastbound Through-Right Movement (Phase 4), (March 27th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	243
Figure B.20 On Time Histograms for Three Cameras. Noblesville Westbound Through-Right Movement (Phase 8), (March 28th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	244
Figure B.21 Off Time Histograms for Three Cameras. Noblesville Westbound Through-Right Movement (Phase 8), (March 28th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	245
Figure B.22 On Time Histograms for Noblesville Eastbound Camera 1 Through-Right Movement (Phase 2), (March 27th, 2004).....	246
Figure B.23 Off Time Histograms for Noblesville Eastbound Camera 1 Through-Right Movement (Phase 2), (March 27th, 2004).....	247
Figure B.24 On Time Histograms for Four Cameras. Noblesville Northbound Left-Turn Movement (Phase 5), (March 26th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	252
Figure B.25 Off Time Histograms for Four Cameras. Noblesville Northbound Left-Turn Movement (Phase 5), (March 26th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	253
Figure B.26 On Time Histograms for Four Cameras. Noblesville Southbound Left-Turn Movement (Phase 1), (Day Period: March 25th, 2004, 12:00 PM to 4:00 PM, Night Period: March 24th, 2004, 8:00 PM to 12:00 AM).....	254
Figure B.27 Off Time Histograms for Four Cameras. Noblesville Southbound Left-Turn Movement (Phase 1), (Day Period: March 25th, 2004, 12:00 PM to 4:00 PM, Night Period: March 24th, 2004, 8:00 PM to 12:00 AM).....	255
Figure B.28 On Time Histograms for Four Cameras. Noblesville Eastbound Left-Turn Movement (Phase 7), (March 27th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	256
Figure B.29 Off Time Histograms for Four Cameras. Noblesville Eastbound Left-Turn Movement (Phase 7), (March 27th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	257
Figure B.30 On Time Histograms for Four Cameras. Noblesville Westbound Left-Turn Movement (Phase 3), (March 28th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	258
Figure B.31 Off Time Histograms for Four Cameras. Noblesville Westbound Left-Turn Movement (Phase 3), (March 28th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	259
Figure B.32 On Time Histograms for Noblesville Eastbound Camera 1 Left-Turn Movement (Phase 5), (March 27th, 2004)	260
Figure B.33 Off Time Histograms for Noblesville Eastbound Camera 1 Left-Turn Movement (Phase 5), (March 27th, 2004)	261
Figure C.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends.....	271

Figure	Page
Figure C.2 Weather at Eagle Creek Airpark (Indianapolis, IN) During April 5th, 2005 Noblesville Testing Period	272
Figure C.3 Noblesville Northbound Through-Right Movement (Phase 2), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3	274
Figure C.4 Noblesville Northbound Left Turn Movement (Phase 5), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3	275
Figure C.5 Noblesville Southbound Through-Right Movement (Phase 6), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3	276
Figure C.6 Noblesville Southbound Left Turn Movement (Phase 1), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3	277
Figure C.7 Noblesville Eastbound Through-Right Movement (Phase 4), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3	278
Figure C.8 Noblesville Eastbound Left-Turn Movement (Phase 7), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3	279
Figure C.9 Noblesville Westbound Through-Right Movement (Phase 8), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3	280
Figure C.10 Noblesville Westbound Left-Turn Movement (Phase 3), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3	281
Figure C.11 Tabulation of Discrepancies Longer than 5 Seconds for All Approaches (April 5th, 2005, Noblesville, Indiana)	282
Figure C.12 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (April 5th, 2005, Noblesville, Indiana)	283
Figure C.13 Tabulation of Discrepancies Longer than 20 Seconds for All Approaches (April 5th, 2005, Noblesville, Indiana)	284
Figure C.14 On Time Histograms for Three Cameras. Noblesville Northbound Through-Right Movement (Phase 2), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	286
Figure C.15 Off Time Histograms for Three Cameras. Noblesville Northbound Through-Right Movement (Phase 2), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	287
Figure C.16 On Time Histograms for Three Cameras. Noblesville Southbound Through-Right Movement (Phase 6), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	288
Figure C.17 Off Time Histograms for Three Cameras. Noblesville Southbound Through-Right Movement (Phase 6), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	289

Figure	Page
Figure C.18 On Time Histograms for Three Cameras. Noblesville Eastbound Through-Right Movement (Phase 4), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	290
Figure C.19 Off Time Histograms for Three Cameras. Noblesville Eastbound Through-Right Movement (Phase 4), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	291
Figure C.20 On Time Histograms for Three Cameras. Noblesville Westbound Through-Right Movement (Phase 8), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	292
Figure C.21 Off Time Histograms for Three Cameras. Noblesville Westbound Through-Right Movement (Phase 8), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	293
Figure C.22 On Time Histograms for Noblesville Eastbound Camera 1 Through-Right Movement (Phase 4), (April 5th, 2005)	294
Figure C.23 Off Time Histograms for Noblesville Eastbound Camera 1 Through-Right Movement (Phase 4), (April 5th, 2005)	295
Figure C.24 On Time Histograms for Four Cameras. Noblesville Northbound Left-Turn Movement (Phase 5), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	300
Figure C.25 Off Time Histograms for Four Cameras. Noblesville Northbound Left-Turn Movement (Phase 5), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	301
Figure C.26 On Time Histograms for Four Cameras. Noblesville Southbound Left-Turn Movement (Phase 1), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	302
Figure C.27 Off Time Histograms for Four Cameras. Noblesville Southbound Left-Turn Movement (Phase 1), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	303
Figure C.28 On Time Histograms for Four Cameras. Noblesville Eastbound Left-Turn Movement (Phase 7), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	304
Figure C.29 Off Time Histograms for Four Cameras. Noblesville Eastbound Left-Turn Movement (Phase 7), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	305
Figure C.30 On Time Histograms for Four Cameras. Noblesville Westbound Left-Turn Movement (Phase 3), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	306
Figure C.31 Off Time Histograms for Four Cameras. Noblesville Westbound Left-Turn Movement (Phase 3), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	307
Figure C.32 On Time Histograms for Noblesville Eastbound Camera 1 Left-Turn Movement (Phase 7), (April 5th, 2005).....	308
Figure C.33 Off Time Histograms for Noblesville Eastbound Camera 1 Left-Turn Movement (Phase 7), (April 5th, 2005).....	309

Figure	Page
Figure D.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends.....	319
Figure D.2 Weather at Purdue University Airport (West Lafayette, IN) During January 25 th , 2005 West Lafayette Testing Period.....	320
Figure D.3 West Lafayette Northbound Through-Right Movement (Phase 2), 12:00 AM January 25 th – 12:00 AM January 26 th L1V0 and L0V1 Graphs for Cameras 1 through 4.....	322
Figure D.4 West Lafayette Northbound Left-Turn Movement (Phase 5), 12:00 AM January 25 th – 12:00 AM January 26 th L1V0 and L0V1 Graphs for Cameras 1 through 4.....	323
Figure D.5 West Lafayette Southbound Through-Right Movement (Phase 6), 12:00 AM January 25 th – 12:00 AM January 26 th L1V0 and L0V1 Graphs for Cameras 1 through 4.....	324
Figure D.6 West Lafayette Southbound Left-Turn Movement (Phase 1), 12:00 AM January 25 th – 12:00 AM January 26 th L1V0 and L0V1 Graphs for Cameras 1 through 4.....	325
Figure D.7 West Lafayette Eastbound Through-Right Movement (Phase 4), 12:00 AM January 25 th – 12:00 AM January 26 th L1V0 and L0V1 Graphs for Cameras 1 through 4.....	326
Figure D.8 West Lafayette Eastbound Left-Turn Movement (Phase 7), 12:00 AM January 25 th – 12:00 AM January 26 th L1V0 and L0V1 Graphs for Cameras 1 through 4.....	327
Figure D.9 West Lafayette Westbound Through-Right Movement (Phase 8), 12:00 AM January 25 th – 12:00 AM January 26 th L1V0 and L0V1 Graphs for Cameras 1 through 4.....	328
Figure D.10 West Lafayette Westbound Left-Turn Movement (Phase 3), 12:00 AM January 25 th – 12:00 AM January 26 th L1V0 and L0V1 Graphs for Cameras 1 through 4.....	329
Figure D.11 Tabulation of Discrepancies Longer than 5 Seconds for All Approaches (January 25 th , 2005, West Lafayette, Indiana).....	330
Figure D.12 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (January 25 th , 2005, West Lafayette, Indiana).....	331
Figure D.13 Tabulation of Discrepancies Longer than 20 Seconds for All Approaches (January 25 th , 2005, West Lafayette, Indiana).....	332
Figure D.14 On Time Histograms for Four Cameras. West Lafayette Northbound Through-Right Movement (Phase 2), (January 25 th , 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	334
Figure D.15 Off Time Histograms for Four Cameras. West Lafayette Northbound Through-Right Movement (Phase 2), (January 25 th , 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	335
Figure D.16 On Time Histograms for Four Cameras. West Lafayette Southbound Through-Right Movement (Phase 6), (January 25 th , 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	336

Figure	Page
Figure D.17 Off Time Histograms for Four Cameras. West Lafayette Southbound Through-Right Movement (Phase 6), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	337
Figure D.18 On Time Histograms for Four Cameras. West Lafayette Eastbound Through-Right Movement (Phase 4), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	338
Figure D.19 Off Time Histograms for Four Cameras. West Lafayette Eastbound Through-Right Movement (Phase 4), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	339
Figure D.20 On Time Histograms for Four Cameras. West Lafayette Westbound Through-Right Movement (Phase 8), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	340
Figure D.21 Off Time Histograms for Four Cameras. West Lafayette Westbound Through-Right Movement (Phase 8), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	341
Figure D.22 On Time Histograms for West Lafayette Northbound Camera 1 Through-Right Movement (Phase 2), (January 25th, 2005)	342
Figure D.23 On Time Histograms for West Lafayette Northbound Camera 4 Through-Right Movement (Phase 2), (January 25th, 2005)	343
Figure D.24 Off Time Histograms for West Lafayette Northbound Camera 1 Through-Right Movement (Phase 2), (January 25th, 2005)	344
Figure D.25 Off Time Histograms for West Lafayette Northbound Camera 4 Through-Right Movement (Phase 2), (January 25th, 2005)	345
Figure D.26 On Time Histograms for Four Cameras. West Lafayette Northbound Left-Turn Movement (Phase 5), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	350
Figure D.27 Off Time Histograms for Four Cameras. West Lafayette Northbound Left-Turn Movement (Phase 5), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	351
Figure D.28 On Time Histograms for Four Cameras. West Lafayette Southbound Left-Turn Movement (Phase 1), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	352
Figure D.29 Off Time Histograms for Four Cameras. West Lafayette Southbound Left-Turn Movement (Phase 1), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	353
Figure D.30 On Time Histograms for Four Cameras. West Lafayette Eastbound Left-Turn Movement (Phase 7), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	354
Figure D.31 Off Time Histograms for Four Cameras. West Lafayette Eastbound Left-Turn Movement (Phase 7), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	355
Figure D.32 On Time Histograms for Four Cameras. West Lafayette Westbound Left-Turn Movement (Phase 3), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	356

Figure	Page
Figure D.33 Off Time Histograms for Four Cameras. West Lafayette Westbound Left-Turn Movement (Phase 3), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	357
Figure D.34 On Time Histograms for West Lafayette Northbound Camera 1 Left-Turn Movement (Phase 5), (January 25th, 2005).....	358
Figure D.35 On Time Histograms for West Lafayette Northbound Camera 4 Left-Turn Movement (Phase 5), (January 25th, 2005).....	359
Figure D.36 Off Time Histograms for West Lafayette Northbound Camera 1 Left-Turn Movement (Phase 5), (January 25th, 2005).....	360
Figure D.37 Off Time Histograms for West Lafayette Northbound Camera 4 Left-Turn Movement (Phase 5), (January 25th, 2005).....	361
Figure E.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends.....	372
Figure E.2 Weather at Purdue University Airport (West Lafayette, IN) During January 20 th , 2005 West Lafayette Testing Period.....	373
Figure E.3 West Lafayette Northbound Through-Right Movement (Phase 2), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4.....	375
Figure E.4 West Lafayette Northbound Left-Turn Movement (Phase 5), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4.....	376
Figure E.5 West Lafayette Southbound Through-Right Movement (Phase 6), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4.....	377
Figure E.6 West Lafayette Southbound Left-Turn Movement (Phase 1), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4.....	378
Figure E.7 West Lafayette Eastbound Through-Right Movement (Phase 4), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4.....	379
Figure E.8 West Lafayette Eastbound Left-Turn Movement (Phase 7), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4.....	380
Figure E.9 West Lafayette Westbound Through-Right Movement (Phase 8), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4.....	381
Figure E.10 West Lafayette Westbound Left-Turn Movement (Phase 3), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4.....	382
Figure E.11: Tabulation of Discrepancies Longer than 5 Seconds for All Approaches (January 20, 2005, West Lafayette, Indiana).....	383
Figure E.12: Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (January 20, 2005, West Lafayette, Indiana).....	384

Figure	Page
Figure E.13: Tabulation of Discrepancies Longer than 20 Seconds for All Approaches (January 20, 2005, West Lafayette, Indiana).....	385
Figure E.14 On Time Histograms for Four Cameras. West Lafayette Northbound Through-Right Movement (Phase 2), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	387
Figure E.15 Off Time Histograms for Four Cameras. West Lafayette Northbound Through-Right Movement (Phase 2), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	388
Figure E.16 On Time Histograms for Four Cameras. West Lafayette Southbound Through-Right Movement (Phase 6), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	389
Figure E.17 Off Time Histograms for Four Cameras. West Lafayette Southbound Through-Right Movement (Phase 6), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	390
Figure E.18 On Time Histograms for Four Cameras. West Lafayette Eastbound Through-Right Movement (Phase 4), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	391
Figure E.19 Off Time Histograms for Four Cameras. West Lafayette Eastbound Through-Right Movement (Phase 4), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	392
Figure E.20 On Time Histograms for Four Cameras. West Lafayette Westbound Through-Right Movement (Phase 8), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	393
Figure E.21 Off Time Histograms for Four Cameras. West Lafayette Westbound Through-Right Movement (Phase 8), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)	394
Figure E.22 On Time Histograms for West Lafayette Northbound Camera 1 Through-Right Movement (Phase 2), (January 20th, 2005)	395
Figure E.23 Off Time Histograms for West Lafayette Northbound Camera 1 Through-Right Movement (Phase 2), (January 20th, 2005)	396
Figure E.24 On Time Histograms for Four Cameras. West Lafayette Northbound Left-Turn Movement (Phase 5), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	401
Figure E.25 Off Time Histograms for Four Cameras. West Lafayette Northbound Left-Turn Movement (Phase 5), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	402
Figure E.26 On Time Histograms for Four Cameras. West Lafayette Southbound Left-Turn Movement (Phase 1), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	403
Figure E.27 Off Time Histograms for Four Cameras. West Lafayette Southbound Left-Turn Movement (Phase 1), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	404

Figure	Page
Figure E.28 On Time Histograms for Four Cameras. West Lafayette Eastbound Left-Turn Movement (Phase 7), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	405
Figure E.29 Off Time Histograms for Four Cameras. West Lafayette Eastbound Left-Turn Movement (Phase 7), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	406
Figure E.30 On Time Histograms for Four Cameras. West Lafayette Westbound Left-Turn Movement (Phase 3), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	407
Figure E.31 Off Time Histograms for Four Cameras. West Lafayette Westbound Left-Turn Movement (Phase 3), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM).....	408
Figure E.32 On Time Histograms for West Lafayette Northbound Camera 1 Left-Turn Movement (Phase 5), (January 20th, 2005).....	409
Figure E.33 Off Time Histograms for West Lafayette Northbound Camera 1 Left-Turn Movement (Phase 5), (January 20th, 2005).....	410

IMPLEMENTATION REPORT

This report served as a comprehensive evaluation of the use of video detection systems at signalized intersections. The following data and conclusions can be used to determine whether to use video detection or loop detection at signalized intersections. Important operational characteristics of video detection have been identified that should be considered if video detection is installed at a location, including:

- Video detection produces a statistically significant higher number of false calls than loop detection.
- Video detection produces a statistically significant higher number of missed calls than loop detection. Loop detectors very rarely, if ever, produce missed calls.
- Cameras placed at vendor preferred lateral and vertical location do not demonstrate any noticeable performance improvements over cameras placed at the less preferable positions.
- Video detection shifts towards earlier activation times at night due to headlight reflection off of the pavement. To provide efficient and consistent signal operation throughout the day, controller timing parameters will need to be adjusted by time of day and day of year when using video detection to account for the difference in video detection performance during night lighting periods. This extra effort should be considered when choosing to deploy video detection at an intersection.
- Video deactivation times are fairly consistent between night and day.

- A camera location above the stop-bar looking down onto the detection zone shows the most consistent detection zone between day and night by reducing the effect of headlights activating the cameras early.
- The ability to adjust video detection zones through software gives a versatile solution which should be considered when providing video detection at locations where the traffic configuration may change frequently such as in construction zones.
- Video detection does not require any in-pavement hardware. It should be considered at locations where an approach consists of a bridge deck, brick roadway or other consideration where the installation of loops into the roadway surface would be undesirable.
- Video detection units required more maintenance than the loop detectors during the course of this research project. The additional demands for maintenance should be considered when deploying video detection.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of this research work by the Joint Transportation Research Program of the Indiana Department of Transportation and Purdue University. We also offer our thanks to the members of the Study Advisory Committee for this project, who so willingly gave us their time and their expert guidance: Shuo Li (Project Administrator), Ed Cox, Ryan Gallagher, Chip Lang, Dennis Lee, Dana Plattner, Dan Shamo, Jim Sturdevant and Greg Walk.

CHAPTER 1. INTRODUCTION

The most common vehicle detection technology used to supply information to an actuated signal controller are inductive loops installed under the pavement or into the pavement through a cut and seal process. Loop detectors are a relatively mature technology that are used by agencies nationwide. Although the technology is reasonably affordable, accurate and easy to use; there remain disadvantages to the technology which prompts alternative detection technologies to continue to be developed.

One of the main disadvantages of loop detectors is that they are an intrusive detection device installed directly onto or into the roadway. Therefore the installation usually requires a road closure. The installation procedure can also be messy as the pavement must be cut and the cut cleaned with high pressure water, which can result in a wet, slick and muddy roadway surface. Finally, loop detectors are prone to failure at splice points and in cracking pavements.

Several alternative technologies have been developed for vehicle detection. The most popular is video detection, a non-intrusive technology, where images from a video camera are processed to determine presence of vehicles. The apparent advantages of a video detection system include, reduced lane closures for an installation and are not impacted by pavement conditions. Also, they are more flexible in that the detection zones can be easily modified, and they can be installed at any location, such as on bridge decks and brick roadways where loop detectors may be impractical. Also, if the video detection system is connected to

a communication system it is possible that video images of intersections can be accessed from a remote location.

Many agencies nationwide have adopted video vehicle detection technology as an alternative to inductive loops. While many product evaluations have been performed, the majority of these evaluations have concentrated on freeway applications where speed and volume were the primary evaluation criteria. At an actuated intersection, the metrics of speed and volume do not necessarily represent how well a device will operate as a presence detector. Occasional errors may not present problems in a freeway application but even a single error may cause a safety concern at a signalized intersection. For example, a driver who is not served by a signal, because the detector has missed a call, may grow impatient and violate a red signal.

As video detection has increased in popularity for use at signalized intersections several researchers have evaluated the technology from this perspective. Most notably, Grenard (1) developed a procedure for the evaluation of presence detection by comparing the outputs of two detectors. This procedure is explained and expanded upon as part of this research. A comprehensive review of previous research is included in Chapter 2.

The methodology proposed by Grenard (1) is presented in Chapter 3. The expansion of the Grenard procedure has been to include signal phase colors as part of the evaluation. This is an important enhancement as most video detection systems modify their detection algorithms depending on the signal phase. For example, during a red signal an algorithm looking for stopped vehicles will be used, while during a green signal an algorithm looking for objects in motion will be used.

The Grenard (1) methodology is useful for looking at the number of missed calls and false calls, however another important characteristic of a vehicle detector is its' ability to provide precise vehicle actuations. For example, if a detector reports a vehicle call, but only after the vehicle has been in the detection zone for 3 seconds this may not register as a missed call but it is still a concern to the traffic engineer who relies on the detector to provide accurate headway measurements. A second methodology was developed to look at latency issues in the turn-on and turn-off times in video detectors.

To collect data used in this research, a well instrumented intersection (with both loop detectors and video detectors) was required. Two intersections were re-constructed with a comprehensive array of detectors and corresponding test bed equipment to accommodate the data collection. The two intersection test beds used in this research are presented in Chapter 4.

The data collected for this research was quite extensive as a data point is recorded at each detector state change and phase change. A data management and processing procedure was used to simplify the storage of data and subsequent calculations from that data. The data management and data processing procedures are described in detail in Chapter 5.

Overall, four tests, each 24 hours in length, were completed and are presented in this report. The results from the tests are presented qualitatively through graphs and histograms in Chapter 6. Additionally, statistical procedures have been used to quantitatively evaluate and compare the performance of the detectors. The results in Chapter 6 represent a small representative portion of the data processed for this project. The test results are reported in their entirety in the Appendices. Finally, the conclusions that were developed as a result of this research are presented in Chapter 7.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

As the cost of video detection has fallen and the familiarity with the technology has increased, the use of this non-intrusive alternative to loops has expanded. Non-intrusive technologies, indicating an installation that is not directly on or in the pavement, are popular because in most cases it eliminates the need for road closures during installation and maintenance activities. While this certainly presents an advantage, the collective experience with video detection and other non-intrusive technologies is somewhat limited compared to inductive loops.

Some advantages of video detection are that it does not require lane closures, saw cutting pavement, or workers in or adjacent to traffic. Additionally, loop failures may occur due to pavement distress or by utility or other construction. However, certain disadvantages in video detection have also been identified such as reflections on wet pavement, sun glare and lateral and longitudinal occlusion. A survey regarding the use of video detection at signalized intersections documenting many of the advantages and disadvantages of loops verses video was completed in December 2004 (17).

The majority of recent research on video detection has focused on product evaluations (1, 2, 4, 5, 6, 8, 9, 13). Many of these evaluations have occurred exclusively in freeway settings (6, 8, 9, 13). As the collective experience with the technology has expanded, many agencies are using video detection at actuated signalized intersections, where the demands on the detector are drastically

different than in a freeway application. The state of Texas has even developed a manual for deploying video detection at signalized intersections (10).

Typically, freeway detectors have been evaluated by comparing the detector output with speed and volume, from manual measurements or from a device known to provide a high degree of accuracy (4, 5, 6, 8, 9, 13). Research on freeway evaluations of video detection have provided many general observations applicable to both freeway and intersection applications. The majority of these observations pertain to environmental factors during the test, including weather, lighting and traffic conditions. Generally, weather has been reported to have a minimal impact on performance (1,4). However, headlight glare from wet pavement resulting in false calls was documented in several research papers (1, 4, 8). Additionally, any environmental condition that reduces visibility will have a negative impact on the video detector's performance (4, 5, 8).

Lighting is the most cited condition associated with video detection errors (1, 4, 5, 6, 8, 9, 13), especially during transitional periods at sunrise and sunset (4, 8). Usually night periods are characterized as having more detection problems than daytime periods because headlights are often all that are visible. However, daytime sun position can also have an impact on operations. The sun may cause reduced visibility due to glare or create moving vehicle shadows and stationary shadows that can sometimes confuse the detector. Newer video detector systems include shadow processing to mitigate these effects.

Cameras mounted at lower mounting heights have been reported to have more detection errors because of vehicle occlusions and more direct headlight reflections on the pavement (4, 5, 6, 8). However, a high camera mount may experience sway and vibration which may compromise detection performance (4, 5). Several video manufacturers and researchers have noted that the optimal

lateral placement for the camera is a head-on view to minimize perspective distortions and eliminate cross lane occlusion events (4, 5, 6, 8).

At an actuated intersection, the aggregate metrics of volume and speed do not necessarily represent how well a device will operate as a presence detector. Occasional errors may not present problems in a freeway application but even a single error may cause a safety concern at a signalized intersection. For example, a driver who is not served by a signal, because the detector has missed a call, may grow impatient and violate a red indication.

Several researchers have recognized that the demands on a vehicle detection device are much different at an intersection than on a freeway. In 2000, Indiana developed a presence based procedure for evaluating video detection (1). That report introduced a method of tabulating the periods of discrepancy between inductive loops and video detectors to identify which time periods required a human to develop ground truth data from a recorded video.

MacCarley and Palen (2) proposed a common method and metrics for evaluating detectors at actuated signalized intersections. Common definitions were introduced to describe the types of detector errors possible in the intersection environment. One part of the methodology penalizes a detector if it makes a mistake. Another part penalizes the detector if the controller makes incorrect decisions because of a detector mistake, such as terminating a phase early or failing to call or extend a phase. Abbas and Bonneson (10) described the performance of video detection in terms of discrepant call frequency, the number of discrepant calls per signal cycle, and an error rate of discrepant calls to true calls. Baculinao (12) documented that if the video detector is used for advanced detection the effective vehicle length will increase because the top of the vehicle is being detected and the signal timing will have to be adjusted accordingly. The

following sections summarize the historical evaluation procedures, categorization of errors and impacts of optics.

The majority of research conducted on video detection systems has concentrated on product evaluations particularly in freeway settings. The most common evaluation procedure is a comparison of speed and volume data from the video detection system, to data collected by a human observer. However, some researchers have automated this procedure to more efficiently gather data and some have expanded the methods and metrics to be more appropriate to more complex situations such as intersection installations.

The literature is remarkably consistent in the identification of the most common inaccuracies observed in the performance of video detection systems. Essentially any event that comprises the visibility of the video detection system will have a degrading effect on the systems' accuracy. From a design perspective this means locating the camera in an optimal position to view the roadway and minimize occlusion. From an operations perspective, this means being aware of weather and lighting events that would reduce the visibility in the video scene, such as fog and rain events, or the daily lighting transitional periods from night-to-day and day-to-night.

While most of the literature has focused on the identification of problems that practitioners need to be aware of, several of the researchers also appropriately identify advantages that video detection may have over other technologies. For example, video offers a more versatile solution than loop detectors and in some situations may be more cost effective as well (6, 7, 10).

The following summary of existing research focuses on the method and metrics used by the researchers in the evaluation of video detection technology. The identified advantages and disadvantages of video detection are also a chief

concern. This chapter concludes with a proposed framework for further evaluations.

2.2. Early Evaluations

One of the earliest evaluations of video detection was conducted by MacCarley et. al. in 1992 (4). MacCarley et. al. identified 10 video detection systems that were available commercially or as a prototype in the early 1990's. In total, eight of the systems were tested in a variety of conditions that the researchers created by editing hundreds of hours of video to create multiple 20-minute test segments with varying traffic, lighting, site and camera positions.

MacCarley et. al. created the video suite using previously recorded video from freeway overpasses and since the test did not occur in real time, each camera could be tested under the same exact conditions. The researchers varied the test conditions by choosing video that was taken at different times of the day, such as during daylight hours, nighttime hours, and the transitional periods of sunrise and sunset. The videos were taken at different locations, and since the freeway overpass height was not consistent, the camera height also varied between locations. The researchers also varied the lateral position of the camera; the first position centered the camera view directly on the freeway centerline, and the second position was from the side of the detected freeway.

The vehicle counts and velocities from the test suite were determined by having a human observer observe the film frame-by-frame. This was then compared with the outputs of each of the camera systems. Video detection performed well under optimal conditions, however, significant error rates in both vehicle counts and speeds were documented during non-optimum conditions.

The general performance issues observed under non-optimum conditions are quite consistent with subsequent evaluations. Higher error rates were generally

observed at the lower mounting height, due to the occlusion created by large vehicles. Slow moving high density traffic also resulted in reduced accuracy. Transitional light periods during the morning and evening periods reduced the accuracy, which was further compounded by high volume traffic corresponding with the morning and evening rush hours.

Rain also posed a problem for video detection by reducing visibility as well as making the road easily reflect headlights. The systems were sometimes unable to distinguish between headlight reflection and actual vehicles. Finally, shadows also posed a problem for many of the systems. Long vehicular or stationary shadows increased the error rates on the systems tested. While video detection manufacturers have certainly worked to improve their product since the early 1990's many of the conditions cited by MacCarley et. al. continue to be mentioned as causes of poor video detection performance in more recent research.

2.3. Aggregated Data Evaluations

As interest in alternative detection technologies increased throughout the 1990's, several agencies have completed evaluations of various technologies. Video detection as one of the most popular emerging technologies is often included in such evaluations. Most of these evaluations occurred in freeway settings where the detector is primarily used to measure volumes and speeds.

One noteworthy evaluation of non-intrusive detection was completed by the Minnesota Department of Transportation (Mn/DOT) in partnership with the Federal Highway Administration (FHWA) in 1996 (5). Included in the review was an evaluation of video detection at both a freeway site and an intersection site.

The researchers in this study were able to evaluate the technology based on a much larger data set, because the output of the video detectors was compared

with the output of loop detectors and did not require a human observer. Prior to beginning the test, the loops were calibrated for volume and speed by using a human observer to verify their accuracy. This was completed at both the freeway and intersection site. Three loops at the intersection site were identified as being extremely accurate and these lanes were chosen for use in the evaluation.

Detector data, including volume, speed and vehicle classification, were collected in 5 and 15-minute bins. Each test site also included a weather monitoring station to provide hourly temperature, precipitation and wind speed values.

A number of methods were used to determine how closely the evaluated detectors conformed to the data reported by the inductive loops. Volume scatter plots were developed to give a visual representation of agreement by plotting the loop counts on the horizontal axis and the video detection count on the vertical axis. Speed data was compared in a similar manner.

The video technologies tested in Minnesota performed very well under optimal conditions at the freeway site. At the intersection site, the results were far more varied. The researchers noted some specific environmental conditions that seemed to degrade the performance of the video at both the freeway and intersection locations. The environmental conditions that degrade performance include stationary and moving shadows, direct sunlight, transitional periods at sunrise and sunset, wind-induced vibration, water, and grime on the camera lens. While these conditions were noted, the majority of errors correspond directly to the position and level of lighting at the site. The remaining environmental and weather conditions seemed to have a minimal impact on the technologies while the ambient lighting seemed to have a substantial impact.

The two main technologies tested during this study were the Econolite Autoscope 2004 and the Peek Video Trak-900. Both exhibited errors in periods during which

the light transitioned especially during the evening. The Autoscope device was impacted by wind movement when one of the lane lines began to activate a detection zone as the camera moved with the wind. The detection zone was repositioned which eliminated further occurrences of this problem.

Mn/DOT also concluded from their experience that the “installation and maintenance of video devices is much more involved than other types of technologies”. During the installation procedure, they realized that camera placement was critical to the successful performance of the system. Additionally, a high mounting position was desirable for two reasons, first the degree of occlusion is reduced and second the camera was more likely to stay clean at the higher position.

The State of Utah examined several video detection systems used in the state (17). The report concluded that video detection systems operate favorably under day and dusk conditions with 87.2% correct detections. However, the video detection performed worse under night conditions with only 73.4% correct detections and 19.9% false calls. Similar results were obtained during inclement weather with 81.3% correct detections and 14.1% false calls. The missed calls, which are of the most concern to agencies, ranged from 4.6% to 6.8%.

The researchers also explored the impact of detector errors on signal timings. Of the discrepant calls, only 14% appeared to have consequences on the traffic signal timings.

Due to the poor performance of the system under nighttime conditions, the study recommended sufficient background lighting be provided at intersections with video detection. Additionally, they recommend the accurate placement of cameras, focusing settings and field of view calibration.

Oh et. al. (13) made a more comprehensive evaluation of a single vendor's product, the PEEK VideoTrak. Again this research focused on a freeway application with the main evaluation metrics being vehicle speeds and volumes. The ground truth data was developed through manual counts of a videotape. Speed counts were manually taken in the field with a laser distance device. While the focus of the research concentrated on evaluation of the size, width and placement of detection tracking strips, the authors also made some general conclusions about the overall performance of the video detector systems.

Problems with occlusion were noted even on cameras mounted up to 50 ft (15 m) high. The system performed particularly poorly during nighttime hours. The cameras were more accurate when they were detecting approaching traffic as compared to when they were detecting departing traffic. Finally, the speed and volume data was found to be minimally affected by weather conditions.

2.4. Texas Transportation Institute Evaluations

The State of Texas through the Texas Transportation Institute has shown significant interest in alternative technologies for vehicle detection. Several of these reports have specifically focused on video detection.

In 1996, Hartmann et. al. identified several problems with traditional loops that have led the State of Texas to investigate replacement technologies (6). These problems include lack of flexibility, loop failure particularly due to pavement stress, and the necessity of roadway closure for installation and repair.

The video system tested by Hartmann et. al. was the Autoscope 2004 detection system. Count, speed accuracy and occlusion were used to evaluate the performance of the system in a freeway setting. Perhaps the most valuable aspect of this particular test was the researcher's use of three different camera mounting heights, to quantify any improvement in camera performance at higher

mounting positions. The camera performance was analyzed at three mounting heights, 30 ft (9.1m) 40 ft (12.2 m) and 49.5 ft (15.1 m). The video was also analyzed using three different vehicle speeds.

The test indicated that the camera height and travel lane location impacted the system's ability to correctly detect vehicles. Generally, the higher camera mounting height and the travel lanes furthest from the camera mounting position showed the most accurate results when there were no vehicles in the nearer lanes. The speeds reported by the camera were significantly different than the speeds obtained from a radar gun. Tests at night revealed significant errors in counts.

A cost study was also completed to compare the life cycle cost of a video detection system to loop detectors. The report estimates that life-cycle costs of video detection are similar to the cost of detection by inductive loops when many loops are replaced by a single camera such as at an intersection. At a freeway location where only a few loops might be replaced by a camera, the video detection will likely not be cost effective.

In 1999, the State of Texas continued to show interest in the use of alternative vehicle detection. Middleton et. al. reported on a freeway detector evaluation that included several non-intrusive technologies (7). One of the non-intrusive technologies evaluated was the VideoTrak 900 video detection system by Peek. The system was evaluated for accuracy from vehicle presence and speed. Installation cost and ease of setup and calibration was also considered and reported. The Peek VideoTrak performed adequately except during nighttime and during rain. The researchers concluded that the video performance during these time periods was unacceptable. Additionally, in comparison with the other non-intrusive technologies (passive acoustic, microloops) and intrusive technologies

(inductive loops) it was considered to be the most difficult to set up and was the most expensive to purchase and install.

Additionally, Middleton et. al. (8) reported on the agency experience, cost effectiveness and performance of various non-intrusive technologies used for both intersections and freeway detection. This report relied on a literature review, as well as surveys of personnel from the Texas Department of Transportation (TxDOT) and other agencies from out of state. The experience with video detection systems reported by Middleton et. al. (2000) is consistent with the literature review performed for this research. The video detection systems operate sufficiently under optimal conditions. Problems mainly occur during night periods, transitional lighting periods, and during any other events, such as weather conditions, that reduce visibility.

Cost comparisons showed that freeway detection by loops or video detection is about the same. However, if the costs to motorists are considered, due to the delay and operating cost increases during a road closure for loop installation, then video detection may be more cost effective.

More recently, Middleton et. al. (9) performed a more comprehensive freeway evaluation of alternative detectors. The report also includes a survey of current detector practice not only of agencies within the state of Texas, but out-of-state agencies as well.

The video detection system evaluated in this report was the Autoscope Solo Pro and the Iteris Vantage. The researchers also tested competing non-intrusive devices including a microwave vehicle detector and an acoustic vehicle detector. Baseline data was created using the Peek ADR-600 vehicle classifier which was connected to four inductive loop detectors (two in each lane)

The accuracy of the ADR-600 was verified by having an observer monitor each traffic lane from a pre-recorded video while tabulating the number of vehicles by class. The classification accuracy and count accuracy was then determined by comparing the human collected data to the data from the ADR-600. The non-intrusive devices were evaluated on the parameters of speed, occupancy and volume.

The speed accuracy of the ADR-600 was achieved by having one observer monitor the video system output while the other took selected speed samples from vehicles during low to moderate traffic using a laser gun.

The classification accuracy of the ADR-600 was not entirely perfect; however the count accuracy was very high with the ADR-600 missing at most one or two vehicles per 15 minute period.

The Autoscope Solo Pro was mounted at 45' while the Iteris Vantage was mounted at 38.5'. The Autoscope Solo Pro provided fairly accurate count data for speeds above 40 MPH, but as congestion increased and speeds dropped significant undercounting occurred.

The Iteris Vantage had the highest standard deviation of counts for all the devices included in the test. However, it also had among the lowest standard deviations for speed. The Iteris also operated well in the congested region with little to no degradation in its' speed and counting accuracy.

Both the Iteris Vantage and the Autoscope Solo Pro showed good and consistent occupancy values.

2.5. Integration of CCTV and video detection

Two studies completed in the State of Virginia demonstrate the versatility of a video detection system. The first study completed in 1994 by Cottrell (14) evaluated the use of combining the Autoscope system with the existing CCTV monitoring system to automatically provide incident detection and monitor traffic.

The Autoscope was evaluated by comparing the counts of loops and from the counts from the video detection system. The speeds reported by the loops and the video detection system were also compared. The Autoscope count was generally much higher than the loop count. Additionally, the Autoscope generated lower speeds than the loops. Overall the loop data appeared to be smooth and consistent, where the Autoscope data was much more erratic.

It should be noted that the CCTV cameras used in the study were not positioned ideally for use with the Autoscope system. For example, the distance from the camera to the detected lanes was twice the distance recommended by the manufacturer. Also, since the cameras continued to be used as surveillance cameras, it was difficult to return the cameras back to the detection position after they had been moved for surveillance purposes.

The researchers were unable to achieve the goal of providing incident detection using the Autoscope system to monitor the freeway CCTV cameras.

In 2004, a similar study was completed in the State of Virginia by Smith et. al. (15) with much more promising results. Again, the idea was to use the already deployed closed-circuit televisions (CCTV) in combination with a video detection system to provide measures of traffic conditions such as flow rate and average speed.

The system was evaluated under two cases. The first case considered the data collection accuracy before the CCTV camera was ever moved. The second case considered the case where the CCTV was repositioned back to its' original calibrated position after being moved for surveillance purposes.

In each case data was collected for a 30 minute period, in 20-second intervals. Video was recorded during each test and analyzed using slow-scan video equipment to count vehicles and obtain speeds by measuring the travel time required between two known points.

The count accuracy was given in terms of the root mean squared error (RMSE) in vehicles per 20 second interval. In Case I, this value was 2.22 while after repositioning this value only increased to 2.35 vehicles/20 seconds.

The speed accuracy was also considered before and after repositioning. The system did an excellent job of measuring average speed and the RMSE did not increase after the camera was repositioned.

Although the video detection system performed adequately during this test it should be noted that data was only collected for a 1-hour time period and that the time period did not comprehensively represent the entire range of conditions that a system deployed full time in the field would have to face.

2.6. Parallax Error

Tian et. al. (2002) (16) have comprehensively explored the phenomenon known as parallax error which represents errors related to distance measurements that are necessary for speed and headway. Parallax error occurs because video-image systems rely on the field of view. Usually video detection systems are calibrated by entering a known distance from two reference points in the field and that correspond to the points on the video image. The problem is that the

reference distance obtained in the field may not correlate exactly with the distance perceived on the video image. For example, a video detector may activate even if a vehicle has not yet reached the detector location in the field.

2.7. Intersection Impacts Evaluations

Bonneson et al. (10) evaluated several video detection products with a focus on quantifying detection accuracy. The authors also focused on developing guidelines that would describe when and how to use video detection. They also developed guidelines for detection design and detection layout.

Eight intersections and two freeway interchanges were included in a before-and-after study. Each location already had video detection installed prior to the study. The detector configurations were adjusted at each site according to the guidelines developed.

Detection accuracy was determined by counting the number of times that video detector either reported a vehicle in the detection zone when no vehicle was in fact present or when the video detector did not report a vehicle in the detection zone when in fact there was a vehicle present. Discrepant calls less than 0.3 seconds in length were disregarded.

The detection accuracy was then reported in terms of discrepant call frequency and error rate. Discrepant call frequency refers to the number of discrepant calls per signal cycle. The error rate is the ratio of discrepant calls to true calls.

The authors also developed a procedure to quantify the performance of the intersection so that it could be related back to the detector performance. Two metrics were chosen that would not pose a significant problem for collection and that could represent how efficiently the intersection was operating. The first measure of performance was phase max-out representing the percentage of

phases that max out rather than gap out. The second metric was control delay which is simply the delay incurred by motorists due to the signal control.

Data was collected by reviewing recorded videotapes that were chosen to represent a variety of geometric configurations, camera locations, traffic control situations, environmental conditions and operational scenarios.

The authors determined that when video detectors were set up to the established guidelines that max-out percentage and control delay were both reduced. Some other general observations were also recorded. An increase in camera height tends to decrease the call error rate. However, some sites experienced significant camera motion during windy periods and in these cases the call error rate increased with increasing camera height. Downstream distance to the camera location, camera pitch angle, and camera focal length did not have an observable effect on performance.

2.8. Design Guidelines

Abbas et. al. (11) published specific guidelines to aid agencies and contractors in the placement and configuration of detection zones on video detection systems. In addition to the occlusion problem noted by Mn/DOT and others, Abbas et. al. (11) also noted that a low camera position can increase the effective length of vehicles, perhaps causing the traffic signal to operate more inefficiently. Baculiano (12) specifically documented the need to reduce controller passage time in the city of Santa Clarita, California because of the increased effective length of vehicles.

Abbas et. al. (11) was more specifically concerned with evaluating the configuration and position of detection zones rather than an equipment evaluation. Data was collected at several intersections in Texas and then the detection zones were refined according to geometric calculations that would put

detection zones in the optimal positions. A before-and-after evaluation was completed using “phase max-out” and “waiting time” as measures of effectiveness. Phase max-out refers to the percentage of phases that are terminated when green reaches its maximum limit. Since phase termination by max-out tends to increase delay to the subject movement, a reduction in the number of phases that max-out would be desirable. Furthermore, the authors note that safety is reduced as compared to the situation where the signal gaps out because of the elimination of dilemma zone protection. The second measure of waiting time represents the time between the arrival of the first sustained call and the end of green for the subject phase.

The Texas study did conclude that properly placed and configured detection zones had a significant effect on the efficient and safe operation of the intersection. From a system evaluation standpoint it is probably most interesting to note that the two competing video systems used in the test performed equally well when properly tuned.

2.9. Stop Bar Evaluations

MacCarley and Palen (3) have suggested a very clearly defined common method and metrics for evaluating competing products for detecting vehicles at an intersection. The report is particularly valuable because it focuses on an evaluation of video detection. They correctly point out that the requirements of a detection system for signal actuation are significantly different than a detector designed only to collect traffic flow metrics such as count, average speed, volume, average headway and queue length. While the statistical errors that occur with this data correct themselves overtime, the possibility of a failure for a detector controlling an actuated intersection could mean a vehicle waiting indefinitely for a signal change.

The researchers note that while the majority of researchers and video manufacturers report detector performance in terms of “detection accuracy” there is little if any consistency in the methods and metrics used to determine detection accuracy.

The methods suggested for a detector evaluation include a measure of vehicle detection accuracy over a range of traffic and environmental scenarios. The authors suggest creating a video test suite, consisting of various video segments representing the typical hours in a day in an average year. A method of fairly and effectively distributing the effects of different traffic environmental conditions through a weighting procedure is presented.

The second part of the method is specifically applicable to actuated intersections as the authors propose a method of predicting the impacts to intersection operation due to the detector behavior.

The most useful vehicle detection procedure presented by the authors is the classification of vehicle detection event classes. These are nine possible events that describe the correct or incorrect behavior of the detector under evaluation. The nine vehicle detection event classes as proposed by MacCarley and Palen are described in Table 2.1.

Table 2.1 Nine Possible Vehicle Detection Event Classes as Defined by MacCarley and Palen (2003)

1.	Correct Detection	A vehicle is detected when it enters a detection zone, stays continuously detected while in the zone, and detection ceases when it leaves the zone.
2.	Detection with Latch	A vehicle is detected when present in a detection zone, stays continuously detected while in the zone, but detection remains on indefinitely after it leaves the zone.
3.	Multiple Detections	A vehicle is detected when present in a zone, but while in the zone detection ceases and repeats at least once, including the possibility of a final latch condition.
4.	Failure to Detect	A vehicle is not detected at all when present in a detection zone.
5.	Drop After Detection	A vehicle is initially detected after entering a zone, but later dropped (and not redetected) while stationary in the zone.
6.	Tailgate	Detection remains on for the second and possibly later vehicles following the leader in a platoon. (Detection correct for presence purposes such as signal actuation, but not for count or queue length determination purposes.)
7.	Tailgate with Latch	Tailgate event, but detection remains on indefinitely after last car in platoon leaves.
8.	False Detection	Detection reported when no vehicle present or near detection zone. Detection ceases when either the causal image artifact is no longer present or after five seconds.
9.	False Detection with Latch	False detection which stays on indefinitely.

The authors further develop the method by proposing a phase actuation test procedure which aims to evaluate the detector's performance on the actual traffic flow through the intersection. The actuation events are divided into three types for each of the two main signal intervals (red and green). The six events proposed by MacCarley and Palen are described in Table 2.2.

Table 2.2 Phase Actuation Events Proposed by MacCarley and Palen (2003)

Red Interval Events		
1.	Correct Actuation	During red interval, detection within one second of arrival of first vehicle, and detection held constant by logical OR of all lanes until observed R/G transition
2.	Failure to Actuate Correctly	During red interval, first vehicle not detected within one second of arrival or, after initial detection, logical OR of detection zones for all waiting vehicles FALSE at any time prior to observed R/G transition.
3.	False Actuation	During red interval, when no vehicles are present in any detection zone, detection occurs, either continuous or intermittent.
Green Interval Events		
4.	Correct Green Extension	During green interval, every vehicle or platoon is detected and no false detection occur.
5.	Potential Failure to Extend Green	During green interval, one or more vehicle(s) or platoon(s) was not detected.
6.	Potentially False Green Extension	During green interval, detection occurred when no vehicle or vehicles was/were present

The events proposed by MacCarley and Palen give a very good standard method for evaluating video and other detection technologies. The metrics that specifically address the performance of the video detector in the context of actuated signal controller are particularly useful. The majority of previous research addressed detection accuracy in terms of their ability to accurately collect volume and speed data. However, the impacts to the performance of a signal system caused by the behavior of the video detector are not necessarily represented by the accuracy of speed and volume measures. The most obvious example is that one missed vehicle in a volume count would be relatively minor, while an undetected motorist stranded indefinitely at a red signal would present serious problem with the detector.

2.10. State of Indiana Experiments

In 2001, the State of Indiana suspended the deployment of video detection at signalized intersections after several problems with video detection systems were

identified by Grenard et. al. (1). That report documented several scenarios, particularly at night in unlit intersections. During night periods, vehicle headlights often caused the cameras to place a call early, thereby extending the effective detection zone and reducing the efficiency of the signal. Also, at night the video detection would sometimes miss or drop a call of a vehicle stopped at the stop bar. The test was repeated with street lighting and showed an incremental improvement in the video detection performance. A summary of the increase in detector activation as reported by Grenard et. al. is shown in Table 2.3.

Table 2.3 Increase in Video Detection Activation Distances from Day to Night Due to Headlights (Source: Grenard (2001))

Approach	System 1		System 2	
	Absolute Increase (feet)	Percent Increase	Absolute Increase (feet)	Percent Increase
Northbound	27.3	207.68%	63.6	519.55%
Southbound	34.8	123.42%	51.2	260.03%
Eastbound	21.0	51.69%	66.3	235.21%

In contrast to most freeway evaluations of video detection, Grenard used detector presence to compare two different detectors. It provided an effective evaluation of signalized intersection stop-bar detection where speed and volume would be less appropriate Measures of Effectiveness (MOE). A comprehensive explanation of the Grenard procedure is included in Chapter 3. An enhancement of the detector presence procedure is used in this paper for the evaluation of newer video detection technology to assess the performance when traffic is moving (for gap timers) and when traffic is stopped (for phase service).

2.11. Approach for this Research

While many of the earlier evaluations concentrated on freeway evaluations, more recently as video detection has become popular for not only freeway applications but controlling intersections, several researchers have evaluated the technology

from this point of view. Intersections are more likely to have a large number of lanes compared to a typical segment of freeway, meaning that video detection is generally more cost effective at intersections and therefore attractive from the agencies point of view. Sensors on freeways are typically used to collect data, provide information to incident detection algorithms or real time traffic reports. Consequently, occasional errors or small errors are acceptable and hardly noticeable in the aggregated data. However, at an intersection a detector supplying erroneous data can cause the signal to run inefficiently or worse, unsafely.

To better quantify the performance of the video detector at a signalized intersection where the metrics of speed and volume may not accurately portray the performance of the system, the number of false and the number of missed calls may be quantified. It is important to note that the number of error calls may be misleading if the duration of such calls are not also quantified. However, it is difficult to define exactly what a missed call or false call consists of. For example, a missed call could be defined as the case in which the detector misses a vehicle completely during the duration of time that the vehicle is on the detector or alternatively a missed call could be defined as the detector not detecting the vehicle for a certain time period, such as if the vehicle pulled onto the detection zone but was not detected for the initial 2 or 3 seconds. In this research, all discrepancies between loops and video longer than 0.5 seconds are shown on the graphs and all discrepancies longer than 5 seconds have been categorized as a loop or video error.

Many of the researchers have developed test suites, where many hours of video have been edited to create a representative sample of the various weather and site conditions that may be encountered in the field. There are many drawbacks to this approach including:

- The video signal should be as crisp as possible. It is difficult to verify that the image quality has not been compromised during recording.
- Each vendor has specific cameras that are deployed with their system and to which their software has been tuned. Most vendors do not want to use a camera that is not typically used with their system.
- Some vendors actively control some of the camera functions to improve performance; in this case using recorded video would undoubtedly reduce the system performance.
- Many video detection systems incorporate real time data into the detector algorithm to help the system perform better. For example, the status of the signal phase can be used to determine whether the video is detecting stopped traffic during a red indication or moving traffic during a green indication.

The method proposed in this research does not rely on aggregated data such as volume counts, speeds, and occupancy which may not accurately reflect how a detector will perform at a signalized intersection. Additionally, by comparing the output from the video detector from the output of an inductive loop, the data can be collected in real time over a long test period. This is advantageous because it allows the video detection algorithms to use information from the phase indication to make decisions. Additionally, it allows a wide range of traffic, lighting and environmental conditions to be included in the test without requiring a substantial editing procedure to develop test video. Finally, by including phase colors on the L0V1 and L1V0 graphs, an indication of the impact to signal performance can be performed. These graphs are also valuable because the most serious errors (those with the longest duration) can be identified and can be verified by a human observer as to whether the error was a loop error or a video error.

The development of the procedure proposed by this research in context with earlier research is illustrated in Figure 2.1.

Figure 2.1 Relationship of Proposed Test Methodology to Previous Research

CHAPTER 3. TEST METHODOLOGY

3.1. Discrepancies between Video Detectors and Loop Detectors

To identify video detection errors, it is necessary to either provide a human observer or compare the video detector with another detector with a high degree of precision and accuracy. We decided upon a 24-hour evaluation on each phase to ensure performance was evaluated over a wide variety of traffic and lighting conditions. Due to the intense labor requirements of providing a human observer over such a long period of time, the video detector output was compared with the output from an inductive loop. A human observer was then required to observe the video only where there were identified discrepancies between the two detectors.

Each detection event was classified into any one of four different states. The first two states occur when the two detectors are in agreement either not placing a call, or both placing a call. For simplicity, these states are referred to as L0V0 and L1V1, where L represents Loop and V represents Video, and the numbers indicate whether the detector is off [0] or on [1].

The other two states occur when the two detectors are not in agreement. These are referred to as L0V1 and L1V0 discrepancies. For example, the discrepancy L1V0 can be interpreted as the loop placing a call but the video not placing a call. A graphical explanation of the detection states is shown in Figure 3.1a.

There are two possible causes of L1V0 and L0V1 discrepancies; either the loop has made an error or the video has made an error. For example, an L1V0

discrepancy might be caused by the loop correctly detecting a vehicle and the camera missing the call; therefore the 'L1V0 discrepancy' can be described as an 'L1V0 video error.' Conversely, the video may have correctly not placed a call and the loop has placed a false call, so the discrepancy can be categorized as a 'L1V0 loop error.'

To accurately categorize each discrepancy, it is necessary for a human observer to interpret and judge each discrepancy and determine which detector is in error. By using this L1V0/L0V1 screening mechanism, it is a much easier process because the observer must only watch the video where discrepancies have been identified.

It is theoretically possible that both detectors are in error at the same time and therefore no discrepancy is recorded. However, if both detectors are functioning as intended, the likelihood of such an event is quite small. To justify these assumptions, four hours of video was observed continuously, with two hours during a day period and two hours during a night period. During these observation periods no errors greater than 2 seconds in length occurred on both the loop detector and video detectors simultaneously.

3.2. Impacts of Detection Errors

The impacts of detector errors are twofold, efficiency and safety. The operational efficiency of the intersection is reduced when false calls extend or call a phase unnecessarily.

Missed detections represent a possible safety problem at the intersection. If the detector does not place a call at the appropriate time, a phase may be skipped and a vehicle demand may not be served. If it is obvious to the driver that the

controller is skipping their phase or if the driver becomes impatient, they may choose to violate the red signal rather than continue to wait.

Obviously, missed detections that may pose possible safety problems are a much higher concern to agencies than the operational inefficiencies introduced by false detections. Therefore minimizing missed detections should be a priority over the minimization of false detections. However, the operational efficiency should not be neglected and a detector that minimized both of these types of errors would represent a technology that is best suited for intersection detection. The impacts of the various combinations of states are tabulated in the “Impact” column of Figure 3.1b.

The efficiency of the traffic signal is compromised when the vehicle detector incorrectly reports a vehicle presence when there is in fact no vehicle present. A common cause of false calls (LOV1 errors) is due to headlights triggering a video detector early during the night hours. This phenomenon is illustrated in Figure 3.2.

Similarly, any factor that would cause a detector to activate late would also affect the signal performance. These types of performance issues primarily occur during the green phase where a crisp detection zone is needed to measure headway between vehicles.

To illustrate the importance of a detector activating at precisely the right moment, one can look at the relationship between headway and flow. Time headway in a traffic stream is defined as the time measured at a spot between two consecutive vehicle passages. This concept is illustrated in Figure 3.3a.

The relationship between headway and traffic flow is expressed in Eq. 3.1.

$$\text{Flow Rate, } q = \frac{3600}{\bar{h}} \text{ VPH} \quad \text{Eq. 3.1}$$

where:

$\bar{h}$ = average vehicle headway

The relationship between headway and flow is also shown graphically in Figure 3.3b. In this figure, several points have been identified to illustrate the dramatic effect on flow rate that a small change in the average headway can have. For example, when the time headway between vehicles changes from 2.0s (Figure 3.3b, Point 1) to 3.0s (Figure 3.3b, Point 2); the corresponding flow rate drops from 1800 Vehicles per Hour (VPH) to 1200 VPH. Similarly, as the headway increases to 4.0s between vehicles, the corresponding flow rate drops further to 900 VPH (Figure 3.3b, Point 3).

The inverse relationship between headway and flow rate illustrates the importance of a consistent and crisp detection zone at an actuated signalized intersection. It is essential the detector has consistent and well-defined on and off points that behave consistently over a wide range of lighting and weather conditions. If the signal controller relies on the detector information to terminate a phase once a gap reaches a pre-defined threshold, it is imperative that the detector provides precise actuations. If the detector is a mere two seconds late, the controller may gap out prematurely when there is in fact still a high flow rate or if the detector is actuated early, the controller may extend a phase unnecessarily when the flow rate has dropped to a low enough level that the phase should be terminated.

The need for a consistent detector zone is most important during the green phase when a controller may rely on information about gaps in the traffic stream to extend or terminate a phase. During a red phase where the primary concern is presence detection, an early or delayed call by a detector will not have a

significant effect on operations. In fact, a delay of a couple of seconds is sometimes included on a video detector during the red phase to minimize false calls caused by pedestrians and vehicles traveling along the perpendicular roadway.

3.3. Graphical Presentations of Data

3.3.1. L1V0 and L0V1 Graphs

The time each L1V0 or L0V1 discrepancy occurs is plotted on a graph where the height of each line corresponds to the duration of the discrepancy. The L1V0 and L0V1 discrepancies are shown on graphs that span the entire test period.

Example L1V0 and L0V1 graphs are shown in Figure 3.4a and Figure 3.4b, respectively. The x-axis of each graph shows the time period of each test. The y-axis represents the duration of each discrepancy in seconds. Occasionally, the duration of a discrepancy will be larger than 60 seconds; however each of the graphs uses this as the maximum value to maintain a consistent scale.

Each of the discrepancy durations are color coded to represent the phase status of the intersection. On L1V0 and L0V1 graphs for through phases ($\Phi 2, 4, 6, 8$) the color is either red or green to correspond to the phase indication. For left-turn phases ($\Phi 1, 3, 5, 7$), the color blue is used to represent permitted phases, while the color green represents protected phases.

3.3.2. On-Time and Off-Time Histograms

Histograms are used to document the difference in the turn-on and turn-off times of the loop detector and video detector. An example of on-time histogram and off-time histograms are shown in Figure 3.4c and Figure 3.4d. The horizontal axis displays the difference in time between the loop detector activating and the video

detector activating. The zero point on this horizontal axis represents the time point at which the loop detector activates. While it is possible that the video detector will activate at the same or nearly the same moment as the loop detector, there will likely be a high number of cases where the two technologies do not behave exactly the same. That is, the video detector will either activate prior to the loop detector or after the loop detector.

Two types of histograms are used, on-time histograms and off-time histograms. On-time histograms represent the behavior of the detector when a vehicle is arriving at the detection zone. The off-time histogram is used to show the behavior of the detector when a vehicle is departing the detection zone.

For on-time histograms, the area on the horizontal scale to the left of the zero point represents video actuations that occurred prior to the loop actuations. Conversely, to the right of the zero point represents an instance of the video detector activating at a point in time after the loop detector. The off-time histograms are arranged with the horizontal axis opposite so that the area on the scale to the left of the zero point shows video actuations that terminated after the loop and to the right of the zero point shows video actuations that terminated before the loop detector.

For off-time histograms, the area on the horizontal scale to the left of the zero point represents video actuations that occurred prior to the loop actuations. Conversely, to the right of the zero point represents an instance of the video detector activating at a point in time after the loop detector.

The histogram is color coded in the exact same fashion as the L1V0 and L0V1 graphs. For example, the through phase indication is represented by green or red, while for left-turn phases, the permitted phases are represented in blue and the protected phases in green.

While the L1V0 and L0V1 discrepancy graphs can be used to show an entire data collection period, the histograms are more useful when they are divided by time period (day versus night) to avoid masking differences in performance between the time periods after the data is aggregated. The histograms can be used to evaluate the consistency and crispness of a vehicle detector's detection zone.

3.4. Example Analyses

3.4.1. L1V0 Discrepancies – (Loop Active, Video Inactive)

In Figure 3.5, the L1V0 errors on camera 1 corresponding to the screen captures are identified on the 24-hour L1V0 graph (Figure 3.5a, P5E1, P5E2, P5E3). The error P5E1 shows a missed call on the left-turn, even though there are two vehicles present (Figure 3.5b). This type of error, where a vehicle would not be detected, was observed frequently especially on the left-turn phases. Cameras 2 and 3 are detecting the vehicles correctly in this example.

The error P5E2 is occurring on all three cameras (Figure 3.5c). This error occurred after sunset and is likely because the headlights are not bright enough or large enough to be detected.

The final L1V0 error presented is an unusual error that was witnessed in multiple video clips (Figure 3.5a, P5E3). At first, a vehicle pulls up to the stop-bar and is detected correctly by all three video detectors (Figure 3.5d). A large vehicle, usually a class-9 truck, passes on the perpendicular roadway, briefly occluding the camera's view of the vehicle at the stopbar (Figure 3.5e). As the large vehicle passes, one or more of the video detectors drop the call and the vehicle is not re-detected (Figure 3.5f).

3.4.2. L0V1 Discrepancies – (Loop Inactive, Video Active)

In Figure 3.6, the L0V1 errors corresponding to the screen captures are identified on the 24-hour L0V1 graph (Figure 3.6a, P8E1, P8E2, P8E3). The error P8E1 demonstrates that it is not always the camera that is the source of the error. Such is the case where a vehicle has pulled beyond the loop's detection zone, although it is still waiting for the signal to change (Figure 3.6b). The only loop errors that were observed consistently were the type where the vehicle pulled ahead of the stop-bar and out of the loop detection zone but not out of the camera detection zone. Errors that were caused by differences in detection zones were eliminated as to not penalize a detector for simply being configured differently than the detector used for comparison.

Two common L0V1 errors that are caused by cameras are shown in Figure 3.6c and Figure 3.6d. The error labeled P8E2 in Figure 3.6c is an example of the camera placing a false call in the through lanes, perhaps due to headlight splash. In this case, Camera 2 and Camera 3 are displaying false calls where Camera 1 does not, perhaps due to camera position.

The second error (P8E3) is caused by the shadows from the vehicles in the left-turn lane. In this case, all three cameras have placed a false call.

3.4.3. On-Time Histogram

In Figure 3.7, two examples are provided to illustrate the data in the On-Time Histogram. The histogram for a night time period (3/26/2004, 8:00pm to 11:59pm) is shown in Figure 3.7a. The place on the histogram where the data point would lie for each of the two examples is denoted on the histogram.

The first example shows a case where the through lane video detector (Cam1) activates 2.30 seconds prior to the loop detector during the green phase (Figure 3.7b, c & d). The second example shows a case where the through lane video

detector (Cam1) activates 0.90 seconds after to the loop detector during the red phase (Figure 3.7e & f).

The first example is shown with screen shots beginning in Figure 3.7b. In this screen capture, both the video detector (Cam1) and the loop detector are inactive because there are no vehicles present. As the vehicle approaches and the headlight reflection continues to intensify in the video image, the video detector activates at t_0 seconds as shown in Figure 3.7c. At time $t_0 + 2.304$ seconds as the vehicle approaches the intersection, the loop detector activates (Figure 3.7d). The video detector activates 2.304 seconds prior to the loop detector and is therefore shown to the left of the zero mark on the horizontal axis of the histogram. This point is labeled in Figure 3.7a with the title: 'Example 1'.

The second example is also shown with screen shots beginning with the activation of the loop at time t_0 in Figure 3.7e. The video detector (Cam1) activates $t_0 + 0.904$ seconds after the loop detector as shown in Figure 3.7f. The corresponding point on the histogram is shown in Figure 3.7a with the title: 'Example 2'.

It is interesting to note in Figure 3.7b that there does appear to be a difference in the detector behavior between red and green phases. This is likely due to a delay that was included on the video detector during a red indication to minimize false calls by pedestrians and vehicles traveling along the crossing roadway.

3.4.4. Off-Time Histogram

In Figure 3.8, an example is given to demonstrate how a histogram can be developed to represent the relative points in time that two detectors turn off after a vehicle has left the detection zone. In Figure 3.8a, an Off-Histogram is presented which shows an 'Example 1' label at approximately 0.6 seconds to the

right of the zero point. This means that the video detector is activated approximately 0.6 seconds after the loop detector activates.

In Figure 3.8b both the loop detector and the video detector (Cam1) are activated by a white van approaching the intersection during the green phase. In Figure 3.8c, the van has just passed the stop bar and the loop detector has just deactivated at time t_0 . In Figure 3.8d, at time $t_0 + 0.636$ seconds the video detector (Cam1) also deactivates. The lag time between the video detector deactivation and the loop detector deactivation is the information represented on the histogram.

3.5. Statistical Analysis

3.5.1. Analysis of L0V1 and L1V0 Results

To ground truth the data each discrepancy longer than 5 seconds was observed on the digital video to categorize it as either a loop error or a video error. The value of 5 seconds was chosen to minimize the labor required for a human observer to categorize every discrepancy on the graph and therefore concentrate only on the most egregious errors. Ideally, the discrepancy between detectors should be less than 1 second, but the performance can still be characterized by looking at only these larger errors. The on-time and off-time histograms are better for illustrating trends of smaller errors.

When developing the ground truth data by categorizing each discrepancy as a loop or video detector error, careful attention was given to the position of each vehicle on the detector to avoid penalizing a detector for having a slightly different detection zone compared to the other detector. For example, westbound right turning vehicles often drive on the shoulder and are not detected by the

loops but perhaps detected by the video because of its larger detection zone (Figure 3.9a). Similarly, it is possible for a vehicle to be in the loop detection zone but not in the video detection zone as shown Figure 3.9b where the vehicle is outside of the Camera 1 and Camera 2 detection zones. The purpose of the categorization was to identify missed calls of vehicles that were in a detection zone and false calls where there were no vehicles in the detection zone; therefore, errors caused by detection zone positional discrepancies were not counted.

Evaluation of the error count for statistical significance was calculated considering the number of phases served as the number of trials, assuming only one large error would occur per cycle. The tabulation of errors greater than 10 seconds is presented in the following figures:

Based on this data, a two-tailed test of hypothesis was performed between the proportion of loop errors and the proportion of errors of each camera. The proportion of errors was calculated by dividing the number of errors by the total number of signal cycles. The null hypothesis that the number of errors by loops and cameras are the same is expressed in Eq. 3.2.

$$H_0 : p_2 = p_1 \quad \text{Eq. 3.2}$$

where: p_1 = error percentage for video detection and
 p_2 = error percentage for loop detection.

The alternative hypothesis represents the case where the number of video detection errors is significantly different than the number of loop detection errors. The alternative hypothesis is expressed in Eq. 3.3.

$$H_A : p_2 \neq p_1 \quad \text{Eq. 3.3}$$

The proportion of errors observed on a detector was assumed to be normally distributed since the number of trials in the test was sufficiently large. There are several hundred phases in a 24-hour test period.

The difference in proportions of the number of loop errors and the number of video detector errors is calculated by Eq. 3.4. The standard error of the difference in proportions is calculated by Eq. 3.5.

$$D = p_2 - p_1 \quad \text{Eq. 3.4}$$

$$SE_D = \frac{(p_1 + p_2)(1 - (p_1 + p_2))}{2n} \quad \text{Eq. 3.5}$$

A Z-value was calculated to test the null hypothesis using Eq. 3.6. The critical Z-value is 1.96 at alpha level 0.05.

$$Z = \frac{D}{SE_D} \quad \text{Eq. 3.6}$$

Once the L1V0 and L0V1 discrepancies were categorized as either a camera error or a loop error, the total number of camera errors on a phase was compared to the total number of loop errors on a phase for statistical significance. As shown in Table 3.1, L1V0 errors caused by the loop are false calls while those caused by the video detection are missed calls. Also shown in Table 3.1, L0V1 errors caused by the loop are missed calls and errors by the video detection are false calls.

Example calculations for errors greater than 10 seconds on the Northbound through phase for the West Lafayette test are detailed in Figure 3.10.

Table 3.1: Error types

Error by:	L1V0	L0V1
Loop	False	Missed
Video	Missed	False

It was identified each time that the proportion of errors for one detector was statistically significantly larger compared to a competing detector. The proportion of missed calls on each video detector is compared to the number of missed calls on the loop detector. The proportion of false calls on each video detector is compared separately to the number of false calls on the loop detector.

3.5.2. Analysis of Difference of On-Time and Off-Time Histograms

The On-Time and Off-Time histograms present the difference in the turn-on and turn-off times of the video detection relative to the loop detection. To quantitatively present the information presented in each of the histograms, the average, standard deviation and median on-time and off-time residuals have been calculated.

To verify that the differences between the video detection and loop detection are statistically significant, a two tailed t-test was used to determine whether the mean turn-on and turn-off times of the video detection is different from the loop turn-on time that was used as the baseline for the test and therefore with a mean of zero.

The null hypothesis that the average discrepancy between the turn-on or turn-off times of the two detectors is less than or equal to an allowable value, d_0 , is expressed in Eq. 3.7.

$$H_0 : \mu_1 - \mu_2 \leq d_0$$

Eq. 3.7

where μ_1 = average turn-on or turn-off time for video detection and
 μ_2 = average turn-on or turn-off time for loop detection

The alternative hypothesis represents the case where the turn-on or turn-off time of the video detection is significantly different than the turn-on or turn-off time of the loop detection by a margin larger than d_0 . The alternative hypothesis is expressed in Eq. 3.8.

$$H_A : \mu_1 - \mu_2 > d_0 \quad \text{Eq. 3.8}$$

The test t statistic is then calculated with Eq. 3.9.

$$t' = \frac{(x_1 - x_2) - d_0}{\sqrt{(s^2 / n)}} \quad \text{Eq. 3.9}$$

where x_1 = average video detection turn-on or turn-off time and
 $x_2 = 0.0s$ = average loop detection turn-on or turn-off time and
 d_0 = allowable threshold for difference in means and

$$s = \text{standard error} = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} \quad \text{and}$$

n = Number of ON or OFF actuations compared between the video detector and loop detector.

with a critical region as shown in Eq. 3.10. An alpha value of 0.05 was used for the test.

$$t' > t_{\alpha/2} \quad \text{Eq. 3.10}$$

The loop turn-off and turn-on times are expected to behave consistently since they are not dependent on ambient lighting conditions, and therefore was chosen as a baseline to evaluate the turn-on and turn-off times of the video. Expressing, $x_1 - x_2$ as Δx and re-arranging Eq. 3.9 yields the appropriate thresholds in seconds as shown in Eq. 3.11.

$$|\Delta x_{margin}| = d_0 + t_{crit} \frac{s}{\sqrt{n}} \quad \text{Eq. 3.11}$$

It is assumed that the variances of the video detection on/off times and the loop detection on/off times are not equal since they come from two different detection technologies. The degrees of freedom for the t-test are calculated from Eq. 3.12.

$$v = n - 1 \quad \text{Eq. 3.12}$$

The thresholds for each test will be different depending on the number of trials and the standard deviation of the difference in times. A trial is created each time that a difference between the on-time or the off-times is recorded between the two detections. An example calculation for these thresholds is shown in Figure 3.11.

The loop detection zone is identified in the center of the figure. As the car moves from right to left it will activate the loop as it enters the detection zone and then deactivate the loop as it leaves the detection zone. The video detection zone is configured to match the loop detection zone as closely as possible.

The histogram on the right side of Figure 3.11 represents the green turn-on times for the West Lafayette Northbound Camera 3 on January 25, 2005 during a night test period. In order to statistically verify that the difference in the turn-on time for the video detection and the loop detection are different, the statistical thresholds are determined for several margins of difference. For example to statistically

verify that the video is activating at least 2.0 seconds before the loop detection, the average would need to be greater than or equal to 2.114s. Similarly, to verify that the video is activating at least 2.0 seconds after the loop detection, the average would need to be less than or equal to -2.114s. The thresholds are labeled on Figure 3.11 with lines drawn to demonstrate how they correspond on the histograms.

At the bottom of the figure detailed calculations are provided that use Eq. 3.11. The right side of the figure shows the turn-on time thresholds and the left side of the figure shows the turn-off time thresholds. These thresholds will change with each phase on each test; therefore the values shown in Figure 3.11 are for illustrative purposes only and are only necessarily valid for the example presented.

Figure 3.12 shows example margins for four different thresholds (2.0 seconds, 1.5 seconds, 1.0 seconds and 0.0 seconds) and the margin to verify statistically that the video is activating within the threshold. For example, if the average video turn-on time is within the 2.0 second margin labeled in Figure 3.12 then it can be concluded that the video activates within 2.0 seconds before or 2.0 seconds after the loop activates. Several more restrictive margins are also included on the figure. In order to say that the video detection and the loop detection activates at the same time, the average video turn-on time must lie in the 0.0 seconds range shown on Figure 3.12.

The threshold calculations are performed for each phase and direction to determine whether the video detection turn-on and turn-off times are different from the loop turn-on and turn-off times by 0.0, 0.5, 1.0 and 2.0 seconds. In Chapter 6, these results are summarized in tables with check marks to indicate where the video detection behaves statistically different than the loops.

The final statistical test used in this research is a chi-squared goodness of fit test to determine the amount of difference between a day histogram and a night histogram from a common phase. Although, the histograms likely will never be statistically identical, the magnitudes of the calculated chi-squared values still give an indication as to how closely the histograms match. The chi-squared value is calculated by

$$\sum \frac{(f_{night} - f_{day})^2}{f_{day}} \quad \text{Eq. 3.13}$$

Figure 3.1 L0V1 and L1V0 Discrepancy Concept

Figure 3.2 Effect of Headlight Reflection on Video Detection

a) Graphical Illustration of Headway in a Traffic Stream

b) Relationship between Headway and Flow

Figure 3.3 Headway Effects

a) L1V0 Discrepancy Graph Example

b) L0V1 Discrepancy Graph Example

c) Discrepancy in Turn On Times Histogram Example

d) Discrepancy in Turn Off Times Histogram Example

Figure 3.4 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends

a) L1V0 Graph for Camera 1 NB Left-Turn Lane (Noblesville, IN)

d) All Three Cameras Detect Vehicle (t=22:01:38)

b) Undetected Vehicle on Camera 1

e) Truck Passes on Perpendicular Street and Calls on Phase 5 are dropped (t=22:01:44)

c) Undetected Vehicle at Night on Cameras 1, 2, and 3

f) Calls on Camera 1 and 3 remain off after truck passes (t=22:01:48)

Figure 3.5 Example L1V0 Errors (Noblesville, IN)

a) L0V1 Graph for Camera 3 WB Through Lanes (Noblesville, IN)

c) False Calls on Phase 8, Cameras 2 and 3

b) Car Outside of Loop Detection Zone

d) False Call on Phase 8, Camera 1, 2 and 3, Triggered by Shadow of Left-Turning Vehicles

Figure 3.6 Example L0V1 Errors (Noblesville, IN)

a) On-Histogram for Cam 1 NB Through Lanes (Noblesville) during Night Period (03/26/04, 8 PM – 12AM)

b) Example 1: Detectors in Through Lanes are Inactive

c) Example 1: Cam1 detector activates in through lanes at t_0 during Φ green

d) Example 1: Loop activates in through lanes at $t_0 + 2.304$ sec. during Φ green

e) Example 2: Loop detector activates in through lanes at t_0 during Φ red

f) Example 2: Cam1 detector activates in through lanes at $t_0 + 0.904$ sec. during Φ red

Figure 3.7 Example On-Histogram Events for Camera 1 (Noblesville, IN)

a) Off-Histogram for Cam 1 NB Through Lanes (Noblesville) during Day Period (03/26/04, 12 PM – 4 PM)

b) Example 1: Detectors in Through Lanes are Activated by White Van

c) Example 1: Loop detector deactivates as white van passes stop bar at t_0 during Φ green

d) Example 1: Cam1 deactivates at $t_0 + 0.636$ sec. during Φ green

Figure 3.8 Example Off-Histogram Events for Camera 1 (Noblesville, IN)

a) Vehicle Located Outside of Loop Detection Zone

b) Vehicle Located Outside of Video Detection Zone

Figure 3.9 Example of Discrepancies between Loop Detection Zones and Video Detection Zones.

		Missed Calls (>10s)				False Calls (>10s)			
		Cam1	Cam2	Cam3	Cam4	Cam1	Cam2	Cam3	Cam4
Cycles		1038				1038			
Loop Errors		0				0			
Cam Errors		0	0	0	7	18	26	17	22
% Loop Error (p_1)		0.00%				0.00%			
% Cam Errors (p_2)		0.00%	0.00%	0.00%	0.67%	1.73%	2.50%	1.64%	2.12%
Diff. ($p_2 - p_1$)		0.00%	0.00%	0.00%	0.67%	1.73%	2.50%	1.64%	2.12%
Std. Error of D (SE_d)		0.00%	0.00%	0.00%	0.25%	0.41%	0.49%	0.40%	0.45%
Z (d/SE_d)		-	-	-	2.65	4.26	5.13	4.14	4.72
Crit. Z Value at $\alpha=0.05$		1.96				1.96			
Conclusion		Accept H_0	Accept H_0	Accept H_0	Reject H_0	Reject H_0	Reject H_0	Reject H_0	Reject H_0
c) Statistical Analysis Calculations									

Figure 3.10 Example Calculations for Statistical Significance of Error Proportions between Loop Detectors and Video Detectors (West Lafayette, January 25th, 2005, Northbound Phase 2)

Figure 3.11 Example Thresholds for West Lafayette Northbound Camera 3 (January 25, 2005) for Evaluation of Average Difference of On and Off Times using the Student's T-distribution

Figure 3.12 On Time Threshold Range for West Lafayette Northbound Camera 3 (January 25, 2005).

CHAPTER 4. TESTING SITE

4.1. Introduction

Two sites were constructed at Noblesville, Indiana and West Lafayette, Indiana in late 2003 and summer 2004, respectively. The re-construction of each of these intersections was a complete rebuild including new cabinets, signal poles, signals, preformed loop detectors, micro-loop detectors, and video detection. Additionally, geometric modifications were made at the West Lafayette site. Both sites were re-paved and re-striped as well.

The intersections were reconstructed with incorporated instrumentation so each could serve as a test bed for signalized intersection detection technology. Each approach was instrumented with multiple stop bar detectors in each lane. The loop detection zones and video detection zones for the northbound approach in West Lafayette is shown in the top portion of Figure 4.1. Each site is designed so that the phase state, loop detector state, and video detector states can be collected and then processed to identify discrepancy events (L0V1 events and L1V0 events). On-time and off-time histograms are also developed to document the smaller differences in the detection technologies. The purpose of the test bed and its' relationship to the final output is explained in Figure 4.1.

4.2. Noblesville, Indiana

The test intersection is located at State Route (SR)-32/38 & SR-37. SR-37 is a major north-south route that serves as a main arterial between Noblesville and Indianapolis. The posted speed limit on SR-37 is 55 miles per hour (MPH). SR-32/38 is also an arterial that runs to the west through downtown Noblesville with a posted speed limit of 35 MPH. To the east SR-32/38 travels through sparse

commercial and residential development with a posted speed limit of 45 MPH. The intersection is shown in plan view in Figure 4.2. A location map is included in Appendix A, Figure A.2.

The northbound and southbound legs (SR-37) each feature two through lanes (Figure 4.2, NA, NB, SA, SB), an exclusive right-turn lane (Figure 4.2, NC, SC), and an exclusive left-turn lane (Figure 4.2, NL, SL). The left turns on these approaches are signalized as protected only. The westbound and eastbound legs carry significantly less traffic than the north-south approaches. On the eastbound approach there is one through lane (Figure 4.2, EA), one exclusive right-turn lane (Figure 4.2, EB), and one exclusive left-turn lane (Figure 4.2, EL). On the westbound approach there is one through lane (Figure 4.2, WA), one through-right lane (Figure 4.2, WB) and one exclusive left-turn lane (Figure 4.2, WL). The left turns on the east and west legs are protected-permitted. The intersection configuration and phasing sequence is shown in Figure 4.2. An aerial photograph of the intersection with pictures of the camera locations and loop detector locations is shown in Appendix A, Figure A.4.

The video detection cameras were mounted according to vendors preferred installation practice, 40 feet above the pavement. Three (3) cameras were installed on each mast arm for a total of twelve (12) cameras. The first camera was located at the vendor specified location at the end of the mast arm (approximately even with the lane-line between the left-most through lane and the left-turn lane) at 60 feet. The next two cameras were located at 48 feet and 36 feet out on the mast arm, respectively. Herein, the camera at 60 feet on the mast arm is referred to as Camera 1, the camera at 48 feet is referred to as Camera 2, and the last camera at 36 feet is referred to as Camera 3. The dimensions for the cameras mounted on the southwest corner of the intersection are shown in Figure 4.2 and are typical of the cameras mounted in each quadrant. The cameras are also shown in profile view in Figure 4.5a. A

photograph of the installed cameras for the eastbound approach is shown in Figure 4.6a.

As shown in Figure 4.2, the distance from the cameras to the southbound lanes is 165 feet. The distances between the cameras and the stop bars on the Northbound, Eastbound, and Westbound approaches are 160 feet, 165 feet, and 165 feet respectively.

The varying camera location on the mast arm affects the angle at which the camera views the lanes it is detecting. As the camera is located further out on the pole, occlusions are minimized because the view will be more from a head-on perspective rather than a side view. The view from each camera on the Eastbound approach and the viewing angle of the inside left-turn lane line are shown in Figure 4.7. As the camera is located further out on the pole, the angle of the lane lines approach the vendor recommended 90 degrees (Figure 4.7c,f). The screen shots shown in Figure 4.7 are shown again in Figure 4.9 with the corresponding video detection zones as set up by the vendor.

Views from two different dates are shown in Figure 4.7. The video captures shown in Figure 4.7a, b, & c were taken on December 12, 2003 while the video captures shown in Figure 4.7d, e, & f were taken on July 12, 2004. From the video captures it does not appear visually that any of the camera positions shifted between December 2003 and July 2004. Similar video captures were taken for the other three directions and again it does not appear visually that the field of view has changed. The video screen captures for the entire Noblesville site included in Appendix A are summarized in Table 4.1.

Table 4.1 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') in Noblesville, Indiana

Approach Direction	Autoscope Camera View Figure	Detection Zone Figure
Northbound	Figure A.11	Figure A.16
Southbound	Figure A.12	Figure A.17
Eastbound	Figure A.13	Figure A.18
Westbound	Figure A.14	Figure A.19

Due to the long mast arms lengths, it was suggested that the ambient temperature could directly affect the camera views by expansion and contraction of the mast arm. The average temperature in Noblesville during December 2003 was 34.0 degrees Fahrenheit. During July 2004, the average temperature was 72.7 degrees Fahrenheit. The temperature during the days of the screen captures are shown on Figure 4.8.

To quantify any change that may have occurred between the summer and winter, a reference point was selected on the video screen capture and the pixel coordinates recorded. The reference point selected was the corner of where the stop bar and the left-turn lane line meet. The pixel coordinates in December 2003, July 2004 and the relative change between the two time periods are shown in Table 4.2. The change in pixels across the two time periods is relatively minor and in some cases there was no change at all. It can be concluded that the temperature has an unnoticeable impact, if any impact at all, on the camera positioning due to contractions or expansions of the mast arm.

The approaches are also instrumented with traditional inductive loops. The inductive loop locations are displayed in Figure 4.2. The video detection zones were configured to match the loop detector zones as closely as possible.

Table 4.2 Pixel Coordinates for Noblesville Video Captures (December 12, 2003, July 12, 2004 and Difference)

	December 2003		July 2004		Change	
	x	y	x	y	x	y
NB1	262	76	262	76	0	0
NB2	257	74	257	74	0	0
NB3	263	84	263	83	0	-1
SB1	245	84	247	83	2	-1
SB2	250	90	252	90	2	0
SB3	257	83	254	78	-3	-5
EB1	269	90	269	91	0	1
EB2	262	85	262	86	0	1
EB3	270	87	270	87	0	0
WB1	276	87	278	87	2	0
WB2	269	85	269	85	0	0
WB3	275	79	273	78	-2	-1

4.3. West Lafayette, Indiana

West Lafayette, Indiana is located approximately 65 miles northwest of Indianapolis, Indiana. It is the home of Purdue University, with approximately 39,000 students. The test intersection of Stadium and Northwestern is located immediately adjacent to the Purdue University campus. This proximity to campus results in a large number of pedestrians traversing the intersection. A location map is included in Appendix A, Figure A.3.

Northwestern Avenue is a United States highway (US-231) that runs north-south through the Purdue University campus area. The posted speed limit on Northwestern Avenue is 35 MPH. Stadium Avenue runs to the west into the Purdue University campus and to the east into the surrounding residential area. The posted speed limit on Stadium Avenue is 30 MPH. The majority of traffic on these two streets is trips to and from Purdue University and trips by residents

who live in the adjacent neighborhoods. The intersection is shown in plan view in Figure 4.3.

The northbound and southbound legs (Northwestern Avenue – US231) each feature two through lanes (Figure 4.3, NA, NB, SA, SB) and an exclusive left-turn lane (Figure 4.3, NL, SL). The southbound leg also has an exclusive right turn lane (Figure 4.3, SC). The left turns on these approaches are signalized as permitted-protected. The westbound and eastbound legs carry less traffic than the north-south approaches. On the eastbound approach there is one through lane (Figure 4.3, EA), one exclusive right-turn lane (Figure 4.3, EB), and one exclusive left-turn lane (Figure 4.3, EL). On the westbound approach there is one through lane (Figure 4.3, WA), one through-right lane (Figure 4.3, WB) and one exclusive left-turn lane (Figure 4.3, WL). The left turns on the east and west legs are protected-permitted. The eastbound right-turn has a signal allowing for it to be serviced with an overlap phase. The intersection is also signalized for pedestrian movements across each leg of the intersection. An aerial photograph of the intersection with pictures of the camera locations and loop detector locations is shown in Appendix A, Figure A.5.

Four different camera locations per approach were installed at this intersection. The locations of the loop detector and video detector zones are shown in detail for the northbound approach in Figure 4.4. It should be noted that the fourth camera for each approach is located directly above the stop bar on a separate pole from the three other cameras which are located directly across the intersection from the stop bar. A profile view of the cameras as they are located on the poles in West Lafayette is shown in Figure 4.5b. A photograph of the installed cameras for the eastbound approach is shown in Figure 4.6b.

Due to the unsymmetrical geometry at this intersection the vendor recommended placements for Cameras 1 and 3 varied by approach. The vendor recommended offsets for each approach are shown in Figure 4.5b.

The distances between the cameras and the stop bars on the Northbound, Southbound, Eastbound, and Westbound approaches are approximately 120 feet, 85 feet, 150 feet, and 140 feet respectively.

The view from each camera on the Northbound approach and the viewing angle of the inside left-turn lane line are shown in Figure 4.10. Camera 1 (Figure 4.10a) was located at the vendor preferred location at 40 feet high and near the end of the mast arm. The second camera was located at the optimal height of 40 feet, but was placed immediately adjacent to the signal pole (Figure 4.10c). The third camera was located immediately below the first camera on the signal mast arm, resulting in a location with optimal lateral placement but at only 20 feet high (Figure 4.10b). The fourth and final camera is located directly above the stop bar looking straight down at traffic (Figure 4.10d). The screen shots shown in Figure 4.10 are shown again in Figure 4.11 with the corresponding video detection zones as set up by the vendor. The video screen captures for the entire West Lafayette site included in Appendix A are summarized in Table 4.3.

The approaches are also instrumented with traditional inductive loops. The inductive loop locations are displayed in Figure 4.3. The video detection zones were configured to match the loop detector zones as closely as possible.

Table 4.3 Autoscope Camera views for Cam4, Cam3, Cam2 and Cam1 in West Lafayette, Indiana

Approach Direction	Autoscope Camera View Figure	Detection Zone Figure
Northbound	Figure A.20	Figure A.24
Southbound	Figure A.21	Figure A.25
Eastbound	Figure A.22	Figure A.26
Westbound	Figure A.23	Figure A.27

4.4. Traffic Cabinets

To support the data collection and equipment testing procedures, a secondary data collection cabinet was installed at both sites in addition to the standard traffic control cabinet. The standard traffic control cabinet houses the controller, detector cards and other equipment necessary to run the intersection. The data collection cabinet houses all of the other equipment that is used for data collection and testing. The controller cabinet is referred to as the INDOT cabinet or Cabinet 1, and the data collection cabinet is referred to as the Purdue cabinet or Cabinet 2.

The important elements of the data collection cabinets at Noblesville and West Lafayette are shown in Figure 4.12 and Figure 4.13. A list of these items is shown in Table 4.4.

The east side of cabinet 2 features a patch panel (Figure 4.12, Item 1; Figure 4.13, Item 1), which is like a large old-fashioned telephone patch board where outputs from devices can be routed to inputs of other devices. The patch panel is divided into quadrants, one for each approach of the intersection. Each quadrant is essentially the same except that the number of detectors on each approach varies with the number of lanes on the approach. The quadrant of the patch panel (Figure 4.12, Item 4; Figure 4.13, Item 4) is shown in detail in Figure 4.12b and Figure 4.13b. The loop detector outputs (Figure 4.12, Item 6; Figure 4.13, Item 6), phase outputs (Figure 4.12, Item 7; Figure 4.13, Item 7) and video

detector outputs (Figure 4.12, Item 9; Figure 4.13, Item 9) can be mapped to the inputs of the video detectors (Figure 4.12, Item 8; Figure 4.13, Item 8). For example, the detector cameras are capable of using the status of the signal phase in their detector algorithms; therefore this output from the signal controller is mapped as an input to the video detection hardware. Traditionally, this connection would be wired in a permanent type installation (such as through a terminal strip). The patch panel was necessary to provide a flexible data collection system where inputs to each video detector can be quickly and easily changed.

A Liquid Crystal Display (LCD) screen (Figure 4.12, Item 2 & Item 15) is included on both sides of the Noblesville cabinet so that video can be observed from either side of the cabinet. A single LCD screen was included at the West Lafayette side (Figure 4.13, Item 15)

The west side of the Purdue cabinet (Figure 4.12c) includes several detector cards (Figure 4.12, Item 16), a video multi-plexer (Figure 4.12, Item 17), a video switch board (Figure 4.12, Item 18), and the video detection hardware (Figure 4.12, Item 19).

The video multi-plexer is used to change camera views, create views of multiple cameras on a single screen, and create picture-in-picture views. Each camera on each approach is routed through the video multi-plexer. The multi-plexer is controllable through a web-interface allowing remote viewing and changing of the cameras. A Pan-Tilt-Zoom (PTZ) camera was also installed at each site on the southeast corner to provide a versatile remote view of each intersection. The PTZ camera is also controlled through the multi-plexer and utilizes a web interface allowing for remote operation.

Table 4.4 Data Collection Cabinet Item Legend for Noblesville (Figure 4.12) and West Lafayette (Figure 4.13)

Item Description	Item Number in Figure 4.12 (Noblesville, Indiana)	Item Number in Figure 4.13 (West Lafayette)
Cabinet 2 Patch Panel (Figure 4.12a and Figure 4.13a)		
Patch Panel	1	1
LCD Monitor	2	NA
Cabinet to Cabinet Connections	3	3
Patch Panel Quad	4	4
Roadway Lighting Control	5	NA
Cabinet 2 Patch Panel Quadrant (Figure 4.12b and Figure 4.13b)		
Loop Detector Outputs	6	6
Signal Phase Indications	7	7
Econolite Autoscope Inputs	8	8
Econolite Autoscope Outputs	9	9
Auxiliary Inputs/Outputs	10	10
Pedestrian Phase Indications	NA	11
Ground / 24 Volt Power	NA	12
Cabinet 2 Instrumentation (Figure 4.12c and Figure 4.13c)		
Back of Patch Panel	13	13
Windows Computer	14	NA
LCD Monitor	15	15
Micro Loop Detector Cards	16	16
Genex Video Multitplexer	17	17
Video Patch Panel	18	18
Autoscope Detector Cards	19	19
AC Power Strip	NS	20
Network Hub	NS	21
Cabinet Power Supply	NS	22
Autoscope Communications Panel	NS	23
NA – Not Applicable NS – Not Shown		

The video detection hardware receives information such as phase indications and the video feed, to use in algorithms that decide whether a vehicle is present. In a traditional cabinet, the calls would be placed to the controller just as a traditional loop places a call. However, in this installation the video detection

hardware is installed in the data collection cabinet and is not used in the control of the intersection. The inductive loops are used to control the intersection during testing and non-testing periods. Relevant information from the INDOT cabinet is relayed to the Purdue cabinet via a conduit connecting the two cabinets (Figure 4.12, Item 3; Figure 4.13, Item 3).

A Windows computer was installed at the Noblesville site. The site was designed with an internet connection through which the computer can be remotely accessed and controlled. The computer is used to record text file logs for data collection and to record video digitally. No computer was installed at West Lafayette, because it is connected to the Civil Engineering building through a fiber line allowing data collection and retrieval to occur directly from campus. Additionally, if a computer was needed at the site a notebook computer was used.

The remote computer in Noblesville, Indiana is used for all data collection at that site. A high speed internet connection is available at this cabinet which allows remote access to the Windows computer. The Autoscope software can be accessed and data collections created using a program for remote access and control to the computer. The files are then downloaded using a File Transfer Protocol (FTP) program.

Digital video is taken during the test period to allow for visual inspection of discrepancies between loops and detectors identified by the data collection. These digital videos are created using Helix Producer Plus 9.01 from RealNetworks.

Some additional items are shown in Figure 4.13 including an AC power strip (Figure 4.13, Item 20), a networking hub (Figure 4.13, Item 21) and the cabinet

power supply (Figure 4.13, Item 22). The Autoscope Econolite Communications Panel is also identified (Figure 4.13, Item 23).

4.5. Software

The video detection is configured using a Windows based software program provided by the vendor. In the software, vehicles are detected in each lane by detection zones that are drawn in each area where detection is desired.

The Noblesville detection zones were set-up by a vendor representative in the field in December 2003 over a two (2) day period. After conducting some initial tests the vendor made a subsequent visit in March 2004 for fine tuning and firmware update over a second two (2) day period. The detection zones as configured by the vendor in March 2004 are shown in Figure 4.9.

The firmware was subsequently updated in March 2005 to version 8.10. Two sets of results are presented in this report for the Noblesville site, the first occurred in March 2004 after the configuration and firmware upgrade installed during the same visit (version 7.03). The second set of data was collected in April 2005 using version 8.10 of the software.

The West Lafayette site was configured over a two (2) day period in September 2004. After completing some initial data collection, the vendor made a subsequent visit in December 2004 for fine tuning and to upgrade the preliminary release version of the 8.00 software to the final release version. The detection zones as configured by the vendor in December 2004 are shown in Figure 4.11.

Two tests were completed at the West Lafayette site, both using version 8.00 of the Autoscope software. The two tests were conducted in January 2005. The first test occurred on January 20, 2005, however a snowstorm began during the early evening hours of the test. This test is presented in this report to demonstrate

performance during non-ideal conditions such as during inclement weather. The second test occurred on January 25, 2005 during clear weather and after the snow had melted.

Each video detection system is capable of logging the status of up to 8 inputs to a text file. The video detection system also provides a mechanism for including dynamic detector states and phase indications on a video overlay. An overlay is created using the Autoscope software. The screen overlay is particularly valuable because the event information can be placed directly over the video meaning the test data can later be verified, analyzed or presented to others.

At Noblesville, it is only necessary to log data from one camera per approach because the states of the other two cameras on the approach are mapped as input to the video detection system used to collect data. All of the information displayed on the video overlay is logged in a time stamped text file each time a detector state or phase state changes. This data file is used for automatically identifying discrepancies between loop detectors and video detectors as described in the next chapter. Once discrepancies are identified, a human observer can consult the recorded video, with the overlay status, to determine the cause of the discrepancy. An example screen overlay from the Noblesville site is shown in Figure 4.14.

The set-up at the West Lafayette site is slightly different due to the large number of cameras (4 cameras per approach for a total of 16 cameras). The West Lafayette data collection must use more than one camera per approach due to the limited number of Autoscope inputs (8 per camera). Therefore, Camera 1 and Camera 4 are used for data collection purposes. Video captures with the screen overlay are shown in Figure 4.15.

The Autoscope Econolite system is designed with 8 inputs that are traditionally used for 8 phase inputs. However, the inputs can be used with any device that provides on-off information through a contact closure. As explained previously, in this research the inputs are used to record detector data. The system is also capable of providing up to 16 outputs

The Autoscope Econolite Solo Mini-Hub II was used in this research and is shown in Figure 4.16a. The lights on the front of the unit indicate whether each of the inputs and outputs is active or inactive. This can also be accessed directly through the Autoscope software as shown in the screen shot on the right side of Figure 4.16a.

In Figure 4.16b, each of the inputs and outputs as they were typically configured during this research is shown. For the inputs, the first four inputs are typically used for the left-turn phase and the final four inputs are used for the through phase. The phase indications are brought into inputs 1 and 5, the loops are brought into inputs 2 and 6, and the remaining inputs (3, 4, 7, & 8) are used for the other video detectors. Since data collection occurs directly on one of the Autoscope cameras it is not necessary to map the status of the video detector used for data collection to an input since the information is already internal to the unit.

Outputs on an Autoscope unit are traditionally used to relay information, such as detector status, to the signal controller. Similarly, in this research the outputs were used to relay the status of each of the video detectors to the video detection system collecting data. The output assignments are also shown in Figure 4.16b. The only important outputs are 1 through 8 where each camera outputs its detector status for the through lane and the left-lane. The output numbers correspond to the phase number to which the detections correspond. For example, the status of the video detectors for the Northbound phases in

Noblesville (as shown in Figure 4.2b) are mapped to outputs 2 and 5 for the through and left-turn lanes respectively.

The main component of the Autoscope software is the network browser. A screen capture of the network browser is shown in Figure 4.17. The network browser allows the user to see all of the Autoscope units accessible from the computer. The available channels are listed on the left side of the network browser (Figure 4.17, Item 1). In this screen capture, the network browser is connected to the West Lafayette site and 'sees' the four Autoscope panels (1 panel per approach containing 4 cameras).

The right side of the network browser (Figure 4.17, Item 2) lists all of the Autoscope units accessible via the channel that was selected on the left side of the network browser (Figure 4.17, Item 1).

Each Autoscope unit is identified uniquely using the CPU serial number of the processor (Figure 4.17, Item 3). A logical name can also be assigned to each Autoscope for identification (Figure 4.17, Item 4). Site service information such as the height of the unit, the zoom level of the lens and other information is displayed in the fourth column (Figure 4.17, Item 5). If the Autoscope has been assigned a network address, the IP number is shown in the next column (Figure 4.17, Item 6).

The load index (Figure 4.17, Item 7) is a measure of the demand being put on the processor by the detection algorithms. The final column (Figure 4.17, Item 8) shows the sensor number on the Autoscope panel. At a typical intersection, a single Autoscope panel is used which is connected to one camera per approach. At this intersection a single panel was used for each approach since there are four cameras per approach.

All of the data collection for this research occurred within the Autoscope software. An excellent data collector is included in the standard Autoscope software. The data collector portion of the software is accessed by selecting the data menu from the Autoscope network browser and selecting 'Data Collector'.

The data collector window is shown in Figure 4.18. The first step in creating a data collection is to select which Autoscope will be polled for data by selecting from the list shown in Figure 4.18, Item 1. A list of all the detectors contained within the detector file loaded on the selected Autoscope is shown in the area denoted by Figure 4.18, Item 3. The user can filter the detector types that are shown in Item 3, by selecting the desired detector types in Figure 4.18, Item 2.

The interval type is selected from the drop down list identified by Figure 4.18, Item 4. For example, the data can be collected every time the state of the detector changes or data can be collected over a certain binned time period, such as a volume count over a 1-minute period. For this data collection, we are interested in events and the time that they occur. Therefore, the 'interval type' of 'state change' is used to collect each time the states of a phase, loop detector and video detector of interest changes.

The retrieval interval (Figure 4.18, Item 5) refers to the time interval at which the computer used as the data collector records data from the Autoscope unit. The Autoscope is equipped with flash memory meaning that a limited amount of data can be stored on the Autoscope, and data does not have to be written to the computer at the exact moment it occurs. This eliminates lost data in the case there is an interruption or delay in the connection between the video detector and the computer collecting data.

Once all of the selections have been made the user creates a poll by adding it to the poll list by clicking the 'Add Poll' button (Figure 4.18, Item 6). Each piece of

data collected by the video detection is called a poll. Since more than one item is typically polled from a single Autoscope during a data collection period, several polls will need to be added per camera. Additional polls can be added for the other Autoscope units as well and included in a single poll file. All of the polls for a particular data collection are collectively referred to as a poll list.

A completed sample poll list for the northbound approach in West Lafayette, Indiana is shown in Figure 4.19. The first ten polled items are from Camera 1 and the final 6 items are from Camera 4. It should be noted that even though Camera 1 and Camera 4 are both collecting data on the northbound approach that the loop status and phase status must be collected on both cameras. The northbound polls for the West Lafayette, Indiana location that are shown in Figure 4.19 are also listed in Table 4.9.

A comprehensive listing of the polls created and used during this research are included in Appendix A and are summarized in Table 4.6. Each poll on the list consists of a specific piece of data that will be collected on a specific camera, for example the state of the loop. Each poll list contains the multiple data polls that are included in a data collection. The data collector records the polls to a semi-colon delimited text file where they can be processed as described in the next chapter.

Table 4.6 List of Tables Containing Poll Lists for Data Collection in Noblesville and West Lafayette

Approach Direction	Noblesville, Indiana	West Lafayette, Indiana
Northbound	Table A.11	Table A.15
Southbound	Table A.12	Table A.16
Eastbound	Table A.13	Table A.17
Westbound	Table A.14	Table A.18

The clocks internal to the Autoscope unit are not accurate enough for time stamps collected by one unit to be compared by time stamps collected on a second Autoscope unit. The time drift within the Autoscope was tested over a 6-day period for all twelve of the video detectors at the Noblesville, Indiana site. Initially all of the clocks were synchronized with the National Institute of Standards and Technology (NIST) atomic time. Over the course of several days the clocks on each of the Autoscope units was compared to the NIST time and the difference computed. These results, along with the average per day over the entire 6 day test period are shown in Table 4.7. It should be noted that the Econolite Autoscope system can be configured to automatically synchronize using the time from a computer on the network, the AC power frequency or the TS2 time set command.

Table 4.7 Time Drift of Autoscope from the NIST Atomic Time

	May 12, 2004 – 10:05:00 AM	May 16, 2004 – 10:05:00 AM	May 17, 2004 – 4:30:00 PM	May 18, 2004 – 8:30:00 AM	Average per day
NB1	0	-12	-15	-18	-3.0
NB2	0	-11	-15	-17	-2.8
NB3	0	-9	-12	-15	-2.5
SB1	0	-11	-16	-18	-3.0
SB2	0	-7	-10	-12	-2.0
SB3	0	-10	-14	-16	-2.7
EB1	0	-9	-13	-14	-2.3
EB2	0	-12	-15	-18	-3.0
EB3	0	-8	-11	-12	-2.0
WB1	0	-11	-14	-16	-2.7
WB2	0	-13	-17	-20	-3.3
WB3	0	-10	-15	-17	-2.8

4.6. Data Collection Example

To demonstrate how the data collector in the Econolite Autoscope software works an example is illustrated in Figure 4.20. The software used for the example is from the version 8 generation. Figure 4.20 is divided into two columns with a screen capture on the right side and the corresponding view of the data collector on the left-hand side.

In Figure 4.20a, the initial state data with an initial screen shot is shown. The initial state data columns are labeled by number. Each of the columns is described in Table 4.8. The columns included in the data collector can be changed by the user in the Autoscope software and the selected columns are those recorded to the text file. The data items described in Table 4.8 are those data typically collected during tests conducted for this research.

Initially, in Figure 4.20a all of the detectors are active because cars are present in both the through and left-turn lanes. Additionally, the phase is connected to the red phase, therefore when the signal is red the data collector indicates that the red signal phase is 'on' or 'active'.

In Figure 4.20b, at time 7:32:57 AM, both the through and left-turn phases have turned green as shown in the video screen capture. This change is reflected in the data collector by the items identified by 'A' and 'B', where the state has changed from 'active' to 'off'.

Table 4.8 Columns in Event Collector shown in Figure 4.20a.

Item #	Title	Description
1	Event State	Shows a red 'A' to indicate event is 'Active'. Shows a black 'O' to indicate event is 'Off'.
2	CPU Identifier	Unique identifier for each Autoscope used to identify unit that data was collected on.
3	Detector ID	Unique ID number for labels in Autoscope detector field, used to identify event that the data point is associated with.
4	Detector Title	Descriptive identifier for labels in Autoscope detector file used for human interpretation of data points.
5	Date	Date stamp in MM/DD/YYYY.
6	Time	Time stamp in HH:MM:SS AM/PM format.
7	Time MS	Time in number of milliseconds since last Autoscope reboot or counter rollover, used for time calculations.
8	State	Reads 'On' to indicate event is 'Active'. Reads 'Off' to indicate event is 'Inactive'.
9	Status	Gives status of Autoscope. Reads 100% when Autoscope is performing correctly, otherwise gives an error code.

In Figure 4.20c, at time 7:33:05 AM the traffic discharges and the loop detector and each of the video detectors remove the call. This is shown on the screen overlay by the label detectors, identified by 'C', having turned from black to white. In the data collector, the state of each of the detectors has also changed from 'active' to 'off' as identified by 'C'.

Finally, in part d of Figure 4.20, vehicles have arrived into the left-turn lane at time 7:33:11 AM, causing the loop detector and the three video detectors to become active as shown by 'D' in the screen capture. This change is also reflected in the data collector by 'D'. Additionally, the left-turn phase has terminated as identified by 'E' in the screen capture. Again this change is reflected in the data collector by 'E' indicating that the red signal is active.

As each of the changes occurs on the video overlay, it also changes in the data collector which logs each change to a text file for further processing. During the test, a digital video is also made to be used for data verification and interpretation.

This text file and the digital video file are essentially the final products of the test bed. As shown in Figure 4.1, the text file includes phase state, loop detector and video detector state. This information is used to develop the L1V0 and L0V1 graphs, and on-time and off-time histograms. The digital video is used to ground truth the data. In the next chapter, the data reduction procedure is described.

Figure 4.1 Summary of Test Bed Purpose and Output

Figure 4.2 Noblesville Intersection Layout

a) Loop Detector and Camera Layout

b) Phase Sequence

Figure 4.3 West Lafayette Intersection Layout

Figure 4.4 Sample Approach Detail (West Lafayette, IN – Northbound Approach)

a) Noblesville, Indiana

b) West Lafayette, Indiana (Vendor recommended offset is inline with lane line between left-turn lane and through lane)

Figure 4.5 Typical Pole Configurations

a) Noblesville Camera Locations (Eastbound)

b) West Lafayette Camera Locations (Northbound)

Figure 4.6 Example Camera Locations

December 12, 2003
(Avg. Temp: 34.0°F)

a) Eastbound Camera (C3E) at 36' Offset

b) Eastbound Camera (C2E) at 48' Offset

c) Eastbound Camera (C1E) at 60' Offset

July 12, 2004
(Avg. Temp: 72.7°F)

d) Eastbound Camera (C3E) at 36' Offset

e) Eastbound Camera (C2E) at 48' Offset

f) Eastbound Camera (C1E) at 60' Offset

Figure 4.7: Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Eastbound Approach in Noblesville during December 2003 and July 2004

Figure 4.8 Temperature at Noblesville, Indiana during December 2003 and July 2004 (Corresponds to Screen Captures in Figure 4.7)

a) Eastbound Camera (C3W) at 36' Offset

b) Eastbound Camera (C2W) at 48' Offset

c) Eastbound Camera (C1W) at 60' Offset

Figure 4.9 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Eastbound Approach in Noblesville

a) Northbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Northbound Camera (C2N) at Optimal Height (40') and No Offset

b) Northbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Northbound Camera (C4N) from Overhead Position

Figure 4.10 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Northbound Approach in West Lafayette during October 2004

a) Northbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Northbound Camera (C2N) at Optimal Height (40') and No Offset

b) Northbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Northbound Camera (C4N) from Overhead Position

Figure 4.11 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Northbound Approach in West Lafayette

a) Cabinet 2 Patch Panel (East side)

b) Detailed View of Item 5

c) Cabinet 2 Instrumentation (West side)

Figure 4.12 Noblesville Data Collection Cabinet

a) Cabinet 2 Patch Panel (East side)

b) Detailed View of Item 4

c) Cabinet 2 Instrumentation (West side)

Figure 4.13 West Lafayette Data Collection Cabinet

Figure 4.14 Noblesville Example Screen Overlay

a) Camera 1 Screen Overlay (Data Collector for Cameras 1 through 3)

b) Camera 4 Screen Overlay (Data Collector for Camera 4)

Figure 4.15 West Lafayette Example Screen Overlay

a) Autoscope ® Solo Mini-Hub II I/O Graphic

Inputs		Outputs			
1	LT Phase	1	SB Cam LT (Φ 1) Output	9	Not Used
2	LT Loop	2	NB Cam TH (Φ 2) Output	10	Not Used
3	LT Camera 2	3	WB Cam LT (Φ 3) Output	11	Not Used
4	LT Camera 3	4	EB Cam TH (Φ 4) Output	12	Not Used
5	TH Phase	5	NB Cam LT (Φ 5) Output	13	Not Used
6	TH Loop	6	SB Cam TH (Φ 6) Output	14	Not Used
7	TH Camera 2	7	EB Cam LT (Φ 7) Output	15	Not Used
8	TH Camera 3	8	WB Cam TH (Φ 8) Output	16	Not Used

b) I/O Assignments

Figure 4.16 Econolite Autoscope Mini-Hub II I/O Indications

Autoscope Network Browser - v7.10 a

File View Network Channel Autoscope Data Tools Help

Autoscope

Server Channel

CIVL1122PC3

COM1

COM2

Offline Channel

Stadium @ NW -- EB Panel

Stadium @ NW -- NB Panel

Stadium @ NW -- SB Panel

Stadium @ NW -- WB Panel

1

CPU Identifier	Approach and Phases	Site Service Information	Network Address	Load Index	Sensor Number
04046AFF826DE811	EBC1 P4,7 (GNX02) W.Stadium Ave.	EBC1 zoom=4064 height=41.3'	192.168.11.3	101	1
040468FF0B65E811	EBC2 P4,7 (GNX06) W.Stadium Ave.	EBC2 zoom=4227 height=40'1"	192.168.11.4	103	2
04046AFFA567E811	EBC3 P4,7 (GNX10) W.Stadium Ave.	EBC3 zoom=4077 height=23'4.5"	192.168.11.2	100	3
040468FFAD70E811	EBC4 P4,7 (GNX14) W.Stadium Ave.	EBC4 zoom=2100 height=40'8.5"	192.168.9.3	102	4
040468FFED63E811	NBC1 P2,5 (GNX01) US-231 Northwestern Ave.	NBC1 zoom=3893 height=40'6"	192.168.8.2	88	1
040467FF21DCE611	NBC2 P2,5 (GNX05) US-231 Northwestern Ave.	NBC2 zoom=3656 height=40'6"	192.168.8.4	89	2
040468FF5C88E811	NBC3 P2,5 (GNX09) US-231 Northwestern Ave.	NBC3 zoom=3952 height=22'9"	192.168.8.3	84	3
04046AFFCD7CE811	NBC4 P2,5 (GNX13) US-231 Northwestern Ave.	NBC4 zoom=0 height=38'7.5"	192.168.11.1	104	4
040467FFA266E811	SBC1 P6,1 (GNX03) US-231 Northwestern Ave.	SBC1 zoom=3928 height=41'9"	192.168.9.1	88	1
040468FF7566E811	SBC2 P6,1 (GNX07) US-231 Northwestern Ave.	SBC2 zoom=3416 height=40'2"	192.168.9.4	87	2
040468FFFA89E811	SBC3 P6,1 (GNX11) US-231 Northwestern Ave.	SBC3 zoom=3968 height=24'2"	192.168.9.2	102	3
040468FF2E76E811	SBC4 P6,1 (GNX15) US-231 Northwestern Ave.	SBC4 zoom=0 height=37'2"	192.168.10.2	95	4
040468FF028CE811	WBC1 P8,3 (GNX04) W.Stadium Ave.	WBC1 zoom=4713 height=41'0"	192.168.10.1	76	1
04046AFF075E811	WBC2 P8,3 (GNX08) W.Stadium Ave.	WBC2 zoom=4695 height=40'2"	192.168.10.3	83	2
04046AFF2666E811	WBC3 P8,3 (GNX12) W.Stadium Ave.	WBC3 zoom=4787 height=23'3"	192.168.10.4	81	3
040467FF476AE811	WBC4 P8,3 (GNX16) W.Stadium Ave.	WBC4 zoom=0 height=39'7"	192.168.8.1	101	4

3 4 5 6 7 8

2

Channel Custom

16 Autoscopes, 1 Selected

Figure 4.17 Autoscope Network Browser

Figure 4.18 Autoscope Data Collector: Creating a Poll

View	Detector Title	Detector ID	Time Interval
Yes	NBC1 Thru -- Phase 2 Output - 101 - Detector Function	NBC1 Thru -- Phase 2 Output	State Change
Yes	NBC1 LT -- Phase 5 Output - 104 - Detector Function	NBC1 LT -- Phase 5 Output	State Change
Yes	NB Thru Loop - Input 6 - 146 - Detector Function	NB Thru Loop - Input 6	State Change
Yes	NBC2 AB Thru - 148 - Detector Function	NBC2 AB Thru	State Change
Yes	NBC3 AB Thru - 149 - Detector Function	NBC3 AB Thru	State Change
Yes	NB LT Loop - Input 2 - 150 - Detector Function	NB LT Loop - Input 2	State Change
Yes	NBC2 LT - 151 - Detector Function	NBC2 LT	State Change
Yes	NBC3 LT - 152 - Detector Function	NBC3 LT	State Change
Yes	NB phase 2 (input Red phase 5) - 153 - Label	NB phase 2 (input Red phase 5)	State Change
Yes	NB phase 5 (input Red phase 1) - 147 - Label	NB phase 5 (input Red phase 1)	State Change
Yes	NBC4 Thru -- Phase 2 Output - 101 - Detector Function	NBC4 Thru -- Phase 2 Output	State Change
Yes	NBC4 LT -- Phase 5 Output - 104 - Detector Function	NBC4 LT -- Phase 5 Output	State Change
Yes	NB Thru Loop - Input 6 - 137 - Detector Function	NB Thru Loop - Input 6	State Change
Yes	NB LT Loop - Input 2 - 142 - Detector Function	NB LT Loop - Input 2	State Change
Yes	NB phase 2 (input Red phase 5) - 149 - Label	NB phase 2 (input Red phase 5)	State Change
Yes	NB Red phase 5 (input Red phase 1) - 150 - Label	NB Red phase 5 (input Red phase 1)	State Change

Figure 4.19 Sample Autoscope Poll List (Northbound – West Lafayette, IN)

Table 4.9 Autoscope Poll List for Northbound (West Lafayette, IN)

#	Detector Title	Input/Output	Det ID
West Lafayette Northbound Camera 1: 040468FFED63E811			
1	NBC1 Thru	Phase 2 Output	101
2	NBC1 LT	Phase 5 Output	104
3	NB Thru Loop	Input 6	146
4	NBC2 AB Thru		148
5	NBC3 AB Thru		149
6	NB LT Loop	Input 2	150
7	NBC2 LT		151
8	NBC3 LT		152
9	NB Phase 2	Input Red Phase 5	153
10	NB Phase 5	Input Red Phase 1	147
West Lafayette Northbound Camera 4: 04046AFFCD7CE811			
11	NBC4 Thru	Phase 2 Output	101
12	NBC4 LT	Phase 5 Output	104
13	NB Thru Loop	Input 6	137
14	NB LT Loop	Input 2	142
15	NB phase 2	Input Red Phase 5	149
16	NB Red phase 5	Input Red Phase 1	150

Figure 4.20 Autoscope Data Collector: State Data with Example Screen Captures

CHAPTER 5. DATA MANAGEMENT AND PROCESSING

5.1. Introduction

A test requiring the collection of each state change for the signal phase, video detector status and loop detector status will naturally result in a large number of data points that are collected and thus must be managed. In fact, a single 24-hour test involving a comparison of two detectors (a video detector and a loop detector) typically results in 2,000 to 12,000 events per movement depending on traffic volume.

To maintain flexibility and efficiency in the data reduction phase of the research it was necessary to develop a robust and versatile data management and processing procedure. A detailed description of this procedure is presented in this chapter.

In this research, the data collect module in the Econolite Autoscope software was used to collect data. However, the procedures presented in this chapter could apply to any data collection software that provides text file output. The data collection equipment and procedures were presented in detail in Chapter 4.

The data produced by the Econolite Autoscope software is recorded in a semi-colon delimited text file. A screen shot of the data collector is shown in Figure 5.1a. The Autoscope software is described in more detail in Chapter 4 of this report and in the Autoscope help files included in the software. The text file can be accessed through any program that can read text files. It is particularly useful to use a spreadsheet or database that is capable of placing the semi-colon delimited fields in a columnar format as shown in Figure 5.1b.

The architecture of the data management and processing procedure is shown in Figure 5.2. A database such as Microsoft Access is used to store each of the

data points. The data is then accessed and processed through a spreadsheet program such as Microsoft Excel.

To allow Microsoft Access and Microsoft Excel to work together a middleware program, Microsoft Query, is used to create the communication link between the database and the spreadsheet. The query program uses parameters provided to it by the spreadsheet to select which data is retrieved from the database.

5.2. Database

The first step in creating the database is populating a table with the information from a data collection. This is accomplished using the 'Get External Data' option within the database. The text file can be directly imported into a database table. The specifications for the file import are shown in Figure 5.3. These specifications can be conveniently saved so that it is not necessary to enter them each time a file is imported.

Initially, the text file must be identified as a semi-colon delimited file. These settings can be arranged at the very top of the window as shown in Figure 5.3.

Each of the fields that are typically imported from the text file are shown at the bottom of the specifications window shown in Figure 5.3. The imported fields in this case include 'CPU', 'Event_ID', 'Event_Name', 'Date', 'Time', 'Autoscope_Status', 'Time_MS' and 'Event_State'. A description of each of the fields is shown in Table 5.1.

Table 5.1 Data collection field names and descriptions

Field Name	Description	Example Data (Description, if any, provided in parentheses)
CPU	The CPU serial number in each Autoscope unit is used to identify on which unit the data was collected.	040468FFED63E811 (WL NB1) 040467FFA266E811 (WL SB1)
Event_ID	Each label in an Autoscope detector file has a unique 3-digit identifier. Each event is associated with a label detector and therefore can be identified by the 3-digit Event_ID.	153 (Through Phase Change) 131 (Through Loop State Change) 135 (Through Cam1 State Change)
Event_Name	Text description that corresponds to the Event_ID field that can be used for human interpretation.	Red Phase 2 (Through Phase) Lpr-ABR (Through Loop) Cam1 (Through Cam1) Cam2 (Through Cam2) Cam3 (Through Cam3)
Date	The date the event occurred in MM/DD/YYYY format.	9/14/2004 1/20/2005
Time	The time the event occurred in HH:MM:SS AM/PM format.	12:01:38 AM 4:22:23 PM
Auto-scope_Status	During events where the Autoscope is performing and collecting data correctly, the value of the field is '100'. In header rows and rows where there are errors, the value will either be an error code or another string such as title in the header row.	100 (Autoscope Working)
Time_MS	The time the event occurred relative to the last Autoscope reboot in milliseconds. The millisecond counter increments upwards from 0, where 0 represents the time of the last Autoscope reboot. The counter will rollover back to zero once the counter reaches $2^{32}-1 = 4294967295$	134947700 162443800 1414871000 1458057000
Event_State	Boolean value (1 or 0) to indicate whether the event state is active (1) or inactive (0).	<u>Phase State</u> 1 (Red Signal is Active) 0 (Red Signal is Inactive) Or <u>Detector State</u> 1 (Detector is Active) 0 (Detector is Inactive)

Each of the fields is imported as a text format. Those fields that are to be stored in a non-text format, namely the date and time fields, are automatically converted because the database table to which the information is imported has the data type set for the date and time fields as Date/Time. The database table used in the import process is called 'Main_Import'. The set-up of this table is shown in Figure 5.4a; each of the data types and a description of each field are shown in the second and third columns.

After the text file has been imported to the database table called 'Main_Import', the data must be further processed before final storage. There are three main purposes of this process. The first is to combine the time and date fields into a single field which simplifies the use of dates and times in later calculations. Secondly, the 'Time_MS' field is converted from text to a number format so that calculations can be performed using these values. The final and most important purpose is to validate the data by removing unneeded records such as those containing header rows, error codes or data that is otherwise not valid.

In the Autoscope data collector, the field, 'Autoscope_Status', can be used to eliminate undesired information. This field will always be equal to '100' in rows where the data is valid. This processing is accomplished in a SQL statement as shown in Figure 5.4b. In this statement each of the records in the table 'Main_Import' is copied to the table 'Processed_Data' as long as the field 'Autoscope_Status' in the table 'Main_Import' is equal to '100'. Additionally, the 'Time' and 'Date' fields from the table 'Main_Import' are combined into a single field 'Date_Time' in the table 'Processed_Data'. The table format for 'Processed Data' with field names, data types and descriptions is shown in Figure 5.4c.

After the data from the original table 'Main_Import' has been processed, the unprocessed data can be deleted. This is accomplished through a very simple SQL statement as displayed in Figure 5.4d.

5.3. Query

To access the data in the database from a spreadsheet program such as Microsoft Excel, a query must be created. Microsoft Query, a program included with Microsoft Office, acts as the middleware between the database and the spreadsheet. The composition of the query is very similar to composing a query from within Microsoft Access.

The setup of the query used in this research is shown in Figure 5.5a. Item 1 shows the table that is being queried, in this case: 'Processed Data'. Each of the fields in the table is also shown as these are the values that can be queried. Item 2 shows the first column of queried values, in this case the criteria field is 'Event_ID'. The next two columns identified by Items 3 and 4 use the criteria fields of 'CPU_ID' and 'Date_Time'.

In each row below the criteria field row, values for each of the criteria can be set. For this procedure, Microsoft Excel will request which data should be returned, therefore the value fields have variables surrounded by brackets whose value will later be provided by Excel.

Each row in the Microsoft Query statement (Figure 5.5a) represents a single statement. For example, Item 5 shows a statement that will return all records that match where the 'Event_ID' matches the provided Loop_ID and the 'CPU' field matches the provided CPU_ID and that are between the Start_Time and End_Time. Each of the parameters enclosed by brackets indicate that the value is a dynamic variable and in this case will be provided by values from another source such as Microsoft Excel (i.e. [cam_cpu], between [start time] and [end time], [cam_id]).

After the Microsoft Query statement has first been defined and returned to Microsoft Excel, the Query program will ask where it should find the parameter

values. A 'Parameters' window as shown in Figure 5.5b will appear with a list of the parameters on the left side of the window as identified by Item 6. These are the values that were enclosed with brackets in Figure 5.5a. The manner in which each of the parameter values can be obtained is defined in the right side of the window. In this case, each of the parameter values is obtained from a cell reference that is entered in the text box identified by Item 7.

The final step of creating the query is setting the remaining 'External Data Range Properties' in the window shown in Figure 5.6. In this window the Query can be saved under a name and a variety of other options can be selected. The set-up for this data collection is shown in Figure 5.6.

5.4. L0V1/L1V0 Graphs

5.4.1. Spreadsheet

All of the data stored in the database is accessed via a spreadsheet. The spreadsheet also passes parameter values to the query to request the relevant data. Finally, the spreadsheet is used to perform the data reduction by using the data to complete calculations and develop graphs. The use of the spreadsheet developed for this research is discussed in this section.

The settings sheet of the Microsoft Excel spreadsheet is shown in Figure 5.7. The parameters identified by item 1 are used to identify the site location, the direction, the camera number and the signal phase of interest in the test. These values are used to determine the CPU number and the detector ID's that need to be accessed from the database. The CPU number and the detector ID's are passed to the database via MS Query and the appropriate values are returned.

Item 2 is where the starting date and time and ending date and time are entered. These values are also passed to the database so that only records within the specified time frame are returned to the spreadsheet.

Item 3 allows the user to set screening options for the discrepancy calculations. The 'Blanking Band' option allows the user to set in seconds a certain threshold for the discrepancy calculation. It is unlikely both of the detectors will activate or deactivate at precisely the same moment, therefore there will naturally always be some discrepancy between the on and off times of the detectors. This setting allows the user to choose the tolerance for these small discrepancies. For the majority of the tests in this research a blanking band of 0.5 seconds was chosen as shown in Figure 5.7.

The fourth item in Figure 5.7 allows a user to select the phase number for the approach. Additionally, the left-turns can be assigned as protected only (pt), permitted-protected (pt-pm) or permitted (pm). This designation is important so that the spreadsheet knows whether or not there is a permitted phase which is color coded with blue on the L0V1 and L1V0 discrepancy graphs.

There are four buttons identified by Item 6 that are used to complete various tasks. The 'Calculate' button, tells the spreadsheet to access the database and recalculate it's cells. This button would typically be used after the user has made changes to the settings. The 'Cycle Through' button will have the spreadsheet automatically cycle through various settings including directions, phases and cameras. This is included so that a user does not have to manually go through each combination of direction, phase and camera to complete the data reduction and graph calculations. The fifth Item in Figure 5.7 is used to set the directions, phases and cameras that will be included in a cycle through request.

The seventh Item in Figure 5.7 refers to the scale shown on the x-axis of the L1V0 and L0V1 graphs. This is useful because the x-axis scale is in time units which must be converted to a numerical unit in order to change the scale.

Figure 5.7, Item 8 is used to set whether the graphs display the discrepancies in color or in black & white. The discrepancies can be correlated to the signal indication that was displayed at the time to distinguish any patterns that may be only occurring during a specific phase color. A legend for the colors used on the L0V1 and L1V0 graphs is shown in Table 5.2.

Table 5.2 Color legend for graphical results

Color on Graph	Through Phase	Left-Turn Phase
Red	Red Indication	Red Indication
Green	Green Indication	Protected Indication
Blue	NA	Permitted Indication

Item 8 also allows the user to choose whether or not a title is displayed on the L1V0 and L0V1 graphs. Additionally, the user can also choose the order in which the color bars are plotted onto the graphs, because the color plotted last will be more prominent than the colors plotted earlier. Therefore, it is sometimes useful to plot the colors in a different order to ensure that one color is not dominant simply because it was plotted last and therefore over the colors that were plotted first.

Figure 5.7, Item 9 lists the number of large discrepancies that are plotted on each graph. While it is useful to look at each of the L1V0 and L0V1 graphs, the number of large discrepancies provides a quantification of the number of discrepancies on each graph.

Finally, Figure 5.7, Item 10 allows the user to choose whether the large errors will be listed and whether a power point presentation will be created. If the checkbox next to create PowerPoint is activated then the graphs generated by the spreadsheet will automatically be correctly formatted and inserted into a PowerPoint presentation to avoid having the user complete this step manually. The 'List Large Errors' checkbox will list all of the large errors with their respective durations and times of occurrences. This list is valuable when the user wishes to validate or ground truth the discrepancies by watching the recorded digital video. An example of the list generated by the spreadsheet is shown in Figure 5.8.

5.4.2. Example Calculations

Once the settings have been selected in the spreadsheet and the data has been returned from the database, the calculations on the data are completed to identify the L1V0 and L0V1 discrepancies. This section describes in detail the procedure used to calculate discrepancy durations from the loop detector events and video detector events.

The column layout of the spreadsheet is shown in Figure 5.9. The first six columns in the spreadsheet are data that are accessed directly from the database. These columns are those shown in Figure 5.9a. This is the data upon which subsequent calculations are performed to calculate the discrepancy durations.

In Figure 5.9b, calculations are made to determine the present state of the system. Column G, H & I are used to calculate the loop, camera and phase states respectively. The calculations in Columns G, H & I of Figure 5.9b are relatively straightforward. Each of the calculations for these three columns are shown in Figure 5.10.

The loop state is calculated in Column G of Figure 5.9b while the detail of this calculation is shown in Figure 5.10a. Referring to Figure 5.10a, the spreadsheet first looks at the 'Object ID Number' (Figure 5.9a, Column A) to see if this data record pertains to the loop detector. If it does not, the loop state is taken from the previous row since no change is made by this record. If the data record does pertain to the loop detector, the spreadsheet checks the 'Object State' field (Figure 5.9a, Column E) for either the number 1, to indicate that the loop detector activated, or the number 0 to indicate that the loop detector deactivated. For example, the loop state in Row 3 of Figure 5.9b is the same as in Row 4 because the 'Event_ID' value of 153 (Figure 5.9a, Row 4, Column A) does not refer to the loop detector. In Row 5, the 'Loop_State' value is 'TRUE' to indicate that the loop detector has activated. This value changes because the 'Event_ID' value of 131 refers to the loop detector as indicated by the Event_Name in Column B. The 'Event_State' (Figure 5.9a, Column E, Row 5) with a value of '1' indicates that the loop detector is active; therefore the value of the 'Loop_State' in Row 5 is now 'TRUE'. In a similar fashion one can see that the loop has deactivated in Row 8. This is reflected in both the 'Loop_State' (Figure 5.9a, Column G, Row 8) and 'System_State' fields (Figure 5.9a, Column K, Row 8).

The video detector state and the phase state are calculated in exactly the same manner as the loop detector state. The details of these calculations are shown in Figure 5.10b & c. It should be noted that the phase state equals TRUE for green phases, and therefore when the red signal is inactive (For example see Figure 5.9a, Column E, Row 7).

The 'Through_Phase' parameter (Figure 5.11b, Column J) is used when developing graphs for a left-turn phase in order to determine if during the left-turn red phase it is in fact permitted. In a calculation for a through phase, Columns I & J would give identical values for the state of the through phase.

The calculation for the system state (Column K) is shown in Figure 5.11. It simply combines the loop detector state, video detector state and signal phase state into a single column that describes the overall system state. The loop detector and the video detector are represented by an 'L' and 'V' in Column J; the number following the letter indicates whether the detector is active (1) or inactive (0). Similarly, the phase state is represented by a 'P', and the number after the 'P' indicates whether the green phase is active (1) or inactive (0).

The last calculation in Figure 5.9b (Column L) gives the duration of the system state that is shown in column K. For example, referring to Figure 5.9b, Row 5, Column L, the duration that the system was in the state L1V0P0 was 2.56 seconds. This calculation is made by calculating the difference between Rows 5 and 6 in Column D of Figure 5.9a as shown in Eq. 3.7.

$$\frac{190207520 - 1902024960}{1000} = 2.56 \text{ seconds} \quad \text{Eq. 5.1}$$

There are four system states of interest, which is when there is a discrepancy between the state of the loop detector and the video detector. These four states are L0V1P0, L0V1P1, L1V0P0, and L1V0P1. Additionally, during calculations for left-turn phases that are signalized as protected-permitted, it is necessary to distinguish between the permitted phase and the red phase, by taking into consideration the status of the through phase. In this case, an additional number is added to indicate whether the through phase is active (1), indicating a permitted left-turn, or inactive (0), indicating that the left-turn is prohibited.

In Figure 5.9c, these four states are separated in Columns N, P, Q and S. The additional columns needed for protected-permitted left-turns are provided with Columns O and R.

The discrepancy where the loop detector is not active and the video detector is active is contained in columns N through P. These values can be plotted against time (Column M), and since they are separated by phase state (L0V1P0-0, L0V1P0-1 or L0V1P1) they can also be plotted in color to represent the phase color, red when the phase is inactive (P0) and green when the phase is active (P1). For protected-permitted left-turns the phase is plotted as green when the phase is active (P1), red when the phase is inactive and the through phase is inactive (P0-0) and blue for the permitted phase when the left-turn phase is inactive and the through phase is active (P0-1).

5.5. On-Time and Off-Time Histograms

5.5.1. Spreadsheet

The spreadsheet developed to produce on-time and off-time histograms is very similar to the spreadsheet used to develop L0V1 and L1V0 graphs. Again, all of the data stored in the database is accessed via a spreadsheet by passing parameter values to the database via the query. All of the calculations for the data reduction are accomplished within the spreadsheet and are described in this section.

The settings sheet of the Microsoft Excel spreadsheet is shown in Figure 5.12. The parameters identified by item 1 are used to identify the site location, the direction, the camera number and the signal phase. These values are used to determine the CPU number and the detector ID's that need to be accessed from the database. The CPU number and the detector ID's are passed to the database via Microsoft Query and the appropriate records are retrieved.

Item 2 contains the starting date and time and ending date and time. On this spreadsheet, two starting and ending times can be entered because it was often

very helpful to compare histograms from two different time periods, such as day versus night. These times are passed to the database so that only records within the specified time frame are returned to be used in calculations.

The third item in Figure 5.12 allows a user to assign phase numbers to approach directions. Additionally, the left-turns can be assigned as protected only (pt), permitted-protected (pt-pm) or permitted (pm). This designation is important so that the spreadsheet knows whether or not there is a permitted phase which is color coded with blue on the histograms.

There are two buttons identified by Item 6 that are used to calculate the spreadsheet. The 'Calculate' button, tells the spreadsheet to access the database and recalculate it's cells. This button would typically be used after the user has made changes to the settings. The 'Cycle Through' button will have the spreadsheet automatically cycle through various settings including directions, phases and cameras. This is included so that a user does not have to manually go through each combination of direction, phase, camera and time periods to complete the data reduction. The fifth Item in Figure 5.12 is used to set the directions, phases and cameras that will be included in a cycle through request.

Finally, the seventh item in Figure 5.12 allows the user to choose whether the graphs and raw numbers are automatically copied by the spreadsheet. This is useful because a user can complete a 'Cycle Through' calculation and the graphs will be stored in the Microsoft Office Clipboard for retrieval into another program. If the checkbox next to create PowerPoint is activated then the graphs generated by the spreadsheet will automatically be correctly formatted and inserted into a Microsoft PowerPoint presentation to avoid having the user complete this step manually.

5.5.2. Example Calculations

Once the settings have been selected in the spreadsheet and the data has been returned from the database, the calculations on the data are completed to create on-time and off-time histograms. This section describes in detail the procedure used to calculate difference in on-times and off-times between the loop detector and the video detectors.

The column layout of the spreadsheet is shown in Figure 5.13. The first six columns in the spreadsheet are data that are accessed directly from the database. These columns are those shown in Figure 5.13a. Notice that this is the same example data on which the procedure for calculating L0V1 and L1V0 discrepancies was based. The loop state, video detector state, and phase state are brought into the spreadsheet in chronological order.

The difference in activation and deactivation times is calculated and reported in Column G, as shown in Figure 5.13b. The difference in on-time and off-time is only calculated when certain conditions are satisfied to ensure that only comparisons are made between two records containing either off-times or on-times between a loop detector and a video detector. The calculation of Column G is shown in a detailed flow chart in Figure 5.14a. The conditions that must be satisfied are shown in the two diamonds on the left-side of the figure. The conditions are repeated here for convenience:

- Is this Event state (Column E) the same as the previous Event State? To ensure that an on-event is not compared to an off-event.

For example, a calculation is not made in Figure 5.13b, Row 3, Column G, because although the event in Row 2 corresponds to a loop detector and the event in Row 3 corresponds to a video detector, the loop detector is activating while the video detector is deactivating.

- Are both this Event ID (Column A) and the previous Event ID **not** related to a phase change? To ensure that a detector on-event or off-event is not compared to a phase on-event or off-event.

For example, no comparison is made between Figure 5.13, Rows 7 and 8, because the event in Row 7 corresponds to the termination of the red phase. The loop detector events and video detector events are only compared to each other, not to phase events.

If the answer to either of the previous two questions is no, then the calculation is not performed. However, if the answer to all of the previous questions is yes, then a calculation is performed to determine the difference in the on-time and off-time between the video detector and the loop detector by subtracting the 'Time_MS' value in the previous row with the 'Time_MS' value in this row. For example, the questions were not satisfied except for in Figure 5.13, Column G, Rows 6 and 9.

Finally, a check is made to see if the video detector or the loop detector activated first. The Event ID in the current row indicates that the detector in the current row activated after the detector in the previous row. Therefore, if the Event ID in the current row relates to the video detector it indicates that the video detector activated after the loop detector. When the video detector activates prior to the loop detector, the magnitude is calculated and reported with a negative sign. When the video detector activates after the loop detector the absolute value of the magnitude is used and therefore a positive number is reported.

For example, in Figure 5.13, in the comparison made between Rows 5 and 6, and also between Rows 8 and 9, the loop detector activated prior to the video detector. Therefore, the number calculated will be a positive value. If in either of

these cases the video detector was in the first row and the loop detector in the subsequent row, it would indicate that the video detector activated first and therefore the calculated number would be negative.

The calculation in Figure 5.13b, Column G is calculated in exactly the same way as it was for the L1V0/L0V1 calculations. For example, referring to Figure 5.13b, Row 6, Column G, the difference in the on-time between the loop and the video detector is calculated by subtracting the 'Time_MS' value (Column D) in Row 6 from the 'Time_MS' value in Row 5 as shown by Eq. 5.2.

$$\frac{1902024960 - 1902027520}{1000} = -2.56 \text{ seconds} \quad \text{Eq. 5.2}$$

Since the 'Event_ID' in Row 5 refers to the loop detector and the 'Event_ID' in the Row 6 refers to the video detector, the absolute value of the previous calculation must be taken to give a positive value indicating that the video detector activated after the loop detector.

The phase state (Figure 5.13b, Column H) is calculated in exactly the same manner as the loop detector state, video detector state and phase state explained in the L0V1/L1V0 Spreadsheet section. The flowchart for this calculation has been repeated in Figure 5.14b.

The 'Through_Phase_State' parameter (Figure 5.13b, Column I) is used when developing graphs for a left-turn phase in order to determine if during the left-turn red phase it is in fact permitted. In a calculation for a through phase, Columns H & I would give identical values for the state of the through phase.

After the difference in on/off time is calculated, the final step is to categorize the calculations appropriately by phase and whether the calculation refers to an on-

time or an off-time. The calculation is easily categorized as an on-time or off-time difference by looking at the 'Event State' value (Column E). A zero (0) would indicate that the detectors are deactivating and the calculation represents a difference in off-times, while a one (1) would indicate the detectors were activating and the calculation represents a difference in on-times.

The phase categorization is made by referencing columns H and I. For a through phase, it is only necessary to look at Column H where it indicates whether the phase state is green or red. For a permitted-protected left-turn phase, it is necessary to look at Column I to determine whether the left-turn phase is indeed red or if it is permitted (during a through green phase).

Finishing the example, the 'Event_State' (Column E) of Rows 5 and 6 both show a '1' indicating that the detector activated. In this case, we know that the value of 2.56 seconds refers to an on-time. It is also categorized by phase by looking at Column H, where Rows 5 and 6 indicate that the phase color is red. The final value of 2.56 seconds is categorized under Red On-Times (Column L). Depending on whether the calculation refers to an on-time or an off-time, determined from Column E, and what phase color the calculation refers to, determined by Column H and I, the final value is correctly categorized in one of the columns J through O.

The histogram plots are made by simply counting the number of values in Columns J through O, that fall into 0.1 seconds bins between 3.0 seconds and minus 3.0 seconds. All values greater than 3.0 seconds or less than minus 3.0 seconds are put into a single bin. The total number of values are added, and the number in each bin is divided by this total value to get the percentage frequency of the bin. These are plotted on histogram plots as was shown in Chapter 3.

5.6. Advantages of Procedure

By collecting individual data points rather than aggregated data, a large amount of flexibility is gained in the subsequent data reduction steps. For example, the same data set in this research is used to develop L1V0, L0V1 and On/Off Histograms. If an alternative method of reducing the data is developed at a later time, the data collection will not have to be repeated since the data has not been aggregated.

By storing data in a database and accessing it as needed through a spreadsheet, the data organization capability of the database can be used while using the computational power of a spreadsheet to complete the calculations. The following chapter makes extensive use of this procedure to process the 96 hours of data collected during four testing periods each 24 hours in length.

CPU Identifier	Detector ID	Detector Title	Date	Time	Time MS	State	Status
040468FFED63E811	152	NBC3 LT	11/8/2004	4:12:32 PM	890405698	Off	100%
040468FFED63E811	104	NBC1 LT -- Pha...	11/8/2004	4:12:31 PM	890404830	Off	100%
040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:31 PM	890404363	On	100%
040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:31 PM	890404263	Off	100%
040468FFED63E811	101	NBC1 Thru -- P...	11/8/2004	4:12:30 PM	890403762	On	100%
040468FFED63E811	150	NB LT Loop - In...	11/8/2004	4:12:30 PM	890403596	Off	100%
040468FFED63E811	146	NB Thru Loop - ...	11/8/2004	4:12:30 PM	890403596	On	100%
040468FFED63E811	101	NBC1 Thru -- P...	11/8/2004	4:12:30 PM	890403596	Off	100%
040468FFED63E811	146	NB Thru Loop - ...	11/8/2004	4:12:30 PM	890403262	Off	100%
040468FFED63E811	152	NBC3 LT	11/8/2004	4:12:29 PM	890402561	On	100%
040468FFED63E811	151	NBC2 LT	11/8/2004	4:12:29 PM	890402461	On	100%
040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:29 PM	890402294	On	100%
040468FFED63E811	104	NBC1 LT -- Pha...	11/8/2004	4:12:29 PM	890402194	On	100%
040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:28 PM	890401793	Off	100%
040468FFED63E811	101	NBC1 Thru -- P...	11/8/2004	4:12:28 PM	890401727	On	100%
040468FFED63E811	146	NB Thru Loop - ...	11/8/2004	4:12:28 PM	890401693	On	100%
040468FFED63E811	150	NB LT Loop - In...	11/8/2004	4:12:28 PM	890401460	On	100%
040468FFED63E811	146	NB Thru Loop - ...	11/8/2004	4:12:28 PM	890401059	Off	100%
040468FFED63E811	101	NBC1 Thru -- P...	11/8/2004	4:12:28 PM	890401059	Off	100%
040468FFED63E811	152	NBC3 LT	11/8/2004	4:12:27 PM	890400558	Off	100%
040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:27 PM	890400158	On	100%
040468FFED63E811	149	NBC3 AB Thru	11/8/2004	4:12:27 PM	890400058	On	100%
040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:27 PM	890400058	Off	100%
040468FFED63E811	149	NBC3 AB Thru	11/8/2004	4:12:27 PM	890399957	Off	100%
040468FFED63E811	151	NBC2 LT	11/8/2004	4:12:26 PM	890399758	Off	100%
040468FFED63E811	146	NB Thru Loop - ...	11/8/2004	4:12:26 PM	890399657	On	100%
040468FFED63E811	101	NBC1 Thru -- P...	11/8/2004	4:12:26 PM	890399657	On	100%
040468FFED63E811	101	NBC1 Thru -- P...	11/8/2004	4:12:26 PM	890399390	Off	100%
040468FFED63E811	146	NB Thru Loop - ...	11/8/2004	4:12:25 PM	890398890	Off	100%
040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:25 PM	890398489	On	100%
040468FFED63E811	149	NBC3 AB Thru	11/8/2004	4:12:25 PM	890398289	On	100%
040468FFED63E811	101	NBC1 Thru -- P...	11/8/2004	4:12:25 PM	890398122	On	100%
040468FFED63E811	104	NBC1 LT -- Pha...	11/8/2004	4:12:24 PM	890397822	Off	100%
040468FFED63E811	146	NB Thru Loop - ...	11/8/2004	4:12:24 PM	890397788	On	100%
040468FFED63E811	150	NB LT Loop - In...	11/8/2004	4:12:24 PM	890397054	Off	100%

a) Autoscope Data Collector: Event Data

	A	B	C	D	E	F	G	H	I
1	Image Sensing Systems, Inc. Data Collector File, Version 7.1.0								
2	CPU Identifier	Detector ID	Detector Title	Date	Time	Status	Time MS	State	
50	040468FFED63E811	150	NB LT Loop - Input 2	11/8/2004	4:12:24 PM	100	890397054	0	
51	040468FFED63E811	146	NB Thru Loop - Input 6	11/8/2004	4:12:24 PM	100	890397788	1	
52	040468FFED63E811	104	NBC1 LT -- Phase 5 Output	11/8/2004	4:12:24 PM	100	890397822	0	
53	040468FFED63E811	101	NBC1 Thru -- Phase 2 Output	11/8/2004	4:12:25 PM	100	890398122	1	
54	040468FFED63E811	149	NBC3 AB Thru	11/8/2004	4:12:25 PM	100	890398289	1	
55	040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:25 PM	100	890398489	1	
56	040468FFED63E811	146	NB Thru Loop - Input 6	11/8/2004	4:12:25 PM	100	890398890	0	
57	040468FFED63E811	101	NBC1 Thru -- Phase 2 Output	11/8/2004	4:12:26 PM	100	890399390	0	
58	040468FFED63E811	101	NBC1 Thru -- Phase 2 Output	11/8/2004	4:12:26 PM	100	890399657	1	
59	040468FFED63E811	146	NB Thru Loop - Input 6	11/8/2004	4:12:26 PM	100	890399657	1	
60	040468FFED63E811	151	NBC2 LT	11/8/2004	4:12:26 PM	100	890399758	0	
61	040468FFED63E811	149	NBC3 AB Thru	11/8/2004	4:12:27 PM	100	890399957	0	
62	040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:27 PM	100	890400058	0	
63	040468FFED63E811	149	NBC3 AB Thru	11/8/2004	4:12:27 PM	100	890400058	1	
64	040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:27 PM	100	890400158	1	
65	040468FFED63E811	152	NBC3 LT	11/8/2004	4:12:27 PM	100	890400558	0	
66	040468FFED63E811	101	NBC1 Thru -- Phase 2 Output	11/8/2004	4:12:28 PM	100	890401059	0	
67	040468FFED63E811	146	NB Thru Loop - Input 6	11/8/2004	4:12:28 PM	100	890401059	0	
68	040468FFED63E811	150	NB LT Loop - Input 2	11/8/2004	4:12:28 PM	100	890401460	1	
69	040468FFED63E811	146	NB Thru Loop - Input 6	11/8/2004	4:12:28 PM	100	890401693	1	
70	040468FFED63E811	101	NBC1 Thru -- Phase 2 Output	11/8/2004	4:12:28 PM	100	890401727	1	
71	040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:28 PM	100	890401793	0	
72	040468FFED63E811	104	NBC1 LT -- Phase 5 Output	11/8/2004	4:12:29 PM	100	890402194	1	
73	040468FFED63E811	148	NBC2 AB Thru	11/8/2004	4:12:29 PM	100	890402294	1	
74	040468FFED63E811	151	NBC2 LT	11/8/2004	4:12:29 PM	100	890402461	1	
75	040468FFED63E811	152	NBC3 LT	11/8/2004	4:12:29 PM	100	890402561	1	
76	040468FFED63E811	146	NB Thru Loop - Input 6	11/8/2004	4:12:30 PM	100	890403262	0	
77	040468FFED63E811	101	NBC1 Thru -- Phase 2 Output	11/8/2004	4:12:30 PM	100	890403596	0	

b) Text File Data Imported to Spreadsheet

Figure 5.1 Autoscope Data Collector: Event Data and Text File

Figure 5.2 Data Management Structure

The 'Example Import Specification' dialog box shows the following settings:

- File Format:** ☒ Delimited, ☐ Fixed Width
- Field Delimiter:** ;
- Text Qualifier:** {none}
- Language:** English
- Code Page:** OEM United States
- Dates, Times, and Numbers:**
 - Date Order:** MDY
 - Date Delimiter:** /
 - Time Delimiter:** :
 - ☒ Four Digit Years
 - ☐ Leading Zeros in Dates
 - Decimal Symbol:** .
- Field Information:**

Field Name	Data Type	Indexed	Skip
CPU	Text	No	☐
Event_ID	Text	No	☐
Event_Name	Text	No	☐
Date	Text	No	☐
Time	Text	No	☐
Autoscope_Status	Text	No	☐
Time_MS	Text	No	☐
Event_State	Text	No	☐

Buttons on the right: OK, Cancel, Save As..., Specs...

Figure 5.3 Microsoft Access: Data Import Specification

Main_Import : Table		
Field Name	Data Type	Description
CPU	Text	Unique ID number for each Autoscope unit.
Event_ID	Text	Unique ID number for labels in Autoscope detector file.
Event_Name	Text	Descriptive identifier for labels in Autoscope detector file.
Date	Date/Time	Date stamp in MM/DD/YYYY format.
Time	Date/Time	Time Stamp in HH:MM:SS AM/PM format
Autoscope_Status	Text	When Autoscope is performing correctly value is 100, otherwise error code
Time_MS	Text	Time in number of milliseconds since last Autoscope reboot or counter rollover
Event_State	Text	Boolean value of 1 (Red phase active, detector active) or 0 (Red phase not active, detector not active)

a) Format of Access Database Table 'Main_Import' for Imported Polling Data

```
INSERT INTO Processed_Data ( CPU, Event_ID, Event_Name,
Date_Time, Time_MS, Event_State )

SELECT Main_Import.CPU, Main_Import.Event_ID,
Main_Import.Event_Name, Main_Import.Date+Main_Import.Time,
Main_Import.Time_MS, Main_Import.Event_State
FROM Main_Import
WHERE Main_Import.Autoscope_Status='100' ;
```

b) SQL Statement to Process Data from 'Main_Import' Table

Processed_Data : Table		
Field Name	Data Type	Description
Event_ID	Text	Used to identify event that the data point is associated with.
Event_Name	Text	Descriptive identifier for human interpretation.
Date_Time	Date/Time	Date and time have been merged and stored in one field. Time stamp of data point.
Time_MS	Number	Time stamp in milliseconds since last Autoscope reboot or counter rollover.
Event_State	Text	Identifies whether the event was activated (1) or deactivated (0).
CPU	Text	Identifies the Autoscope unit on which the data point was collected.

c) Format of Database Table 'Processed_Data' for Processed Polling Data

```
DELETE *
FROM Main_Import ;
```

d) SQL Statement to Clear the Raw Data from 'Main_Import' Table

Figure 5.4 Data Processing: Microsoft Access Database Structure

a) Microsoft Query Statement

b) Parameter Definition

Figure 5.5 Data Processing: Microsoft Query used to Connect Microsoft Access Database and Microsoft Excel

Figure 5.6: Data Processing: Microsoft Query used to Connect Microsoft Access Database and Microsoft Excel: Data Range Properties

ANNA

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		Approach Direction			Noblesville, IN		Eastbound	Calculate						
2		Camera ID			Iteris (6)			Cycle Through						
3		Signal Phase			Phase 4									
4														
5		Start Time			04/21/2005		Pick							
6		Start Date			9:30:00 AM		Date/Time							
7														
8		End Time			04/22/2005		Pick							
9		End Date			9:30:00 AM		Date/Time							
10														
11		Blanking Band (Seconds)			1.0		seconds							
12		Errors to List >			5		seconds							
13														
14														
15														
16														
17		Phase Numbers:			Through		Left-Turn		Cycle Through:		Through		Left-Turn	
18		1 NB	2	5	Pt			3	3	Direction (1 to 4; NB, SB, EB, WB)				
19		2 SB	6	1	Pt			1	1	Phase (1 to 2; Through, Left)				
20		3 EB	4	7	Pt-Pm			4	6	Camera Number				
21		4 WB	8	3	Pt-Pm									
22														

Chart: X-Axis Scale Increment

- ☒ 8-Hour
- ☐ 1/2-Hour
- ☐ 1-Hour
- ☐ 2-Hour
- ☐ 4-Hour

Chart Options

- ☒ Color Bars
- ☐ B&W Bars
- RGB
- ☒ Title

Error Information

	L1V0	L0V1
# Phases	931	
>=2	36	333
>=5	14	173
>=10	7	79
>=20	1	5

Other Options

- ☒ Create Powerpoint
- ☐ List Large Errors
- ☐ Copy Graphs

Figure 5.7: Data Processing: Microsoft Excel – L0V1/L1V0 Spreadsheet Settings

	A	B	C	D	E	F	G	H
		L1V0 -- 040467FFA266E811 Camera 1 -- Phase 1 -- 1/25/2005 (12:00:00 AM) to 1/26/2005 (12:00:00 AM)				L0V1 -- 040467FFA266E811 Camera 1 -- Phase 1 -- 1/25/2005 (12:00:00 AM) to 1/26/2005 (12:00:00 AM)		
1	#		Dur.	Source of Discrepancy	#		Dur.	Source of Discrepancy
2	1	1/20/2005 12:11:02 AM	33.2		1	1/20/2005 3:14:51 AM	30.8	
3	2	1/20/2005 11:48:27 AM	5.6		2	1/20/2005 5:29:43 AM	6.0	
4	3	1/20/2005 10:59:45 PM	5.4		3	1/20/2005 6:26:47 AM	5.2	
5					4	1/20/2005 6:40:28 AM	29.8	
6					5	1/20/2005 7:08:39 AM	26.1	
7					6	1/20/2005 7:48:17 AM	7.4	
8					7	1/20/2005 11:25:12 AM	18.4	
9					8	1/20/2005 11:25:37 AM	43.8	
10					9	1/20/2005 4:08:49 PM	38.5	
11					10	1/20/2005 4:41:05 PM	7.8	
12					11	1/20/2005 6:04:34 PM	6.1	
13					12	1/20/2005 6:12:16 PM	21.5	
14					13	1/20/2005 6:18:54 PM	13.6	
15					14	1/20/2005 6:19:44 PM	6.1	
16					15	1/20/2005 6:21:57 PM	7.0	
17					16	1/20/2005 6:23:18 PM	6.0	
18					17	1/20/2005 6:23:46 PM	9.0	
19					18	1/20/2005 6:24:53 PM	22.9	
20					19	1/20/2005 6:26:27 PM	43.8	
21					20	1/20/2005 6:28:01 PM	6.4	
22					21	1/20/2005 6:31:43 PM	5.9	
23					22	1/20/2005 6:35:33 PM	7.7	
24					23	1/20/2005 6:37:09 PM	10.0	
25					24	1/20/2005 6:42:10 PM	6.5	
26					25	1/20/2005 6:42:37 PM	26.8	
27					26	1/20/2005 6:53:47 PM	6.8	
28					27	1/20/2005 6:56:08 PM	10.4	
29					28	1/20/2005 7:32:19 PM	18.8	
30					29	1/20/2005 7:40:13 PM	23.7	
31					30	1/20/2005 7:53:35 PM	9.0	
32					31	1/20/2005 9:02:10 PM	8.6	
33					32	1/20/2005 9:18:46 PM	29.3	
34					33	1/20/2005 9:52:59 PM	21.2	
35					34	1/20/2005 10:00:13 PM	24.7	
36					35	1/20/2005 10:01:49 PM	6.5	
37					36	1/20/2005 10:02:27 PM	7.9	
38					37	1/20/2005 10:03:34 PM	5.1	
39					38	1/20/2005 10:07:33 PM	12.7	
40					39	1/20/2005 10:13:01 PM	6.9	
ErrorCount LargeErrors IDErrors L1V0 L0V1 Settings Query Code Det_Files /								

Figure 5.8 Data Processing: Microsoft Excel – L0V1/L1V0 Spreadsheet List of Large Errors

	A	B	C	D	E	F
	Event ID	Event_Name	Date_Time	Time _MS	Event State	CPU
1						
2	131	Loop	1/25/2005 3:23:17 PM	1902023040	0	040468FFED63E811
3	135	NBC1	1/25/2005 3:23:18 PM	1902023680	0	040468FFED63E811
4	153	NB phase 2 Red	1/25/2005 3:23:18 PM	1902023936	1	040468FFED63E811
5	131	Loop	1/25/2005 3:23:19 PM	1902024960	1	040468FFED63E811
6	135	NBC1	1/25/2005 3:23:22 PM	1902027520	1	040468FFED63E811
7	153	NB phase 2 Red	1/25/2005 3:24:00 PM	1902065408	0	040468FFED63E811
8	131	Loop	1/25/2005 3:24:10 PM	1902076288	0	040468FFED63E811
9	135	NBC1	1/25/2005 3:24:13 PM	1902079104	0	040468FFED63E811

a) Example Data Returned to Microsoft Excel via Microsoft Query

	G	H	I	J	K	L
	Loop_State	Camera_ State	Phase_State	Through_ Phase	System_ State	System_ State _Duration
1						
2	FALSE	TRUE	TRUE	TRUE	L0V1P1	0.64
3	FALSE	FALSE	TRUE	TRUE	L0V0P1	0.256
4	FALSE	FALSE	FALSE	FALSE	L0V0P0	1.024
5	TRUE	FALSE	FALSE	FALSE	L1V0P0	2.56
6	TRUE	TRUE	FALSE	FALSE	L1V1P0	37.888
7	TRUE	TRUE	TRUE	TRUE	L1V1P1	10.88
8	FALSE	TRUE	TRUE	TRUE	L0V1P1	2.816
9	FALSE	FALSE	TRUE	TRUE	L0V0P1	1.664

b) Example Results from the Data Displayed in Part A

	M	N	O	P	Q	R	S
	Date_Time	L1V0P0-0	L1V0P0-1	L1V0P1	L0V1P0-0	L0V1P0-1	L0V1P1
1							
2	1/25/2005 3:23:17 PM	0.0	0.0	0.0	0.0	0.0	0.6
3	1/25/2005 3:23:18 PM	0.0	0.0	0.0	0.0	0.0	0.0
4	1/25/2005 3:23:18 PM	0.0	0.0	0.0	0.0	0.0	0.0
5	1/25/2005 3:23:19 PM	2.6	0.0	0.0	0.0	0.0	0.0
6	1/25/2005 3:23:22 PM	0.0	0.0	0.0	0.0	0.0	0.0
7	1/25/2005 3:24:00 PM	0.0	0.0	0.0	0.0	0.0	0.0
8	1/25/2005 3:24:10 PM	0.0	0.0	0.0	0.0	0.0	2.8
9	1/25/2005 3:24:13 PM	0.0	0.0	0.0	0.0	0.0	0.0

c) Example Results used for Plotting Purposes

Figure 5.9 Data Processing Microsoft Excel: Sample Input and Output (Query Data Sheet)

a) Loop Detector State (See Column G in Figure 5.9)

b) Video Detector State (See Column H in Figure 5.9)

c) Signal Phase State (See Column I in Figure 5.9)

Figure 5.10 Data Processing: Calculations Methodology

Figure 5.11 Data Processing: Calculations Methodology (System State - (See Column J in Figure 5.9))

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		Approach Direction	Southbound		Noblesville, IN			Calculate			☒ Copy Graphs	☐ Create Powerpoint		
2	1	Camera ID	Cam3					Cycle Through			☐ Copy Numbers			7
3		Signal Phase	Phase 1											
4				Day		Night								
5		Start Time	03/25/2004		03/24/2004									
6		Start Date	12:00:00 PM		8:00:00 PM									
7														
8		End Time	03/25/2004		03/25/2004									
9		End Date	4:00:00 PM		12:00:00 AM									
10														
11														
12														
13														
14														
15														
16														
17														
18	1	NB	Through	Left-Turn	Pt			Through	Left-Turn					
19	2	SB	6	1	Pt			1	1					
20	3	EB	4	7	Pt-Pm			1	1					
21	4	WB	8	3	Pt-Pm			1	1					

Figure 5.12 Data Processing: Microsoft Excel – On-Time/Off-Time Spreadsheet Settings Sheet

	A	B	C	D	E	F
	Event_ID	Event_Name	Date_Time	Time_MS	Event_State	CPU
1						
2	135	Loop	1/25/2005 3:23:17 PM	1902023040	1	040468FFED63E811
3	135	NBC1	1/25/2005 3:23:18 PM	1902023680	0	040468FFED63E811
4	153	NB phase 2	1/25/2005 3:23:18 PM	1902023936	1	040468FFED63E811
5	131	Loop	1/25/2005 3:23:19 PM	1902024960	1	040468FFED63E811
6	135	NBC1	1/25/2005 3:23:22 PM	1902027520	1	040468FFED63E811
7	153	NB phase 2	1/25/2005 3:24:00 PM	1902065408	0	040468FFED63E811
8	131	Loop	1/25/2005 3:24:10 PM	1902076288	0	040468FFED63E811
9	135	NBC1	1/25/2005 3:24:13 PM	1902079104	0	040468FFED63E811

a) Example Data Returned to Microsoft Excel via Microsoft Query

	G	H	I	J	K	L	M	N	O
	Difference in On/Off Time	Phase State	Through Phase State	Green On Times	Green Off Times	Red On Times	Red Off Times	Permitted (Blue) On Times	Permitted (Blue) Off Times
1									
2	--	Green	Green	--	--	--	--	--	--
3	--	Green	Green	--	--	--	--	--	--
4	--	Red	Red	--	--	--	--	--	--
5	--	Red	Red	--	--	--	--	--	--
6	2.56	Red	Red	--	--	2.56	--	--	--
7	--	Green	Green	--	--	--	--	--	--
8	--	Green	Green	--	--	--	--	--	--
9	2.816	Green	Green	--	2.816	--	--	--	--

b) Example Results from the Data Displayed in Part A

Figure 5.13 Data Processing Microsoft Excel: Sample Input and Output (Query Data Sheet)

a) Difference in Detector Activation (See Column G in Figure 5.13)

b) Signal Phase State (See Column H in Figure 5.13)

Figure 5.14 Data Processing: Calculations Methodology

CHAPTER 6. RESULTS

6.1. Introduction

Using the test methodology presented in Chapter 3, several test runs were completed at the two test beds described in Chapter 4 and the data was processed using the procedure described in Chapter 5. The tests occurred on non-holiday weekdays as convenient. Each test run consists of a continuous 24-hour data collection period in order to capture the performance under a variety of lighting and traffic conditions that occur on a typical weekday.

Four 24-hour video tests have been completed. The initial test occurred in March 2004 at the Noblesville test site using the Econolite Autoscope software v7.03. After this initial evaluation several problems with the video detection were identified. In an attempt to address the problems documented by this first test, the manufacturer released an updated version of the Econolite Autoscope software in early 2005. This version of the software (v8.00) was tested at the West Lafayette site in January 2005. A second test was completed at the Noblesville site in April 2005 using v8.10 of the software.

The initial test at the West Lafayette site occurred on January 20, 2005 using v8.00 of the Econolite Autoscope software. During this initial test snow began to fall in the late afternoon hours. This test provided a good opportunity to evaluate the performance of both the loops and the video detection under non-ideal weather conditions.

On January 25, 2005 a second test was conducted at the West Lafayette site again using the v8.00 software. There were no extreme weather events noted

during this test period. Since this test was conducted under “ideal” conditions it is better suited for comparison against other test runs.

A list of the tests presented in this chapter is displayed in Table 6.1, along with any significant weather that was recorded at any time during the testing period.

Table 6.1 List of Tests Presented in the Results

Test Site	Dir.	Start Time	End Time	Significant Weather
Noblesville	NB	3/26/2004 12:00 AM	3/27/2004 12:00 AM	Rain, Fog
Noblesville	SB	3/24/2004 6:00 PM	3/25/2004 6:00 PM	Rain, Fog
Noblesville	EB	3/27/2004 12:30 AM	3/28/2004 12:30 AM	Rain, Fog
Noblesville	WB	3/28/2004 1:00 AM	3/29/2004 1:00 AM	Fog, Haze
Noblesville	NB	4/05/2005 12:00 AM	4/06/2005 12:00 AM	Fog
Noblesville	SB	4/05/2005 12:00 AM	4/06/2005 12:00 AM	Fog
Noblesville	EB	4/05/2005 12:00 AM	4/06/2005 12:00 AM	Fog
Noblesville	WB	4/05/2005 12:00 AM	4/06/2005 12:00 AM	Fog
West Lafayette	NB	1/20/2005 12:00 AM	1/20/2005 12:00 AM	Snow, Fog
West Lafayette	SB	1/20/2005 12:00 AM	1/20/2005 12:00 AM	Snow, Fog
West Lafayette	EB	1/20/2005 12:00 AM	1/20/2005 12:00 AM	Snow, Fog
West Lafayette	WB	1/20/2005 12:00 AM	1/20/2005 12:00 AM	Snow, Fog
West Lafayette	NB	1/25/2005 12:00 AM	1/25/2005 12:00 AM	Fog
West Lafayette	SB	1/25/2005 12:00 AM	1/25/2005 12:00 AM	Fog
West Lafayette	EB	1/25/2005 12:00 AM	1/25/2005 12:00 AM	Fog
West Lafayette	WB	1/25/2005 12:00 AM	1/25/2005 12:00 AM	Fog

The results are presented in a variety of graphical formats as described previously in Chapter 3. These include L0V1 graphs, L1V0 graphs, Difference in On-Time Histograms and Difference in Off-Time Histograms. Additionally, the results are presented quantitatively in a tabular format. For example, the L0V1 and L1V0 discrepancies have been categorized by error type, either video detection error or loop detection error, and presented as bar graphs by the number of errors by detector. Similarly, the information conveyed on the

histograms is presented quantitatively in a table by showing the average, standard deviation and median of the difference in on and off times. The concepts expressed in each graph were explained in detail in Chapter 3. The interpretation of the results will be presented in Chapter 7 with conclusions.

Finally, a statistical analysis has been completed on the results to determine if there is a statistically significant difference in the performance of the loop detection and video detection. The total numbers of missed calls and false calls greater than 10 seconds in length are shown in the following figures:

- Figure 6.1 Noblesville, March 25th – 28th 2004 (v7.03)
- Figure 6.2 Noblesville, April 5, 2005 (v8.10)
- Figure 6.3 West Lafayette, January 25, 2005 (v8.00)
- Figure 6.4 West Lafayette, January 20, 2005 (v8.00)

An 'S' has been used to identify those detectors that had a statistically significant number of errors compared to the competing technology. For example, if the camera had statistically significant more errors than the loop errors the top of the bar would have an 'S'. Conversely, if the loop detector had statistically significant more errors than at least one of the video detectors, the top of the bar representing the number of loop errors would have an 'S'.

The statistical significance information is also presented in a tabular format for the total number of missed calls and false calls greater than 5 seconds, greater than 10 seconds and greater than 20 seconds. A check-mark indicates that the detector performed statistically significantly worse than the competing detector. The statistical significance between tests of the video detection and loop detection are presented in the following tables:

- Table 6.2: Noblesville, March 25th – 28th 2004 (v7.03)
- Table 6.5: Noblesville, April 5, 2005 (v8.10)
- Table 6.8: West Lafayette, January 25, 2005 (v8.00)
- Table 6.13: West Lafayette, January 20, 2005 (v8.00)

The on-time and off-time histograms were verified statistically in a similar manner as described in Chapter 3. The results of this statistical test are presented in the following tables for on and off-times respectively. If a check mark is present it indicates that the video detector turn on-time or turn off-time is statistically significantly different from the loop times.

- Table 6.3 and Table 6.4: Noblesville, March 25th – 28th, 2004 (v7.03)
- Table 6.6 and Table 6.7: Noblesville, April 5, 2005 (v8.10)
- Table 6.9 and Table 6.10: West Lafayette, January 25, 2005 (v8.00)
- Table 6.14 and Table 6.15: West Lafayette, January 20, 2005 (v8.00)

6.2. Noblesville, Indiana, March 2004, Econolite Autoscope software v7.03

The first test completed for this project occurred in March 2004 at the Noblesville site. The test was completed using version 7.03 of the Autoscope software. Subsequent upgrades were made to the software in an attempt to address some of the problems documented in the first test. The test was completed over a four day period, with a 24-hour test period for each approach.

The number of missed calls and false calls are shown in Figure 6.1. A summary of the statistical significance of the number of errors is included in Table 6.2.

In comparison to loop detectors, video detectors produced a statistically significant number of missed calls on phases 2, 3, 4, 5 and 7. The odd numbered phases are left turn phases and experienced the majority of missed calls.

In all cases, the cameras displayed a significantly higher proportion of false detections than the loops, except for cameras 2 and 3 on phase 6. This exception was due to a faulty loop splice which caused the loop to produce false calls during wet weather. Although the loop splice was subsequently repaired, the errors in Figure 6.1b, Phase 6 were not discarded because the problem was present during the test. Similarly, the performance of camera 2 on phases 3 and 8 was affected when the video detector went into a failsafe mode and placed a constant call after a loss of contrast was detected in the video image. These errors were also not discarded.

The video detectors tended to show a shift towards earlier activation times during the night period. A summary of the statistical significance tests for turn-on times and turn off times are shown in Table 6.3 and Table 6.4, respectively.

A complete presentation of this test is included in Appendix B.

6.3. Noblesville, Indiana, April 5, 2005, Econolite Autoscope software v8.10

The second test in Noblesville, Indiana occurred on April 5, 2005 using version 8.10 of the Autoscope software. The software version included modifications intended to address some of the observed problems from the test of a year earlier. The Northbound Camera 2 was not operational during the test period and therefore no results are shown for this video detector.

The number of missed calls and false calls are shown in Figure 6.2. A summary of the statistical significance of the number of errors is included in Table 6.5.

A summary of the statistical significance tests for turn-on times and turn off times are shown in Table 6.6 and Table 6.7, respectively.

There does not appear to be a change in performance between this test run and the previous tests completed in March 2004.

A complete presentation of this test is included in Appendix C.

6.4. West Lafayette, Indiana, January 25, 2005, Econolite Autoscope software v8.00 (Clear Weather)

The first test completed at West Lafayette, Indiana occurred on January 20, 2005 however a heavy snowfall began during the evening hours of the test. Therefore, a second test was completed five days later under clear conditions and after the snow had melted to provide more optimal test conditions. The performance of the video detector under adverse weather conditions is of interest; however a test under more typical conditions was desired. The results of the January 20, 2005 test are included in this research as well.

The number of missed calls and false calls are shown in Figure 6.3. A summary of the statistical significance of the number of errors is included in Table 6.8.

In comparison to loop detectors, video detectors produced a statistically significant number of missed calls greater than or equal to 5 seconds on phases 2, 3, 4, 5 and 8. Camera 4 showed the greatest number of missed calls primarily because of poor performance on phases 2 and 5.

In all cases, the cameras displayed a significantly higher proportion of false detections (greater than or equal to 5 seconds) than the loops.

Camera 4 showed consistent on-times between day and night. The other three cameras showed a shift of earlier turn on-times during the night period. This shift is not as pronounced the one observed at the Noblesville site likely due to the intersection being more illuminated at night. A summary of the statistical

significance tests for turn-on times and turn off times are shown in Table 6.9 and Table 6.10, respectively.

A chi-squared goodness of fit test was also performed between the histograms developed for the night period and the day period. These values are presented in Table 6.11 and Table 6.12, for on-times and off times respectively. For the on-times, Camera 4 more consistently displays a lower chi-squared value than the other cameras. For the off-times, the chi-squared values are much lower than the values for the on-times, indicating that the differences in off-times between day and night are less pronounced than for on times. Additionally, the chi-squared values for the off-times are fairly consistent across camera locations.

A complete presentation of this test is included in Appendix D.

6.5. West Lafayette, Indiana, January 20, 2005, Econolite Autoscope software v8.00 (Snow)

The original test in West Lafayette, Indiana occurred on January 20, 2005. During the evening hours, snow began to fall providing a glimpse into the performance of the video detector under non-ideal conditions.

The number of missed calls and false calls are shown in Figure 6.4. A summary of the statistical significance of the number of errors is included in Table 6.13.

Generally, the video detector provided performance similar to the performance achieved under clear conditions. As snow accumulated on the roadway, the lane lines were obscured and drivers did not follow good lane discipline. This behavior results in inaccurate detection for both devices because vehicles are not traveling through the defined detection zones. For example, a vehicle turning left, that is unsure of the exact location of the lane, may straddle the lane line between the

left-turn lane and the through lane, causing a false call in the through lane on both detectors.

The detector turn-on and turn-off times did not appear to be impacted greatly by the snow event. However, during wet pavement conditions it is expected that the headlight reflection would be exaggerated causing earlier detection by the video detector. A summary of the statistical significance tests for turn-on times and turn off times are shown in Table 6.14 and Table 6.15, respectively.

The southbound through movement (phase 6) was not included in the test due to an error that occurred with the data collection on this phase during the test.

A complete presentation of this test is included in Appendix E.

a) Count of Missed Detections Longer than 10 Seconds

b) Count of False Detections Longer than 10 Seconds

Figure 6.1 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (March 2004, Noblesville, Indiana)

Table 6.2 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (Noblesville, Indiana, March 2004)

Φ	Cam1			Cam2			Cam3			Loop		
	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1				✓			✓					
2		✓			✓			✓				
3	✓	✓	✓	✓	✓	✓	✓	✓	✓			
4	✓			✓	✓		✓	✓				
5	✓	✓		✓	✓		✓	✓				
6				✓								
7	✓	✓		✓	✓		✓	✓				
8												

a) Missed Detections

Φ	Cam1			Cam2			Cam3			Loop		
	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2		✓	✓		✓	✓	✓	✓	✓			
3	✓	✓		✓	✓	✓	✓	✓	✓			
4	✓	✓	✓	✓	✓	✓	✓	✓	✓			
5	✓	✓	✓	✓	✓	✓	✓	✓	✓			
6										✓	✓	✓
7	✓	✓	✓	✓	✓	✓	✓	✓	✓			
8	✓	✓	✓	✓	✓	✓	✓	✓	✓			

b) False Detections

✓ - Indicates that detector had a statistically significant larger number of errors than detector used for comparison

Table 6.3 Difference between Loop Detector and Video Detector Turn On Times
(Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night
Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓	✓	✓								*	*	*	*	✓			
EBC2	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	*	*	*	*	✓			
EBC3	D	✓	✓	✓	✓	✓				✓	✓	✓		*	*	*	*	✓			
NBC1	D	✓	✓	✓	✓					✓	✓	✓	✓	✓				NA			
NBC2	D	✓	✓	✓	✓	✓				✓	✓	✓		✓				NA			
NBC3	D	✓	✓	✓	✓					✓	✓	✓	✓	✓				NA			
SBC1	D	✓	✓			✓								*	*	*	*	NA			
SBC2	D	✓	✓	✓		✓								*	*	*	*	NA			
SBC3	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	NA			
WBC1	D					✓				✓	✓	✓	✓	*	*	*	*	✓			
WBC2	D	✓								✓	✓	✓	✓	*	*	*	*	✓	✓		
WBC3	D	✓	✓			✓				✓	✓	✓	✓	*	*	*	*	✓	✓		
EBC1	N	✓	✓	✓						✓	✓	✓		*	*	*	*	✓			
EBC2	N	✓	✓	✓						✓	✓	✓		*	*	*	*	✓			
EBC3	N	✓	✓	✓						✓	✓	✓		*	*	*	*	✓			
NBC1	N	✓				✓	✓							*	*	*	*	NA			
NBC2	N	✓				✓	✓							✓	✓			NA			
NBC3	N					✓	✓	✓						✓				NA			
SBC1	N					✓	✓			✓	✓	✓		*	*	*	*	NA			
SBC2	N					✓	✓							*	*	*	*	NA			
SBC3	N					✓	✓							*	*	*	*	NA			
WBC1	N	✓				✓	✓			✓	✓	✓		*	*	*	*	✓			
WBC2	N	✓	✓	✓	✓	✓	✓			*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N					✓	✓			✓	✓	✓	✓	*	*	*	*				

* Indicates Insufficient Data

Table 6.4 Difference between Loop Detector and Video Detector Turn Off Times
(Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night
Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D					✓				*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC2	D	✓				✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC3	D	✓				✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
NBC1	D	✓				✓	✓			*	*	*	*	✓	✓			NA			
NBC2	D	✓	✓			✓	✓			*	*	*	*	✓	✓			NA			
NBC3	D	✓	✓			✓	✓			*	*	*	*	✓	✓	✓		NA			
SBC1	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓			NA			
SBC2	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		NA			
SBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓			NA			
WBC1	D	*	*	*	*	✓	✓			*	*	*	*	*	*	*	*	✓	✓	✓	✓
WBC2	D	*	*	*	*	✓	✓	✓		*	*	*	*	*	*	*	*	✓	✓	✓	✓
WBC3	D	*	*	*	*	✓	✓	✓		*	*	*	*	*	*	*	*	✓	✓	✓	✓
EBC1	N	✓				✓				*	*	*	*	✓	✓			✓	✓		
EBC2	N	✓				✓				*	*	*	*	✓	✓			✓	✓		
EBC3	N	✓				✓				*	*	*	*	✓	✓	✓		✓	✓		
NBC1	N					✓				*	*	*	*	✓				NA			
NBC2	N					✓	✓			*	*	*	*	✓				NA			
NBC3	N					✓	✓			*	*	*	*	✓				NA			
SBC1	N	*	*	*	*	✓				*	*	*	*					NA			
SBC2	N	*	*	*	*	✓				*	*	*	*	✓				NA			
SBC3	N	*	*	*	*	✓				*	*	*	*	✓				NA			
WBC1	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
WBC2	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		*	*	*	*
WBC3	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	

* Indicates Insufficient Data

a) Count of Missed Detections Longer than 10 Seconds

b) Count of False Detections Longer than 10 Seconds

Figure 6.2 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (April 5, 2005, Noblesville, Indiana)

Table 6.5 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (Noblesville, Indiana, April 5, 2005)

Φ	Cam1			Cam2			Cam3			Loop		
	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2				NA	NA	NA						
3	✓			✓			✓	✓				
4	✓	✓		✓	✓		✓	✓				
5	✓			NA	NA	NA						
6	✓			✓	✓		✓	✓				
7												
8	✓	✓		✓	✓		✓	✓				

a) Missed Detections

Φ	Cam1			Cam2			Cam3			Loop		
	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2	✓			NA	NA	NA	✓					
3	✓	✓	✓	✓	✓	✓	✓	✓	✓			
4	✓	✓	✓	✓	✓	✓	✓	✓	✓			
5	✓	✓	✓	NA	NA	NA	✓	✓	✓			
6	✓											
7	✓	✓	✓	✓	✓	✓	✓	✓	✓			
8	✓	✓	✓	✓	✓	✓	✓	✓	✓			

b) False Detections

✓ - Indicates that detector had a statistically significant larger number of errors than detector used for comparison

Table 6.6 Difference between Loop Detector and Video Detector Turn On Times
(Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night
Period: 8:00 PM to 12:00 AM)

		Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
Camera	Time of Day	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓		✓								*	*	*	*				
EBC2	D	✓	✓	✓	✓	✓								*	*	*	*				
EBC3	D	✓	✓	✓	✓	✓	✓							*	*	*	*	✓			
NBC1	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓				Protected only			
NBC2	D	Not included in test																			
NBC3	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓			Protected only			
SBC1	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	*	*	*	*	Protected only			
SBC2	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	*	*	*	*	Protected only			
SBC3	D	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	*	*	*	*	Protected only			
WBC1	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	*	*	*	*	✓	✓		
WBC2	D	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	*	*	*	*	✓	✓		
WBC3	D	✓	✓	✓		✓	✓			✓	✓	✓	✓	*	*	*	*	✓	✓	✓	
EBC1	N	✓	✓			✓	✓			✓	✓			*	*	*	*	✓	✓	✓	
EBC2	N	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	✓	✓		
EBC3	N					✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓		
NBC1	N	✓	✓	✓		✓	✓			✓	✓			*	*	*	*	Protected only			
NBC2	N	Not included in test																			
NBC3	N	✓				✓	✓			✓	✓	✓		✓				Protected only			
SBC1	N					✓	✓	✓						*	*	*	*	Protected only			
SBC2	N					✓	✓							*	*	*	*	Protected only			
SBC3	N	✓				✓	✓							*	*	*	*	Protected only			
WBC1	N	✓	✓	✓						✓	✓	✓		*	*	*	*	✓			
WBC2	N	✓	✓							✓	✓	✓		*	*	*	*	✓			
WBC3	N									✓	✓	✓	✓	*	*	*	*				

* Indicates Insufficient Data

Table 6.7 Difference between Loop Detector and Video Detector Turn Off Times
(Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night
Period: 8:00 PM to 12:00 AM)

		Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
Camera	Time of Day	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D					✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC2	D					✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
EBC3	D					✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
NBC1	D	✓				✓				*	*	*	*	✓				Protected only			
NBC2	D	Not included in test																			
NBC3	D	✓	✓			✓	✓			*	*	*	*	✓	✓	✓		Protected only			
SBC1	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓			Protected only			
SBC2	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		Protected only			
SBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		Protected only			
WBC1	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
WBC2	D	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	✓
WBC3	D	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	✓
EBC1	N	✓				✓				*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC2	N	✓				✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC3	N					✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
NBC1	N					✓	✓			*	*	*	*	✓	✓			Protected only			
NBC2	N	Not included in test																			
NBC3	N	✓				✓	✓			*	*	*	*	✓	✓			Protected only			
SBC1	N	*	*	*	*	✓	✓			*	*	*	*	✓				Protected only			
SBC2	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓				Protected only			
SBC3	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓				Protected only			
WBC1	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
WBC2	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
WBC3	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	

* Indicates Insufficient Data

a) Count of Missed Detections Longer than 10 Seconds

b) Count of False Detections Longer than 10 Seconds

Figure 6.3 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (January 25, 2005, West Lafayette, Indiana)

Table 6.8 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (West Lafayette, Indiana, January 25, 2005)

	Cam1			Cam2			Cam3			Cam4			Loop		
Φ	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1															
2										✓	✓				
3				✓											
4										✓					
5	✓			✓						✓	✓	✓			
6															
7															
8				✓	✓		✓	✓		✓					

a) Missed Detections

	Cam1			Cam2			Cam3			Cam4			Loop		
Φ	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
6	✓			✓	✓	✓	✓	✓		✓	✓	✓			
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			

b) False Detections

✓ - Indicates that detector had a statistically significant larger number of errors than detector used for comparison

Table 6.9 Difference between Loop Detector and Video Detector Turn On Times
(West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM,
Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓		✓								✓				✓			
EBC2	D	✓	✓	✓		✓	✓			✓	✓			✓	✓			✓	✓		
EBC3	D	✓	✓	✓		✓								✓				✓			
EBC4	D	✓	✓	✓		✓								✓				✓			
NBC1	D					✓				✓				*	*	*	*	✓			
NBC2	D					✓								*	*	*	*	✓	✓		
NBC3	D	✓				✓				✓				*	*	*	*	✓	✓		
NBC4	D					✓								✓	✓			✓			
SBC1	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	✓			
SBC2	D	✓	✓	✓		✓								*	*	*	*	✓	✓	✓	
SBC3	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*				
SBC4	D	✓	✓	✓	✓	✓	✓			✓				*	*	*	*	✓			
WBC1	D	✓	✓			✓				✓	✓	✓		*	*	*	*	✓	✓		
WBC2	D	✓	✓			✓	✓	✓		✓	✓	✓	✓	*	*	*	*	*	*	*	*
WBC3	D	✓				✓	✓			✓	✓	✓	✓	*	*	*	*	*	*	*	*
WBC4	D					✓								*	*	*	*	✓	✓	✓	
EBC1	N					✓	✓			✓				✓				✓	✓		
EBC2	N	✓				✓	✓	✓		✓	✓	✓		✓				✓			
EBC3	N	✓	✓			✓	✓	✓						✓	✓			✓	✓		
EBC4	N					✓				✓	✓										
NBC1	N					✓	✓			✓				*	*	*	*	✓	✓		
NBC2	N	✓				✓	✓			✓	✓			✓				✓			
NBC3	N	✓				✓	✓			✓				*	*	*	*	✓	✓		
NBC4	N	✓	✓	✓		✓				✓	✓	✓		✓				✓			
SBC1	N	✓				✓	✓			✓				*	*	*	*	✓	✓		
SBC2	N	✓				✓	✓			✓	✓	✓		*	*	*	*	*	*	*	*
SBC3	N					✓	✓			✓				*	*	*	*	✓	✓		
SBC4	N	✓	✓	✓		✓	✓			✓	✓			*	*	*	*	*	*	*	*
WBC1	N	✓	✓			✓	✓							*	*	*	*	*	*	*	*
WBC2	N	✓				✓	✓			✓	✓	✓		*	*	*	*	*	*	*	*
WBC3	N	✓				✓								*	*	*	*	*	*	*	*
WBC4	N	✓				✓								*	*	*	*	*	*	*	*

* Indicates Insufficient Data

Table 6.10 Difference between Loop Detector and Video Detector Turn Off Times
(West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM,
Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓		✓	✓			*	*	*	*	✓	✓			✓	✓	✓	
EBC2	D	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC3	D	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	✓
EBC4	D	✓				✓				*	*	*	*	✓				✓			
NBC1	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓		
NBC2	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓		
NBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
NBC4	D	*	*	*	*	✓				*	*	*	*	✓							
SBC1	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	✓
SBC2	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
SBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
SBC4	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
WBC1	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
WBC2	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
WBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
WBC4	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
EBC1	N	✓	✓	✓		✓	✓			*	*	*	*	✓				✓	✓		
EBC2	N	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓			✓	✓		
EBC3	N	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓			✓	✓	✓	
EBC4	N	✓	✓			✓				*	*	*	*	✓				✓			
NBC1	N	*	*	*	*	✓				*	*	*	*	✓				✓	✓		
NBC2	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓		
NBC3	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓	✓	✓
NBC4	N	*	*	*	*	✓				*	*	*	*	✓							
SBC1	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓		
SBC2	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓		
SBC3	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
SBC4	N	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓		
WBC1	N	✓	✓			✓				*	*	*	*	✓				*	*	*	*
WBC2	N					✓				*	*	*	*	✓				*	*	*	*
WBC3	N	✓				✓	✓			*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	✓								*	*	*	*	✓				*	*	*	*

* Indicates Insufficient Data

Table 6.11 Chi-Squared Goodness of Fit Test between Day and Night On-Time Histograms (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	On-Times			
	Northbound	Southbound	Eastbound	Westbound
Cam1	2825.8	144.2	9438.7	734.5
Cam2	4531.2	212.2	6688.6	112.6
Cam3	2749.2	525.0	6880.7	781.6
Cam4	638.7	216.1	3264.0	376.9

Table 6.12 Chi-Squared Goodness of Fit Test between Day and Night Off-Time Histograms (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Off-Times			
	Northbound	Southbound	Eastbound	Westbound
Cam1	28.9	359.8	64.4	153.5
Cam2	116.9	274.2	121.5	707.9
Cam3	164.6	165.5	140.2	135.1
Cam4	162.9	671.2	266.1	95.1

a) Count of Missed Detections Longer than 10 Seconds

b) Count of False Detections Longer than 10 Seconds

Figure 6.4 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (January 20, 2005, West Lafayette, Indiana)

Table 6.13 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (West Lafayette, Indiana, January 20, 2005)

	Cam1			Cam2			Cam3			Cam4			Loop		
Φ	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1										✓					
2															
3				✓	✓										
4															
5										✓	✓				
6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	✓			✓	✓		✓			✓					
8				✓	✓	✓	✓								

a) Missed Detections

	Cam1			Cam2			Cam3			Cam4			Loop		
Φ	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
3	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
8	✓			✓	✓		✓	✓		✓					

b) False Detections

✓ - Indicates that detector had a statistically significant larger number of errors than detector used for comparison

Table 6.14 Difference between Loop Detector and Video Detector Turn On Times
(West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM,
Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓		✓				✓	✓	✓		✓				✓			
EBC2	D	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓			✓	✓		
EBC3	D	✓	✓	✓		✓				✓	✓	✓		✓				✓			
EBC4	D	✓	✓	✓		✓				✓	✓	✓		✓				✓			
NBC1	D	✓	✓	✓		✓				✓	✓			✓				✓			
NBC2	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	✓			
NBC3	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	✓			
NBC4	D	✓	✓	✓		✓				✓	✓	✓		✓	✓			✓	✓		
SBC1	D	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓		*	*	*	*	✓			
SBC2	D	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	*	*	*	*	✓	✓	✓	✓
SBC3	D	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓		*	*	*	*	✓			
SBC4	D	NA	NA	NA	NA	NA	NA	NA	NA					*	*	*	*	✓			
WBC1	D	✓	✓	✓		✓								*	*	*	*	✓	✓		
WBC2	D	✓	✓	✓		✓	✓			✓	✓	✓	✓	*	*	*	*	*	*	*	*
WBC3	D	✓	✓			✓				✓	✓	✓	✓	*	*	*	*	✓	✓	✓	✓
WBC4	D					✓	✓			✓				*	*	*	*	✓	✓		
EBC1	N	✓				✓	✓	✓						✓				✓	✓		
EBC2	N					✓	✓	✓		✓				*	*	*	*	✓			
EBC3	N	✓	✓	✓		✓	✓	✓						✓				✓	✓	✓	
EBC4	N	✓	✓			✓															
NBC1	N	✓	✓	✓		✓	✓							*	*	*	*	✓	✓		
NBC2	N	✓	✓	✓		✓	✓	✓		✓				*	*	*	*	✓			
NBC3	N	✓	✓	✓	✓	✓	✓	✓		✓	✓			*	*	*	*	✓	✓	✓	
NBC4	N	✓				✓				✓	✓	✓		*	*	*	*	✓			
SBC1	N	NA	NA	NA	NA	NA	NA	NA	NA	✓				*	*	*	*	✓	✓		
SBC2	N	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓		*	*	*	*	✓	✓	✓	
SBC3	N	NA	NA	NA	NA	NA	NA	NA	NA					*	*	*	*	✓			
SBC4	N	NA	NA	NA	NA	NA	NA	NA	NA	✓				*	*	*	*	✓	✓		
WBC1	N	✓	✓			✓	✓							*	*	*	*	*	*	*	*
WBC2	N	✓	✓			✓	✓			✓	✓	✓		*	*	*	*	*	*	*	*
WBC3	N	✓	✓	✓		✓	✓							*	*	*	*	*	*	*	*
WBC4	N	✓												*	*	*	*	*	*	*	*

* Indicates Insufficient Data

Table 6.15 Difference between Loop Detector and Video Detector Turn Off Times
(West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM,
Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓			✓	✓			*	*	*	*	✓				✓	✓	✓	
EBC2	D	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC3	D	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	✓
EBC4	D	✓								*	*	*	*	✓							
NBC1	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
NBC2	D	*	*	*	*	✓				*	*	*	*	✓	✓	✓		✓	✓	✓	
NBC3	D	*	*	*	*	✓				*	*	*	*	✓	✓	✓		✓	✓	✓	✓
NBC4	D	*	*	*	*	✓	✓			*	*	*	*	✓							
SBC1	D	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
SBC2	D	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
SBC3	D	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓	✓		✓	✓	✓	✓
SBC4	D	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
WBC1	D	*	*	*	*	✓				*	*	*	*	✓				✓	✓		
WBC2	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓	✓	
WBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
WBC4	D	*	*	*	*	✓				*	*	*	*	✓				✓	✓		
EBC1	N	✓	✓	✓		✓				*	*	*	*	✓				✓			
EBC2	N	✓	✓	✓		✓	✓			*	*	*	*	✓	✓			✓	✓		
EBC3	N	✓	✓	✓		✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC4	N	✓	✓	✓		✓				*	*	*	*	✓				✓			
NBC1	N	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓		
NBC2	N	*	*	*	*	✓				*	*	*	*	✓	✓	✓		✓	✓	✓	
NBC3	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓	✓	✓
NBC4	N	*	*	*	*	✓	✓			*	*	*	*	✓				✓			
SBC1	N	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
SBC2	N	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
SBC3	N	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓	✓	
SBC4	N	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓				✓			
WBC1	N	✓	✓			✓				*	*	*	*	*	*	*	*				
WBC2	N	*	*	*	*	✓				*	*	*	*	*	*	*	*				
WBC3	N	✓	✓			✓	✓			*	*	*	*	*	*	*	*	✓	✓	✓	✓
WBC4	N	✓				✓				*	*	*	*	*	*	*	*				

* Indicates Insufficient Data

CHAPTER 7. CONCLUSIONS

7.1. Introduction

There are several significant contributions presented in this report. The goal of this research project was to complete a follow-up evaluation of video detection for the State of Indiana. The State suspended the deployment of video detection in 2001, after several problems were identified in a previous Joint Transportation Research Program report. Subsequent to the publication of this previous report, several video detection vendors suggested installation improvements that would improve the operation of their systems. These suggestions were incorporated and included in a reconstruction of two intersections in Noblesville, IN and West Lafayette, IN; which ultimately served as the test bed for this research. The performance of video detection with the suggest installation improvements has been thoroughly documented in this report.

The evaluation procedure developed for this research is summarized in the next section. It is then followed by conclusions that were made from the evaluation procedure.

7.2. Evaluation Procedure

This research extended an evaluation procedure first introduced by Grenard et. al (1). Many of the previously developed evaluation procedures have relied on recorded data from which ground truth data has been developed from human observation. The procedure presented in this research is advantageous because it does not use recorded video which could compromise the performance of a video system. The second significant advantage that the procedure has requires

a human to ground truth data where there is a discrepancy between two detectors.

The underlying logic of the Grenard procedure was programmed into a database and spreadsheet software package to allow quick production of results. If there is a high degree of confidence in the reliability of one of the detectors used in the test, the L1V0 and L0V1 graphs are valuable tools for evaluation of a detector even without checking the discrepancies versus ground truth data. The database and spreadsheet software developed in this research allow the creation of such graphs in a matter of minutes even though such graphs are based on thousands of data points.

While L1V0 and L0V1 graphs give a picture of the overall performance of a detector, the effect of smaller detector errors on the intersection operation is somewhat masked. In this research, a method of presenting this smaller errors through on-time and off-time histograms was developed (Figure 7.1). These histograms were used to quantify the change in behavior of the video detection in day versus night conditions.

Finally, the effect of phase color was included on both the L1V0 and L0V1 graphs, as well as the on-time and off-time histograms to capture any changes in detection performance under different phase colors. This is particularly important for video detection where several video packages modify their detection algorithm based on the current phase color. This procedure resulted in a manufacturer revising their detection algorithm for permitted left-turn phases.

Additionally, the inclusion of phase color is important because certain functions of the detector are more important depending on the signal phase. For example, a missed presence detection during a green phase is far less important than a missed detection during a red phase. Another example is that during the green

phase an immediate indication of a vehicle's presence is important in headway measurements, however during the red phase a delay of 1 or 2 seconds between the vehicle arriving and a call being placed is not a big concern.

7.3. Comparison of Traditional Inductive Loops to Video Detection

The research presented in this report has identified several problems with video detection. The tests indicate that in most cases video detection performs statistically significantly worse than loops. The missed calls are particularly troublesome because of the safety implications involved. However, the false calls are also undesirable as increasing traffic congestion is requiring increasingly efficient signal systems.

The number of missed calls and false calls greater than 10 seconds for each of the four tests completed for this research are presented in Figure 6.1, Figure 6.2, Figure 6.3, and Figure 6.4.

7.4. Consistency of Detector Turn-On and Turn-Off Times

The consistency of turn-on and turn-off times are important because of their use for gap timing in a traffic signal controller. Gap times are used to terminate a green phase once the traffic density falls below a certain threshold. A detector that measures gap times differently between day and night will also behave quite differently between the two time periods. The capacity of the intersection will be effected due to the green phase extending or terminating due to the measured gap time. This concept was illustrated in Figure 3.3.

The video detectors have a tendency to activate several seconds earlier at night due to headlight reflections on the pavement. This problem is exacerbated during or following rain when the pavement is wet and more prone to light reflections.

Although less dramatic, the video detectors also have a tendency to terminate their calls earlier at night. During the night period, the video detectors tend to be activated by the headlights. Therefore when the headlight leaves the detection zone the video detector call terminates even though the rest of the car may still be within the detection zone. The loop detector is more consistent in this regard since the part of the car that is being detected is not dependent on the ambient lighting conditions.

7.5. Camera Position Evaluation

At each intersection several camera locations were chosen for the video detection on each roadway approach. In this way the performance of the video at different positions at an intersection could be compared and evaluated. For far side mounted cameras (Figure 7.2), the video detection was similar at each location, with no dramatic reduction in missed calls and false calls for the video detector placed at the vendor recommended optimal position.

The only camera location whose operation was noticeably different from the other cameras, was the cameras located directly above the stop bar and therefore looking directly down at the detection zone (Figure 7.6). There was one camera mounted in this manner on each approach at the West Lafayette site and labeled as Camera 4. While this camera location did not significantly perform better in terms of missed calls and false calls, it did show much more consistency in terms of turn-on times between day and night. This intuitively makes sense as the far side cameras view the detection zone from across the intersection, while this camera looks directly down, greatly reducing the occurrence of headlight reflection in the camera view. The camera locations at the two sites are shown in Figure 7.2. An example of the difference in detector activation between cameras at the far side position and the above stop bar position is shown in Figure 7.3. A histogram comparison of the performance of a far side mounted camera and the camera mounted directly above the stopbar is shown in Figure 7.5.

7.6. Lighting Effects on Video Detection Performance

There were much fewer missed detections at the West Lafayette site when compared to the Noblesville site. The numbers of false detections and missed detections greater than 10 seconds in duration are summarized for three of the tests completed for this research in Table 7.1 and Table 7.2.

Additionally, the shift in the on-time histograms is much more pronounced between day and night at the Noblesville site which is darker due to less street lighting. A photograph of the roadway lighting positions is shown in Figure 7.5.

Table 7.1 Summary of statistical significance for false detections greater than 10 seconds in duration for three test periods

	Φ	1	2	3	4	5	6	7	8
Noblesville March 2004	Cam1	✓	✓	✓	✓	✓		✓	✓
	Cam2	✓	✓	✓	✓	✓		✓	✓
	Cam3	✓	✓	✓	✓	✓		✓	✓
	Loop						✓		
Noblesville March 2005	Cam1	✓	✓	✓	✓	✓		✓	✓
	Cam2	✓	NA	✓	✓	NA		✓	✓
	Cam3	✓	✓	✓	✓	✓		✓	✓
	Loop								
West Lafayette January 2005	Cam1	✓	✓	✓	✓	✓		✓	✓
	Cam2	✓	✓	✓	✓	✓	✓	✓	✓
	Cam3	✓	✓	✓	✓	✓	✓	✓	✓
	Cam4	✓	✓	✓	✓	✓	✓	✓	✓
	Loop								

Table 7.2 Summary of statistical significance for missed detections greater than 10 seconds in duration for three test periods

	Φ	1	2	3	4	5	6	7	8
Noblesville March 2004	Cam1		✓	✓		✓		✓	
	Cam2		✓	✓	✓	✓		✓	
	Cam3		✓	✓	✓	✓		✓	
	Loop								
Noblesville March 2005	Cam1	✓			✓		✓		✓
	Cam2	✓	NA		✓	NA	✓		✓
	Cam3	✓		✓	✓		✓		✓
	Loop								
West Lafayette January 2005	Cam1								
	Cam2								✓
	Cam3								✓
	Cam4		✓			✓			
	Loop								

7.7. Weather Effects on Video Detection

During the first test at Noblesville in March 2004, fog caused each of the three cameras being tested to go into a failsafe recall mode where a constant call was placed during the red phase. This caused a large amount of false detections by the video detectors during the 1-hour period that it was in the failsafe mode.

Rain impacts video detection performance by amplifying the headlight reflections on the pavement and causing the video detectors to activate even earlier than they would on a night with dry pavement.

One test occurred with a snow event. The snow hampered detection performance when the accumulated snow began to obscure the lane lines causing drivers to use poor lane discipline. Therefore, both the loop detector and video detector were affected when vehicles did not travel in the detection zones.

a) L1V0 Discrepancy Graph Example

b) L0V1 Discrepancy Graph Example

c) Discrepancy in Turn On Times Histogram Example

d) Discrepancy in Turn Off Times Histogram Example

Figure 7.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends

a) Noblesville Far Side Cameras

b) West Lafayette Far Side Cameras

Figure 7.2 Far Side Camera Locations at Noblesville, Indiana and West Lafayette, Indiana

a) Far Side Camera Activations
 (Cam1: 1.468 sec. before loop)
 (Cam2: 1.702 sec. before loop)
 (Cam3: 3.003 sec. before loop)

b) Above Stop Bar Camera Activation
 (0.134 sec. after loop)

Figure 7.3 Example of Difference in Turn On Times During a Night Period
 between Far Side Camera Location and Above Stop Bar Camera Location

a) Camera 1

b) Camera 4

Figure 7.4 On-Time Histograms for two camera locations at West Lafayette, Indiana (January 25, 2005)

a) Noblesville, Indiana

b) West Lafayette, Indiana

Figure 7.5 Roadway Lighting at Noblesville, Indiana and West Lafayette, Indiana

Figure 7.6 Roadway Lighting and Camera 4 Position at West Lafayette, Indiana

LIST OF REFERENCES

LIST OF REFERENCES

1. Grenard, J., D. Bullock, and A. P. Tarko. *Evaluation of Selected Video Detection Systems at Signalized Intersections*. Publication FHWA/IN/JTRP-2001/22. Joint Transportation Research Program, Indiana Department of Transportation, Purdue University, 2001.
2. Rhodes A., D. Bullock, J. Sturdevant, Z. Clark and D. Candey. *Evaluation of Stop Bar Video Detection Accuracy at Signalized Intersections*. Transportation Research Board (#05-0384), TRB, National Research Council, Washington, D.C. 2005.
3. MacCarley, C. A., and J. Palen. *Evaluation of Video Traffic Sensors for Intersection Signal Actuation: Methods and Metrics*. Transportation Research Board, National Research Council, Washington, D.C., 2003.
4. MacCarley, C. A., S. L. M. Hockaday, D. Need, and S. Taff. Evaluation of Video Image Processing Systems for Traffic Detection. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1360, TRB, National Research Council, Washington, D.C. 1992.
5. Minnesota Department of Transportation – Minnesota Guidestar and SRF Consulting Group. *Field Test of Monitoring of Urban Vehicle Operations Using Non-Intrusive Technologies*, Volume 5, Task Three Report: Extended Field Test Results, Minnesota Guidestar, St. Paul, Minnesota, and SRF Consulting Group, Minneapolis, Minnesota, 1996.
6. Hartmann, D., D. Middleton, and D. Morris. *Assessing Vehicle Detection Utilizing Video Image Processing Technology*. Publication FHWA/TX-97/1467-4. Texas Transportation Institute, Texas Department of Transportation, FHWA, 1996.
7. Middleton, D., D. Jasek and R. Parker. *Evaluation of Some Existing Technologies for Vehicle Detection*. Publication FHWA/TX-00/1715-S. Texas Transportation Institute, Texas Department of Transportation, FHWA, 1999.

8. Middleton, D., and R. Parker. *Initial Evaluation of Selected Detectors to Replace Inductive Loops on Freeways*. Publication FHWA/TX-00/1439-7-S. Texas Transportation Institute, Texas Department of Transportation, FHWA, College Station, Texas, 2000.
9. Middleton, D., and R. Parker. *Vehicle Detector Evaluation*. Publication FHWA/TX-03/2119-1. Texas Transportation Institute, Texas Department of Transportation, FHWA, 2002.
10. Bonneson, J., and M. Abbas. *Video Detection for Intersection and Interchange Control*. Publication FHWA/TX-03/4285-1. Texas Transportation Institute, Texas Department of Transportation, FHWA, 2002.
11. Abbas, M., and J. Bonneson. *Detection Placement and Configuration Guidelines for Video Image Vehicle Detection Systems*. Transportation Research Board, National Research Council, Washington, D.C., 2004.
12. Baculinao, N. M. *Video Detection Technology – Is it Ready to Replace Loops?* Compendium of Papers for the 1998 ITE District 6 Meeting in San Jose, CA, Institute of Transportation Engineers, Washington, D.C., 1998.
13. Oh, J., and J. D. Leonard II. *Vehicle Detection Using Video Image Processing System: Evaluation of Peek Videotrak*. *Journal of Transportation Engineering*, Vol. 129, No. 4, 2003, pp. 462-465.
14. Cottrell, B. H. Jr. *Evaluation of a Video Image Detection System (VIDS) – Final Report*, Research Report No. VTRC 94-R22, Virginia Transportation Research Council, Virginia Department of Transportation, Charlottesville, Virginia, 1994.
15. Smith, B. L., S. J. Namkoong, and H. Tanikella. *Final Contract Report: Integrated CCTV/VIVDS Prototype Field Test*. Publication VTRC 05-CR2. Virginia Transportation Research Council, Virginia Department of Transportation, University of Virginia, Charlottesville, Virginia, 2004.
16. Tian, Z. Z., M. D. Kyte, and C. J. Messer. *Parallax Error in Video-Image Systems*. *Journal of Transportation Engineering*, Vol. 128, No. 3, 2002, pp. 218-223.
17. Martin, P.T., G. Dharmavaram and A. Stevanovic. *Evaluation of UDOT's Video Detection Systems: System's Performance in Various Test Conditions*. Publication UT-04.14, University of Utah, Utah Department of Transportation, Salt Lake City, UT, 2004.

18. The Urban Transportation Monitor. *The Use of Video Detection at Signalized Intersections, A National Survey Conducted in December 2004.* Lawley Publications, Burke, Virginia, December 2004.

Appendix A. Test Bed

Figure A.1 Summary of Test Bed Purpose and Output

Figure A.2 Noblesville Intersection Location

Figure A.4 Aerial Photograph of Noblesville Intersection

Figure A.5 Aerial Photograph of West Lafayette Intersection

a) Loop Detector and Camera Layout

b) Phase Sequence

Figure A.6 Noblesville Intersection Layout

a) Loop Detector and Camera Layout

b) Phase Sequence

Figure A.7 West Lafayette Intersection Layout

Figure A.8 Sample Approach Detail (West Lafayette, IN – Northbound Approach)

a) Noblesville, Indiana

b) West Lafayette, Indiana (Vendor recommended offset is inline with lane line between left-turn lane and through lane)

Figure A.9 Typical Pole Configurations

a) Noblesville Camera Locations (Eastbound)

b) West Lafayette Camera Locations (Northbound)

Figure A.10 Example Camera Locations

Table A.3 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60')
in Noblesville, Indiana

Approach Direction	Autoscope Camera View Figure	Detection Zone Figure
Northbound	Figure A.11	Figure A.16
Southbound	Figure A.12	Figure A.17
Eastbound	Figure A.13	Figure A.18
Westbound	Figure A.14	Figure A.19

December 12, 2003
(Avg. Temp: 34.0°F)

a) Northbound Camera (C3N) at 36' Offset

b) Northbound Camera (C2N) at 48' Offset

c) Northbound Camera (C1N) at 60' Offset

July 12, 2004
(Avg. Temp: 72.7°F)

d) Northbound Camera (C3N) at 36' Offset

e) Northbound Camera (C2N) at 48' Offset

f) Northbound Camera (C1N) at 60' Offset

Figure A.11 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Northbound Approach in Noblesville during December 2003 and July 2004.

December 12, 2003

July 12, 2004

a) Southbound Camera (C3S) at 36' Offset

d) Southbound Camera (C3S) at 36' Offset

b) Southbound Camera (C2S) at 48' Offset

e) Southbound Camera (C2S) at 48' Offset

c) Southbound Camera (C1S) at 60' Offset

f) Southbound Camera (C1S) at 60' Offset

Figure A.12 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Southbound Approach in Noblesville during December 2003 and July 2004.

December 12, 2003

July 12, 2004

a) Eastbound Camera (C3E) at 36' Offset

d) Eastbound Camera (C3E) at 36' Offset

b) Eastbound Camera (C2E) at 48' Offset

e) Eastbound Camera (C2E) at 48' Offset

c) Eastbound Camera (C1E) at 60' Offset

f) Eastbound Camera (C1E) at 60' Offset

Figure A.13 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Eastbound Approach in Noblesville during December 2003 and July 2004.

December 12, 2003

a) Westbound Camera (C3W) at 36' Offset

b) Westbound Camera (C2W) at 48' Offset

c) Westbound Camera (C1W) at 60' Offset

July 12, 2004

d) Westbound Camera (C3W) at 36' Offset

e) Westbound Camera (C2W) at 48' Offset

f) Westbound Camera (C1W) at 60' Offset

Figure A.14 Autoscope Camera views for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Westbound Approaches in Noblesville during December 2003 and July 2004.

Figure A.15 Temperature at Noblesville, Indiana during December 2003 and July 2004 (Corresponds to Screen Captures in Figure 4.7)

Table A.4 Pixel Coordinates for Noblesville Video Captures (December 12, 2003, July 12, 2004 and Difference)

	December 2003		July 2004		Change	
	x	y	x	y	x	y
NB1	262	76	262	76	0	0
NB2	257	74	257	74	0	0
NB3	263	84	263	83	0	-1
SB1	245	84	247	83	2	-1
SB2	250	90	252	90	2	0
SB3	257	83	254	78	-3	-5
EB1	269	90	269	91	0	1
EB2	262	85	262	86	0	1
EB3	270	87	270	87	0	0
WB1	276	87	278	87	2	0
WB2	269	85	269	85	0	0
WB3	275	79	273	78	-2	-1

a) Northbound Camera (C3N) at 36' Offset

b) Northbound Camera (C2N) at 48' Offset

c) Northbound Camera (C1N) at 60' Offset

Figure A.16 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Northbound Approach in Noblesville.

a) Southbound Camera (C3W) at 36' Offset

b) Southbound Camera (C2W) at 48' Offset

c) Southbound Camera (C1W) at 60' Offset

Figure A.17 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Southbound Approach in Noblesville.

a) Eastbound Camera (C3W) at 36' Offset

b) Eastbound Camera (C2W) at 48' Offset

c) Eastbound Camera (C1W) at 60' Offset

Figure A.18 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Eastbound Approach in Noblesville

a) Westbound Camera (C3W) at 36' Offset

b) Westbound Camera (C2W) at 48' Offset

c) Westbound Camera (C1W) at 60' Offset

Figure A.19 Autoscope Camera Detection Zones for Cam3 (36'), Cam2 (48') and Cam1 (60') on the Westbound Approach in Noblesville.

Table A.5 Autoscope Camera views for Cam4, Cam3, Cam2 and Cam1 in West Lafayette, Indiana

Approach Direction	Autoscope Camera View Figure	Detection Zone Figure
Northbound	Figure A.20	Figure A.24
Southbound	Figure A.21	Figure A.25
Eastbound	Figure A.22	Figure A.26
Westbound	Figure A.23	Figure A.27

a) Northbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Northbound Camera (C2N) at Optimal Height (40') and No Offset

b) Northbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Northbound Camera (C4N) from Overhead Position

Figure A.20 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Northbound Approach in West Lafayette during October 2004

a) Southbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Southbound Camera (C2N) at Optimal Height (40') and No Offset

b) Southbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Southbound Camera (C4N) from Overhead Position

Figure A.21 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Southbound Approach in West Lafayette during October 2004.

a) Eastbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Eastbound Camera (C2N) at Optimal Height (40') and No Offset

b) Eastbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Eastbound Camera (C4N) from Overhead Position

Figure A.22 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Eastbound Approach in West Lafayette during October 2004.

a) Westbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Westbound Camera (C2N) at Optimal Height (40') and No Offset

b) Westbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Westbound Camera (C4N) from Overhead Position

Figure A.23 Autoscope Camera views for Camera 1, Camera 2, Camera 3, and Camera 4 on the Westbound Approach in West Lafayette during October 2004.

a) Northbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Northbound Camera (C2N) at Optimal Height (40') and No Offset

b) Northbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Northbound Camera (C4N) from Overhead Position

Figure A.24 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Northbound Approach in West Lafayette

a) Southbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Southbound Camera (C2N) at Optimal Height (40') and No Offset

b) Southbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Southbound Camera (C4N) from Overhead Position

Figure A.25 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Southbound Approach in West Lafayette.

a) Eastbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Eastbound Camera (C2N) at Optimal Height (40') and No Offset

b) Eastbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Eastbound Camera (C4N) from Overhead Position

Figure A.26 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Eastbound Approach in West Lafayette.

a) Westbound Camera (C1N) at Optimal Height (40') and Optimal Offset

c) Westbound Camera (C2N) at Optimal Height (40') and No Offset

b) Westbound Camera (C3N) at Mast Arm Height (25') and Optimal Offset

d) Westbound Camera (C4N) from Overhead Position

Figure A.27 Autoscope Camera Detection Zones for Camera 1, Camera 2, Camera 3, and Camera 4 on the Westbound Approach in West Lafayette.

Table A.6 Data Collection Cabinet Item Legend for Noblesville (Figure A.28) and West Lafayette (Figure A.29)

Item Description	Item Number in Figure 4.12 (Noblesville, Indiana)	Item Number in Figure 4.13 (West Lafayette)
Cabinet 2 Patch Panel (Figure 4.12a and Figure 4.13a)		
Patch Panel	1	1
LCD Monitor	2	NA
Cabinet to Cabinet Connections	3	3
Patch Panel Quad	4	4
Roadway Lighting Control	5	NA
Cabinet 2 Patch Panel Quadrant (Figure 4.12b and Figure 4.13b)		
Loop Detector Outputs	6	6
Signal Phase Indications	7	7
Econolite Autoscope Inputs	8	8
Econolite Autoscope Outputs	9	9
Auxiliary Inputs/Outputs	10	10
Pedestrian Phase Indications	NA	11
Ground / 24 Volt Power	NA	12
Cabinet 2 Instrumentation (Figure 4.12c and Figure 4.13c)		
Back of Patch Panel	13	13
Windows Computer	14	NA
LCD Monitor	15	15
Micro Loop Detector Cards	16	16
Genex Video Multitplexer	17	17
Video Patch Panel	18	18
Autoscope Detector Cards	19	19
AC Power Strip	NS	20
Network Hub	NS	21
Cabinet Power Supply	NS	22
Autoscope Communications Panel	NS	23
NA – Not Applicable NS – Not Shown

a) Cabinet 2 Patch Panel (East side)

b) Detailed View of Item 5

c) Cabinet 2 Instrumentation (West side)

Figure A.28 Noblesville Data Collection Cabinet

a) Cabinet 2 Patch Panel (East side)

b) Detailed View of Item 4

c) Cabinet 2 Instrumentation (West side)

Figure A.29 West Lafayette Data Collection Cabinet

Figure A.30 Noblesville Example Screen Overlay

a) Camera 1 Screen Overlay (Data Collector for Cameras 1 through 3)

b) Camera 4 Screen Overlay (Data Collector for Camera 4)

Figure A.31 West Lafayette Example Screen Overlay

a) Autoscope® Solo Mini-Hub II I/O Graphic

Inputs		Outputs			
1	LT Phase	1	SB Cam LT ($\Phi 1$) Output	9	Not Used
2	LT Loop	2	NB Cam TH ($\Phi 2$) Output	10	Not Used
3	LT Camera 2	3	WB Cam LT ($\Phi 3$) Output	11	Not Used
4	LT Camera 3	4	EB Cam TH ($\Phi 4$) Output	12	Not Used
5	TH Phase	5	NB Cam LT ($\Phi 5$) Output	13	Not Used
6	TH Loop	6	SB Cam TH ($\Phi 6$) Output	14	Not Used
7	TH Camera 2	7	EB Cam LT ($\Phi 7$) Output	15	Not Used
8	TH Camera 3	8	WB Cam TH ($\Phi 8$) Output	16	Not Used

b) I/O Assignments

Figure A.32 Econolite Autoscope Mini-Hub II I/O Indications

Autoscope Network Browser - v7.10 a

File View Network Channel Autoscope Data Tools Help

Server Channel

CIVL1122PC3

COM1

COM2

Offline Channel

Stadium @ NW -- EB Panel

Stadium @ NW -- NB Panel

Stadium @ NW -- SB Panel

Stadium @ NW -- WB Panel

CPU Identifier	Approach and Phases	Site Service Information	Network Address	Load Index	Sensor Number
04046AFF826DE811	EBC1 P4,7 (GNX02) W.Stadium Ave.	EBC1 zoom=4064 height=41.3'	192.168.11.3	101	1
040468FF0B65E811	EBC2 P4,7 (GNX06) W.Stadium Ave.	EBC2 zoom=4227 height=40'1"	192.168.11.4	103	2
04046AFFA567E811	EBC3 P4,7 (GNX10) W.Stadium Ave.	EBC3 zoom=4077 height=23'4.5"	192.168.11.2	100	3
040468FFAD70E811	EBC4 P4,7 (GNX14) W.Stadium Ave.	EBC4 zoom=2100 height=40'6.5"	192.168.9.3	102	4
040468FFED63E811	NBC1 P2,5 (GNX01) US-231 Northwestern Ave.	NBC1 zoom=3893 height=40'6"	192.168.8.2	88	1
040467FF21DCE611	NBC2 P2,5 (GNX05) US-231 Northwestern Ave.	NBC2 zoom=3656 height=40'6"	192.168.8.4	89	2
040468FF5C88E811	NBC3 P2,5 (GNX09) US-231 Northwestern Ave.	NBC3 zoom=3952 height=22'9"	192.168.8.3	84	3
04046AFFCD7CE811	NBC4 P2,5 (GNX13) US-231 Northwestern Ave.	NBC4 zoom=0 height=38'7.5"	192.168.11.1	104	4
040467FFA266E811	SBC1 P6,1 (GNX03) US-231 Northwestern Ave.	SBC1 zoom=3928 height=41'9"	192.168.9.1	88	1
040468FF7566E811	SBC2 P6,1 (GNX07) US-231 Northwestern Ave.	SBC2 zoom=3416 height=40'2"	192.168.9.4	87	2
040468FFFA89E811	SBC3 P6,1 (GNX11) US-231 Northwestern Ave.	SBC3 zoom=3968 height=24'2"	192.168.9.2	102	3
040468FF2E76E811	SBC4 P6,1 (GNX15) US-231 Northwestern Ave.	SBC4 zoom=0 height=37'2"	192.168.10.2	95	4
040468FF028CE811	WBC1 P8,3 (GNX04) W.Stadium Ave.	WBC1 zoom=4713 height=41'0"	192.168.10.1	76	1
04046AFF075E811	WBC2 P8,3 (GNX08) W.Stadium Ave.	WBC2 zoom=4695 height=40'2"	192.168.10.3	83	2
04046AFF2666E811	WBC3 P8,3 (GNX12) W.Stadium Ave.	WBC3 zoom=4787 height=23'3"	192.168.10.4	81	3
040467FF476AE811	WBC4 P8,3 (GNX16) W.Stadium Ave.	WBC4 zoom=0 height=39'7"	192.168.8.1	101	4

Channel Custom

16 Autoscopes, 1 Selected

①

②

③

④

⑤

⑥

⑦

⑧

Figure A.33 Autoscope Network Browser

Figure A.34 Autoscope Data Collector: Creating a Poll

View	Detector Title	Detector ID	Time Interval
Yes	NBC1 Thru -- Phase 2 Output - 101 - Detector Function	NBC1 Thru -- Phase 2 Output	State Change
Yes	NBC1 LT -- Phase 5 Output - 104 - Detector Function	NBC1 LT -- Phase 5 Output	State Change
Yes	NB Thru Loop - Input 6 - 146 - Detector Function	NB Thru Loop - Input 6	State Change
Yes	NBC2 AB Thru - 148 - Detector Function	NBC2 AB Thru	State Change
Yes	NBC3 AB Thru - 149 - Detector Function	NBC3 AB Thru	State Change
Yes	NB LT Loop - Input 2 - 150 - Detector Function	NB LT Loop - Input 2	State Change
Yes	NBC2 LT - 151 - Detector Function	NBC2 LT	State Change
Yes	NBC3 LT - 152 - Detector Function	NBC3 LT	State Change
Yes	NB phase 2 (input Red phase 5) - 153 - Label	NB phase 2 (input Red phase 5)	State Change
Yes	NB phase 5 (input Red phase 1) - 147 - Label	NB phase 5 (input Red phase 1)	State Change
Yes	NBC4 Thru -- Phase 2 Output - 101 - Detector Function	NBC4 Thru -- Phase 2 Output	State Change
Yes	NBC4 LT -- Phase 5 Output - 104 - Detector Function	NBC4 LT -- Phase 5 Output	State Change
Yes	NB Thru Loop - Input 6 - 137 - Detector Function	NB Thru Loop - Input 6	State Change
Yes	NB LT Loop - Input 2 - 142 - Detector Function	NB LT Loop - Input 2	State Change
Yes	NB phase 2 (input Red phase 5) - 149 - Label	NB phase 2 (input Red phase 5)	State Change
Yes	NB Red phase 5 (input Red phase 1) - 150 - Label	NB Red phase 5 (input Red phase 1)	State Change

Figure A.35 Sample Autoscope Poll List (Northbound – West Lafayette, IN)

View	Detector Title	Detector ID	Time Interval
Yes	NBC1 Thru -- Phase 2 Output - 101 - Detector Function	NBC1 Thru -- Phase 2 Output	State Change
Yes	NBC1 LT -- Phase 5 Output - 104 - Detector Function	NBC1 LT -- Phase 5 Output	State Change
Yes	NB Thru Loop - Input 6 - 146 - Detector Function	NB Thru Loop - Input 6	State Change
Yes	NBC2 AB Thru - 148 - Detector Function	NBC2 AB Thru	State Change
Yes	NBC3 AB Thru - 149 - Detector Function	NBC3 AB Thru	State Change
Yes	NB LT Loop - Input 2 - 150 - Detector Function	NB LT Loop - Input 2	State Change
Yes	NBC2 LT - 151 - Detector Function	NBC2 LT	State Change
Yes	NBC3 LT - 152 - Detector Function	NBC3 LT	State Change
Yes	NB phase 2 (input Red phase 5) - 153 - Label	NB phase 2 (input Red phase 5)	State Change
Yes	NB phase 5 (input Red phase 1) - 147 - Label	NB phase 5 (input Red phase 1)	State Change
Yes	NBC4 Thru -- Phase 2 Output - 101 - Detector Function	NBC4 Thru -- Phase 2 Output	State Change
Yes	NBC4 LT -- Phase 5 Output - 104 - Detector Function	NBC4 LT -- Phase 5 Output	State Change
Yes	NB Thru Loop - Input 6 - 137 - Detector Function	NB Thru Loop - Input 6	State Change
Yes	NB LT Loop - Input 2 - 142 - Detector Function	NB LT Loop - Input 2	State Change
Yes	NB phase 2 (input Red phase 5) - 149 - Label	NB phase 2 (input Red phase 5)	State Change
Yes	NB Red phase 5 (input Red phase 1) - 150 - Label	NB Red phase 5 (input Red phase 1)	State Change

Figure A.36 Sample Autoscope Poll List (Northbound – West Lafayette, IN)

Table A.8 Columns in Event Collector shown in Figure A.37a.

Item #	Title	Description
1	Event State	Shows a red 'A' to indicate event is 'Active'. Shows a black 'O' to indicate event is 'Off'.
2	CPU Identifier	Unique identifier for each Autoscope used to identify unit that data was collected on.
3	Detector ID	Unique ID number for labels in Autoscope detector field, used to identify event that the data point is associated with.
4	Detector Title	Descriptive identifier for labels in Autoscope detector file used for human interpretation of data points.
5	Date	Date stamp in MM/DD/YYYY.
6	Time	Time stamp in HH:MM:SS AM/PM format.
7	Time MS	Time in number of milliseconds since last Autoscope reboot or counter rollover, used for time calculations.
8	State	Reads 'On' to indicate event is 'Active'. Reads 'Off' to indicate event is 'Inactive'.
9	Status	Gives status of Autoscope. Reads 100% when Autoscope is performing correctly, otherwise gives an error code.

Table A.9 Time Drift of Autoscope from the NIST Atomic Time

	May 12, 2004 – 10:05:00 AM	May 16, 2004 – 10:05:00 AM	May 17, 2004 – 4:30:00 PM	May 18, 2004 – 8:30:00 AM	Average per day
NB1	0	-12	-15	-18	-3.0
NB2	0	-11	-15	-17	-2.8
NB3	0	-9	-12	-15	-2.5
SB1	0	-11	-16	-18	-3.0
SB2	0	-7	-10	-12	-2.0
SB3	0	-10	-14	-16	-2.7
EB1	0	-9	-13	-14	-2.3
EB2	0	-12	-15	-18	-3.0
EB3	0	-8	-11	-12	-2.0
WB1	0	-11	-14	-16	-2.7
WB2	0	-13	-17	-20	-3.3
WB3	0	-10	-15	-17	-2.8

a) Initial State Data with Screen Capture (07:32:51)

b) State Data with Screen Capture (07:32:57)

c) State Data with Screen Capture (07:33:05)

d) State Data with Screen Capture (07:32:57)

Figure A.37 Autoscope Data Collector: State Data with Example Screen Capture

Table A.10 Autoscope Poll List for Northbound (Noblesville, IN)

Approach Direction	Noblesville, Indiana	West Lafayette, Indiana
Northbound	Table A.11	Table A.15
Southbound	Table A.12	Table A.16
Eastbound	Table A.13	Table A.17
Westbound	Table A.14	Table A.18

Table A.11 Autoscope Poll List for Northbound (Noblesville, IN)

#	Detector Title	Input/Output	Det ID
Noblesville Northbound Camera 1: 040468FF0866600E			
1	NBC1 LT		136
2	NBC1 Thru		135
3	NBC2 LT	Input 3	129
4	NBC2 Thru	Input 7	132
5	NBC3 LT	Input 4	130
6	NBC3 Thru	Input 8	133
7	NB Loop LT	Input 2	137
8	NB Loop Thru	Input 6	131
9	NB Phase 2	Input Red Phase 5	147
10	NB Phase 5	Input Red Phase 1	143

Table A.12 Autoscope Poll List for Southbound (Noblesville, IN)

#	Detector Title	Input/Output	Det ID
Noblesville Southbound Camera 1: 040468FFC972620E			
1	SBC1 LT		136
2	SBC1 Thru		135
3	SBC2 LT	Input 3	129
4	SBC2 Thru	Input 7	132
5	SBC3 LT	Input 4	130
6	SBC3 Thru	Input 8	133
7	SB Loop LT	Input 2	137
8	SB Loop Thru	Input 6	131
9	SB Phase 6	Input Red Phase 5	147
10	SB Phase 1	Input Red Phase 1	143

Table A.13 Autoscope Poll List for Eastbound (Noblesville, IN)

#	Detector Title	Input/Output	Det ID
Noblesville Eastbound Camera 1: 040468FFDC65620E			
1	EBC1 LT		136
2	EBC1 Thru		135
3	EBC2 LT	Input 3	129
4	EBC2 Thru	Input 7	132
5	EBC3 LT	Input 4	130
6	EBC3 Thru	Input 8	133
7	EB Loop LT	Input 2	137
8	EB Loop Thru	Input 6	131
9	EB Phase 6	Input Red Phase 5	147
10	EB Phase 1	Input Red Phase 1	143

Table A.14 Autoscope Poll List for Westbound (Noblesville, IN)

#	Detector Title	Input/Output	Det ID
Noblesville Westbound Camera 1: 040467FF7569600E			
1	WBC1 LT		136
2	WBC1 Thru		135
3	WBC2 LT	Input 3	129
4	WBC2 Thru	Input 7	132
5	WBC3 LT	Input 4	130
6	WBC3 Thru	Input 8	133
7	WB Loop LT	Input 2	137
8	WB Loop Thru	Input 6	131
9	WB Phase 6	Input Red Phase 5	147
10	WB Phase 1	Input Red Phase 1	143

Table A.15 Autoscope Poll List for Northbound (West Lafayette, IN)

#	Detector Title	Input/Output	Det ID
West Lafayette Northbound Camera 1: 040468FFED63E811			
1	NBC1 Thru	Phase 2 Output	101
2	NBC1 LT	Phase 5 Output	104
3	NB Thru Loop	Input 6	146
4	NBC2 AB Thru		148
5	NBC3 AB Thru		149
6	NB LT Loop	Input 2	150
7	NBC2 LT		151
8	NBC3 LT		152
9	NB Phase 2	Input Red Phase 5	153
10	NB Phase 5	Input Red Phase 1	147
West Lafayette Northbound Camera 4: 04046AFFCD7CE811			
11	NBC4 Thru	Phase 2 Output	101
12	NBC4 LT	Phase 5 Output	104
13	NB Thru Loop	Input 6	137
14	NB LT Loop	Input 2	142
15	NB phase 2	Input Red Phase 5	149
16	NB Red phase 5	Input Red Phase 1	150

Table A.16 Autoscope Poll List for Southbound (West Lafayette, IN)

#	Detector Title	Input/Output	Det ID
West Lafayette Southbound Camera 1: 040467FFA266E811			
1	SBC1 Thru	Phase 6 Output	101
2	SBC1 LT	Phase 1 Output	104
3	SB Thru Loop	Input 6	146
4	SBC2 AB Thru		148
5	SBC3 AB Thru		149
6	SB LT Loop	Input 2	150
7	SBC2 LT		151
8	SBC3 LT		152
9	SB phase 6	Input Red Phase 5	153
10	SB phase 1	Input Red Phase 1	147
West Lafayette Southbound Camera 4: 040468FF2E76E811			
11	SBC4 Thru	Phase 6 Output	101
12	SBC4 LT	Phase 1 Output	104
13	SB Thru Loop	Input 6	137
14	SB LT Loop	Input 2	142
15	SB phase 6	Input Red Phase 5	149
16	SB Red phase 1	Input Red Phase 1	150

Table A.17 Autoscope Poll List for Eastbound (West Lafayette, IN)

#	Detector Title	Input/Output	Det ID
West Lafayette Eastbound Camera 1: 04046AFF826DE811			
1	EBC1 Thru	Phase 4 Output	101
2	EBC1 LT	Phase 7 Output	104
3	EB Thru Loop	Input 6	146
4	EBC2 AB Thru		148
5	EBC3 AB Thru		149
6	EB LT Loop	Input 2	150
7	EBC2 LT		151
8	EBC3 LT		152
9	EB Phase 4	Input Red Phase 5	153
10	EB Phase 7	Input Red Phase 1	147
West Lafayette Eastbound Camera 4: 040468FFAD70E811			
11	EBC4 Thru	Phase 4 Output	101
12	EBC4 LT	Phase 7 Output	104
13	EB Thru Loop	Input 6	137
14	EB LT Loop	Input 2	142
15	EB phase 4	Input Red phase 5	149
16	EB Red phase 7	Input Red phase 1	150

Table A.18 Autoscope Poll List for Westbound (West Lafayette, IN)

#	Detector Title	Input/Output	Det ID
West Lafayette Westbound Camera 1: 040468FF028CE811			
1	WBC1 Thru	Phase 8 Output	101
2	WBC1 LT	Phase 3 Output	104
3	WB Thru Loop	Input 6	146
4	WBC2 AB Thru		148
5	WBC3 AB Thru		149
6	WB LT Loop	Input 2	150
7	WBC2 LT		151
8	WBC3 LT		152
9	WB phase 8	Input Red Phase 5	153
10	WB Phase 3	Input Red Phase 1	147
West Lafayette Westbound Camera 4: 040467FF476AE811			
11	WBC4 Thru	Phase 8 Output	101
12	WBC4 LT	Phase 3 Output	104
13	WB Thru Loop	Input 6	137
14	WB LT Loop	Input 2	142
15	WB Phase 8	Input Red Phase 5	149
16	WB Red phase 3	Input Red Phase 1	150

Appendix B. Results – Noblesville, Indiana, March 24th – 28th, 2004

a) L1V0 Discrepancy Graph Example

b) L0V1 Discrepancy Graph Example

c) Discrepancy in Turn On Times Histogram Example

d) Discrepancy in Turn Off Times Histogram Example

Figure B.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends

a) Precipitation (Inches)

b) Wind Speed (Knots)

Figure B.2 Weather at Eagle Creek Airpark (Indianapolis, IN) During March 2004
Noblesville Testing Period

c) Temperature (Fahrenheit)

d) Sky Cover (%)

Figure B.2 (continued): Weather at Eagle Creek Airpark (Indianapolis, IN) During March 2004 Noblesville Testing Period

Figure B.3 Noblesville Northbound Through-Right Movement (Phase 2), 12:00 AM March 26th – 12:00 AM March 27th L1V0 and L0V1 Graphs for Cameras 1 through 3

a) L1V0 Camera 3

d) L0V1 Camera 3

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure B.4 Noblesville Northbound Left Turn Movement (Phase 5), 12:00 AM March 26th – 12:00 AM March 27th L1V0 and L0V1 Graphs for Cameras 1 through 3

Figure B.5 Noblesville Southbound Through-Right Movement (Phase 6), 6:00 PM March 24th – 6:00 PM March 25th L1V0 and L0V1 Graphs for Cameras 1 through 3

a) L1V0 Camera 3

d) L0V1 Camera 3

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure B.6 Noblesville Southbound Left Turn Movement (Phase 1), 6:00 PM March 24th – 6:00 PM March 25th L1V0 and L0V1 Graphs for Cameras 1 through 3

Figure B.7 Noblesville Eastbound Through-Right Movement (Phase 4), 12:30 AM March 27th – 12:30 AM March 28th L1V0 and L0V1 Graphs for Cameras 1 through 3

a) L1V0 Camera 3

d) L0V1 Camera 3

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure B.8 Noblesville Eastbound Left-Turn Movement (Phase 7), 12:30 AM March 27th – 12:30 AM March 28th L1V0 and L0V1 Graphs for Cameras 1 through 3

a) L1V0 Camera 3

d) L0V1 Camera 3

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure B.9 Noblesville Westbound Through-Right Movement (Phase 8), 1:00 AM March 28th – 1:00 AM March 29th L1V0 and L0V1 Graphs for Cameras 1 through 3

Figure B.10 Noblesville Westbound Left-Turn Movement (Phase 3), 1:00 AM March 28th – 1:00 AM March 29th L1V0 and L0V1 Graphs for Cameras 1 through 3

a) Count of Missed Detections Longer than 5 Seconds

b) Count of False Detections Longer than 5 Seconds

Figure B.11 Tabulation of Discrepancies Longer than 5 Seconds for All Approaches (March 2004, Noblesville, Indiana)

a) Count of Missed Detections Longer than 10 Seconds

b) Count of False Detections Longer than 10 Seconds

Figure B.12 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (March 2004, Noblesville, Indiana)

a) Count of Missed Detections Longer than 20 Seconds

b) Count of False Detections Longer than 20 Seconds

Figure B.13 Tabulation of Discrepancies Longer than 20 Seconds for All Approaches (March 2004, Noblesville, Indiana)

Table B.1 Table of Statistically Significant Difference between Number of Missed
 Detections and False Detections between Loop Detector and Video Detector
 (Noblesville, Indiana, March 2004)

Φ	Cam1			Cam2			Cam3			Loop		
	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1				✓			✓					
2		✓			✓			✓				
3	✓	✓	✓	✓	✓	✓	✓	✓	✓			
4	✓			✓	✓		✓	✓				
5	✓	✓		✓	✓		✓	✓				
6				✓								
7	✓	✓		✓	✓		✓	✓				
8												

a) Missed Detections

Φ	Cam1			Cam2			Cam3			Loop		
	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2		✓	✓		✓	✓	✓	✓	✓			
3	✓	✓		✓	✓	✓	✓	✓	✓			
4	✓	✓	✓	✓	✓	✓	✓	✓	✓			
5	✓	✓	✓	✓	✓	✓	✓	✓	✓			
6										✓	✓	✓
7	✓	✓	✓	✓	✓	✓	✓	✓	✓			
8	✓	✓	✓	✓	✓	✓	✓	✓	✓			

b) False Detections

✓ - Indicates that detector had a statistically significant larger number of errors
 than detector used for comparison

a) On Time Histogram Camera 1
(Day)

c) On Time Histogram Camera 2
(Day)

b) On Time Histogram Camera 1
(Night)

d) On Time Histogram Camera 2
(Night)

e) On Time Histogram Camera 3
(Day)

f) On Time Histogram Camera 3
(Night)

Figure B.14 On Time Histograms for Three Cameras. Noblesville Northbound Through-Right Movement (Phase 2), (March 26th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.15 Off Time Histograms for Three Cameras. Noblesville Northbound Through-Right Movement (Phase 2), (March 26th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.16 On Time Histograms for Three Cameras. Noblesville Southbound Through-Right Movement (Phase 6), (Day Period: March 25th, 2004, 12:00 PM to 4:00 PM, Night Period: March 24th, 2004, 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1
(Day)

c) Off Time Histogram Camera 2
(Day)

b) Off Time Histogram Camera 1
(Night)

d) Off Time Histogram Camera 2
(Night)

e) Off Time Histogram Camera 3
(Day)

f) Off Time Histogram Camera 3
(Night)

Figure B.17 Off Time Histograms for Three Cameras. Noblesville Southbound Through-Right Movement (Phase 6), (Day Period: March 25th, 2004, 12:00 PM to 4:00 PM, Night Period: March 24th, 2004, 8:00 PM to 12:00 AM)

a) On Time Histogram Camera 1
(Day)

c) On Time Histogram Camera 2
(Day)

b) On Time Histogram Camera 1
(Night)

d) On Time Histogram Camera 2
(Night)

e) On Time Histogram Camera 3
(Day)

f) On Time Histogram Camera 3
(Night)

Figure B.18 On Time Histograms for Three Cameras. Noblesville Eastbound Through-Right Movement (Phase 4), (March 27th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.19 Off Time Histograms for Three Cameras. Noblesville Eastbound Through-Right Movement (Phase 4), (March 27th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.20 On Time Histograms for Three Cameras. Noblesville Westbound Through-Right Movement (Phase 8), (March 28th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.21 Off Time Histograms for Three Cameras. Noblesville Westbound Through-Right Movement (Phase 8), (March 28th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Day: 8:00 AM to 12:00 PM

b) Day: 12:00 PM to 4:00 PM

c) Night: 12:00 AM to 4:00 AM

d) Night 8:00 PM to 12:00 AM

e) Transition: 4:00 AM to 8:00 AM

e) Transition: 4:00 PM to 8:00 PM

Figure B.22 On Time Histograms for Noblesville Eastbound Camera 1 Through-Right Movement (Phase 2), (March 27th, 2004)

a) Day: 8:00 AM to 12:00 PM

b) Day: 12:00 PM to 4:00 PM

c) Night: 12:00 AM to 4:00 AM

d) Night 8:00 PM to 12:00 AM

e) Transition: 4:00 AM to 8:00 AM

e) Transition: 4:00 PM to 8:00 PM

Figure B.23 Off Time Histograms for Noblesville Eastbound Camera 1 Through-Right Movement (Phase 2), (March 27th, 2004)

Table B.2 Difference between Loop Detector and Video Detector Turn On Times During Red Through Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	2.8	0.7	2.8	123	2.27	45.2	37.1	29.0	12.8	✓	✓	✓	✓
EBC2	D	2.6	1.6	2.8	124	2.27	17.8	14.4	11.0	4.2	✓	✓	✓	✓
EBC3	D	2.9	0.9	3.0	120	2.27	36.4	30.2	24.0	11.5	✓	✓	✓	✓
NBC1	D	2.5	0.4	2.5	142	2.27	69.7	55.9	42.1	14.4	✓	✓	✓	✓
NBC2	D	2.5	0.6	2.6	145	2.27	48.9	39.1	29.2	9.5	✓	✓	✓	✓
NBC3	D	2.2	1.1	2.3	142	2.27	24.8	19.2	13.6	2.3	✓	✓	✓	✓
SBC1	D	1.1	1.4	1.2	136	2.27	9.7	5.5	1.2	¹	✓	✓		
SBC2	D	1.2	0.7	1.4	138	2.27	22.2	13.2	4.2	¹	✓	✓	✓	
SBC3	D	1.7	0.4	1.7	137	2.27	50.7	35.9	21.1	¹	✓	✓	✓	
WBC1	D	0.5	3.8	1.6	138	2.27	1.5	0.0	¹	¹				
WBC2	D	1.0	4.8	2.2	137	2.27	2.4	1.2	0.0	¹	✓			
WBC3	D	1.1	2.7	1.8	136	2.27	4.8	2.6	0.5	¹	✓	✓		
EBC1	N	1.9	1.5	1.7	205	2.26	17.8	13.2	8.5	¹	✓	✓	✓	
EBC2	N	1.8	1.7	1.6	203	2.26	15.2	10.9	6.7	¹	✓	✓	✓	
EBC3	N	1.6	3.4	1.5	195	2.26	6.7	4.6	2.5	¹	✓	✓	✓	
NBC1	N	0.6	0.8	0.7	170	2.26	9.7	2.0	¹	¹	✓			
NBC2	N	0.5	1.0	0.5	174	2.26	7.3	0.4	¹	¹	✓			
NBC3	N	0.0	1.4	0.2	157	2.26	0.0	¹	¹	¹				
SBC1	N	0.0	0.9	-0.1	131	2.27	0.6	¹	¹	¹				
SBC2	N	-0.2	0.9	-0.1	133	2.27	2.1	¹	¹	¹				
SBC3	N	0.2	1.4	0.3	132	2.27	1.7	¹	¹	¹				
WBC1	N	0.4	0.7	0.5	126	2.27	7.3	¹	¹	¹	✓			
WBC2	N	-25.8	22.6	-19.5	126	2.27	12.8	12.5	12.3	11.8	✓	✓	✓	✓
WBC3	N	0.1	1.5	0.2	131	2.27	0.7	¹	¹	¹				

¹ T Statistic is out of range

Table B.3 Difference between Loop Detector and Video Detector Turn On Times
During Green Through Phase (Noblesville, Indiana, March 2004, Day Period:
12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.2	0.2	0.2	151	2.26	18.0	¹	¹	¹	✓			
EBC2	D	0.3	0.2	0.3	122	2.27	16.5	¹	¹	¹	✓			
EBC3	D	0.4	0.2	0.4	118	2.27	21.8	¹	¹	¹	✓			
NBC1	D	0.0	0.2	0.0	621	2.25	1.4	¹	¹	¹				
NBC2	D	0.1	0.3	0.1	543	2.25	7.7	¹	¹	¹	✓			
NBC3	D	0.0	0.3	0.0	518	2.25	1.2	¹	¹	¹				
SBC1	D	-0.4	0.2	-0.4	274	2.25	29.3	¹	¹	¹	✓			
SBC2	D	-0.2	0.2	-0.2	264	2.25	17.8	¹	¹	¹	✓			
SBC3	D	-0.1	0.2	-0.1	279	2.25	7.7	¹	¹	¹	✓			
WBC1	D	-0.4	0.4	-0.3	220	2.26	14.4	¹	¹	¹	✓			
WBC2	D	0.0	0.3	0.1	200	2.26	0.6	¹	¹	¹				
WBC3	D	-0.2	0.6	-0.1	205	2.26	5.3	¹	¹	¹	✓			
EBC1	N	0.0	0.6	0.2	151	2.26	0.9	¹	¹	¹				
EBC2	N	0.0	0.5	0.2	146	2.26	0.2	¹	¹	¹				
EBC3	N	-0.1	0.6	0.0	149	2.26	1.9	¹	¹	¹				
NBC1	N	-1.0	0.6	-0.9	479	2.25	38.7	19.7	0.7	¹	✓	✓		
NBC2	N	-0.9	0.5	-0.9	468	2.25	40.7	18.9	¹	¹	✓	✓		
NBC3	N	-1.2	0.7	-1.1	428	2.25	34.9	20.5	6.2	¹	✓	✓	✓	
SBC1	N	-1.0	0.5	-1.0	235	2.26	30.3	14.7	¹	¹	✓	✓		
SBC2	N	-1.0	0.4	-0.9	229	2.26	34.3	16.7	¹	¹	✓	✓		
SBC3	N	-0.8	0.4	-0.8	237	2.26	28.3	10.7	¹	¹	✓	✓		
WBC1	N	-0.9	0.5	-0.9	69	2.29	13.9	6.3	¹	¹	✓	✓		
WBC2	N	-0.8	0.5	-0.8	68	2.29	12.8	5.2	¹	¹	✓	✓		
WBC3	N	-1.0	0.6	-0.9	68	2.29	13.6	6.6	¹	¹	✓	✓		

¹ T Statistic is out of range

Table B.4 Difference between Loop Detector and Video Detector Turn Off Times During Red Through Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.0	0.8	0.1	57	2.30	0.5	¹	¹	¹				
EBC2	D	0.4	0.7	0.4	58	2.30	3.9	¹	¹	¹	✓			
EBC3	D	0.4	0.6	0.4	55	2.31	5.0	¹	¹	¹	✓			
NBC1	D	0.5	0.3	0.4	38	2.34	9.9	¹	¹	¹	✓			
NBC2	D	0.6	0.3	0.6	43	2.32	14.0	2.8	¹	¹	✓	✓		
NBC3	D	0.9	0.8	0.7	42	2.33	7.2	3.4	¹	¹	✓	✓		
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	-0.9	1.7	-0.5	68	2.29	4.3	1.9	¹	¹	✓			
EBC2	N	-1.0	1.9	-0.7	67	2.29	4.3	2.1	¹	¹	✓			
EBC3	N	-0.7	1.6	-0.4	66	2.29	3.6	0.9	¹	¹	✓			
NBC1	N	-0.1	1.4	0.1	44	2.32	0.6	¹	¹	¹				
NBC2	N	0.1	1.5	0.1	45	2.32	0.3	¹	¹	¹				
NBC3	N	0.4	1.2	0.4	39	2.33	1.9	¹	¹	¹				
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*

¹ T Statistic is out of range

Table B.5 Difference between Loop Detector and Video Detector Turn Off Times
During Green Through Phase (Noblesville, Indiana, March 2004, Day Period:
12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.5	0.4	0.5	210	2.26	19.0	0.8	¹	¹	✓			
EBC2	D	0.8	0.5	0.7	178	2.26	20.2	7.0	¹	¹	✓	✓		
EBC3	D	0.8	0.4	0.7	184	2.26	23.7	8.6	¹	¹	✓	✓		
NBC1	D	0.5	0.3	0.5	725	2.25	45.6	2.4	¹	¹	✓	✓		
NBC2	D	0.8	0.3	0.8	643	2.25	57.6	20.9	¹	¹	✓	✓		
NBC3	D	0.8	0.3	0.8	618	2.25	62.7	24.7	¹	¹	✓	✓		
SBC1	D	0.6	0.4	0.5	389	2.25	31.9	6.3	¹	¹	✓	✓		
SBC2	D	0.9	0.4	0.8	376	2.25	39.0	16.8	¹	¹	✓	✓		
SBC3	D	1.0	0.5	0.9	390	2.25	40.5	19.4	¹	¹	✓	✓		
WBC1	D	0.9	0.6	0.7	346	2.25	29.6	13.4	¹	¹	✓	✓		
WBC2	D	1.4	0.7	1.1	324	2.25	37.4	23.9	10.3	¹	✓	✓	✓	
WBC3	D	1.3	0.7	1.1	330	2.25	35.9	22.2	8.5	¹	✓	✓	✓	
EBC1	N	0.4	0.9	0.5	282	2.25	8.7	¹	¹	¹	✓			
EBC2	N	0.5	0.8	0.7	277	2.25	11.4	0.8	¹	¹	✓			
EBC3	N	0.6	0.7	0.6	275	2.25	13.2	2.0	¹	¹	✓			
NBC1	N	0.4	0.4	0.4	638	2.25	24.9	¹	¹	¹	✓			
NBC2	N	0.6	0.4	0.6	625	2.25	34.1	3.2	¹	¹	✓	✓		
NBC3	N	0.7	0.5	0.6	580	2.25	32.0	8.4	¹	¹	✓	✓		
SBC1	N	0.4	1.6	0.5	362	2.25	5.2	¹	¹	¹	✓			
SBC2	N	0.5	1.6	0.6	358	2.25	5.8	¹	¹	¹	✓			
SBC3	N	0.6	1.6	0.6	364	2.25	7.2	1.3	¹	¹	✓			
WBC1	N	0.6	0.8	0.6	183	2.26	11.1	2.4	¹	¹	✓	✓		
WBC2	N	1.0	0.9	1.0	181	2.26	15.3	7.9	0.5	¹	✓	✓		
WBC3	N	1.0	0.8	0.9	183	2.26	15.3	7.3	¹	¹	✓	✓		

¹ T Statistic is out of range

Figure B.24 On Time Histograms for Four Cameras. Noblesville Northbound Left-Turn Movement (Phase 5), (March 26th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.25 Off Time Histograms for Four Cameras. Noblesville Northbound Left-Turn Movement (Phase 5), (March 26th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.26 On Time Histograms for Four Cameras. Noblesville Southbound Left-Turn Movement (Phase 1), (Day Period: March 25th, 2004, 12:00 PM to 4:00 PM, Night Period: March 24th, 2004, 8:00 PM to 12:00 AM)

Figure B.27 Off Time Histograms for Four Cameras. Noblesville Southbound Left-Turn Movement (Phase 1), (Day Period: March 25th, 2004, 12:00 PM to 4:00 PM, Night Period: March 24th, 2004, 8:00 PM to 12:00 AM)

Figure B.28 On Time Histograms for Four Cameras. Noblesville Eastbound Left-Turn Movement (Phase 7), (March 27th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.29 Off Time Histograms for Four Cameras. Noblesville Eastbound Left-Turn Movement (Phase 7), (March 27th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.30 On Time Histograms for Four Cameras. Noblesville Westbound Left-Turn Movement (Phase 3), (March 28th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1 (Day)

c) Off Time Histogram Camera 2 (Day)

b) Off Time Histogram Camera 1 (Night)

d) Off Time Histogram Camera 2 (Night)

e) Off Time Histogram Camera 3 (Day)

f) Off Time Histogram Camera 3 (Night)

Figure B.31 Off Time Histograms for Four Cameras. Noblesville Westbound Left-Turn Movement (Phase 3), (March 28th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure B.32 On Time Histograms for Noblesville Eastbound Camera 1 Left-Turn Movement (Phase 5), (March 27th, 2004)

Figure B.33 Off Time Histograms for Noblesville Eastbound Camera 1 Left-Turn Movement (Phase 5), (March 27th, 2004)

Table B.6 Difference between Loop Detector and Video Detector Turn On Times
During Red Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period:
12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	1.2	8.4	2.6	106	2.27	1.4	0.8	0.2	¹				
EBC2	D	2.9	0.4	2.9	107	2.27	76.0	62.7	49.4	22.8	✓	✓	✓	✓
EBC3	D	2.3	3.9	2.7	107	2.27	6.2	4.9	3.5	0.9	✓	✓	✓	
NBC1	D	2.5	0.3	2.6	93	2.28	71.5	57.4	43.4	15.3	✓	✓	✓	✓
NBC2	D	2.5	3.3	3.0	90	2.28	7.3	5.8	4.4	1.5	✓	✓	✓	
NBC3	D	2.5	1.0	2.6	84	2.28	23.0	18.5	13.9	4.8	✓	✓	✓	✓
SBC1	D	1.0	6.7	2.0	98	2.28	1.5	0.8	0.0	¹				
SBC2	D	1.6	9.8	2.3	98	2.28	1.6	1.1	0.6	¹				
SBC3	D	2.3	4.9	2.5	99	2.28	4.6	3.6	2.6	0.5	✓	✓	✓	
WBC1	D	2.9	0.8	3.0	65	2.30	30.3	25.1	19.8	9.4	✓	✓	✓	✓
WBC2	D	3.4	0.9	3.4	64	2.30	28.5	24.3	20.0	11.5	✓	✓	✓	✓
WBC3	D	3.6	1.0	3.6	64	2.30	29.4	25.3	21.2	12.9	✓	✓	✓	✓
EBC1	N	1.6	0.9	1.3	90	2.28	17.8	12.3	6.8	¹	✓	✓	✓	
EBC2	N	2.0	1.0	1.7	88	2.28	18.2	13.6	9.0	¹	✓	✓	✓	
EBC3	N	2.1	0.7	2.1	88	2.28	26.6	20.2	13.7	0.8	✓	✓	✓	
NBC1	N	-0.5	5.8	-0.1	139	2.27	1.1	0.1	¹	¹				
NBC2	N	0.3	5.7	0.7	140	2.27	0.7	¹	¹	¹				
NBC3	N	-0.2	8.7	1.1	139	2.27	0.2	¹	¹	¹				
SBC1	N	1.9	0.8	2.0	38	2.34	14.3	10.4	6.6	¹	✓	✓	✓	
SBC2	N	1.2	5.6	2.1	38	2.34	1.3	0.7	0.2	¹				
SBC3	N	1.6	5.7	2.5	38	2.34	1.7	1.2	0.6	¹				
WBC1	N	1.8	0.7	1.7	90	2.28	23.1	16.6	10.1	¹	✓	✓	✓	
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	2.4	0.8	2.4	90	2.28	28.4	22.5	16.6	4.9	✓	✓	✓	✓

* Indicates Insufficient Data

¹ T Statistic is out of range

Table B.7 Difference between Loop Detector and Video Detector Turn On Times During Protected Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	D	0.2	0.4	0.2	64	2.30	4.5	¹	1	1	✓			
NBC2	D	0.6	0.3	0.6	49	2.31	13.1	2.0	1	1	✓			
NBC3	D	0.4	0.2	0.4	44	2.32	11.0	¹	1	1	✓			
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	-1.0	0.4	-1.0	32	2.36	12.8	6.0	1	1	✓	✓		
NBC3	N	-0.6	0.4	-0.7	38	2.34	9.5	2.0	1	1	✓			
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*

* Indicates Insufficient Data

¹ T Statistic is out of range

Table B.8 Difference between Loop Detector and Video Detector Turn On Times During Permitted Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.1	0.2	0.1	103	2.27	7.1	¹	¹	¹	✓			
EBC2	D	0.4	0.2	0.4	99	2.28	20.5	¹	¹	¹	✓			
EBC3	D	0.3	0.4	0.3	101	2.28	6.0	¹	¹	¹	✓			
NBC1	D	Protected Left Turn Only												
NBC2	D	Protected Left Turn Only												
NBC3	D	Protected Left Turn Only												
SBC1	D	Protected Left Turn Only												
SBC2	D	Protected Left Turn Only												
SBC3	D	Protected Left Turn Only												
WBC1	D	0.5	0.3	0.4	78	2.29	17.0	¹	¹	¹	✓			
WBC2	D	0.8	0.3	0.8	76	2.29	20.5	7.7	¹	¹	✓	✓		
WBC3	D	0.9	0.4	1.0	74	2.29	18.2	8.5	¹	¹	✓	✓		
EBC1	N	-0.6	0.6	-0.7	63	2.30	9.0	1.8	¹	¹	✓			
EBC2	N	-0.4	0.5	-0.5	63	2.30	6.4	¹	¹	¹	✓			
EBC3	N	-0.3	0.5	-0.2	64	2.30	4.7	¹	¹	¹	✓			
NBC1	N	Protected Left Turn Only												
NBC2	N	Protected Left Turn Only												
NBC3	N	Protected Left Turn Only												
SBC1	N	Protected Left Turn Only												
SBC2	N	Protected Left Turn Only												
SBC3	N	Protected Left Turn Only												
WBC1	N	-0.6	0.4	-0.6	40	2.33	9.7	1.7	¹	¹	✓			
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	-0.1	0.4	-0.1	41	2.33	1.2	¹	¹	¹				

¹ T Statistic is out of range

Table B.9 Difference between Loop Detector and Video Detector Turn Off Times
During Red Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period:
12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*

* Indicates Insufficient Data

¹ T Statistic is out of range

Table B.10 Difference between Loop Detector and Video Detector Turn Off Times During Protected Left-Turn Phase (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	1.5	0.8	1.5	73	2.29	16.5	10.9	5.2	¹	✓	✓	✓	
EBC2	D	1.8	1.0	1.9	68	2.29	15.2	10.9	6.6	¹	✓	✓	✓	
EBC3	D	1.6	1.1	1.8	73	2.29	13.2	9.1	5.1	¹	✓	✓	✓	
NBC1	D	0.6	0.4	0.6	131	2.27	16.7	2.5	¹	¹	✓	✓		
NBC2	D	1.1	0.4	1.1	115	2.27	32.2	16.9	1.6	¹	✓	✓		
NBC3	D	1.1	0.3	1.1	107	2.27	40.8	21.6	2.5	¹	✓	✓	✓	
SBC1	D	0.8	0.4	0.8	100	2.28	21.4	8.3	¹	¹	✓	✓		
SBC2	D	1.2	0.4	1.2	95	2.28	30.4	17.7	4.9	¹	✓	✓	✓	
SBC3	D	1.1	0.3	1.1	95	2.28	32.9	17.5	2.2	¹	✓	✓		
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	1.0	0.5	1.0	88	2.28	18.0	9.3	0.7	¹	✓	✓		
EBC2	N	1.1	0.7	1.2	87	2.28	14.9	8.2	1.4	¹	✓	✓		
EBC3	N	1.3	0.6	1.4	89	2.28	21.0	13.0	5.0	¹	✓	✓	✓	
NBC1	N	0.2	0.5	0.3	140	2.27	5.5	¹	¹	¹	✓			
NBC2	N	0.4	0.4	0.4	156	2.26	12.4	¹	¹	¹	✓			
NBC3	N	0.4	0.4	0.5	162	2.26	14.3	¹	¹	¹	✓			
SBC1	N	0.1	0.7	0.2	38	2.34	0.5	¹	¹	¹				
SBC2	N	0.4	0.5	0.5	38	2.34	5.3	¹	¹	¹	✓			
SBC3	N	0.3	0.4	0.4	38	2.34	5.5	¹	¹	¹	✓			
WBC1	N	1.2	0.5	1.2	88	2.28	22.1	12.8	3.6	¹	✓	✓	✓	
WBC2	N	1.5	0.5	1.5	87	2.28	29.3	19.3	9.3	¹	✓	✓	✓	
WBC3	N	1.5	0.4	1.5	86	2.28	34.0	22.8	11.5	¹	✓	✓	✓	

¹ T Statistic is out of range

Table B.12 Difference between Loop Detector and Video Detector Turn On Times (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓	✓	✓								*	*	*	*	✓			
EBC2	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	*	*	*	*	✓			
EBC3	D	✓	✓	✓	✓	✓				✓	✓	✓		*	*	*	*	✓			
NBC1	D	✓	✓	✓	✓					✓	✓	✓	✓	✓				NA			
NBC2	D	✓	✓	✓	✓	✓				✓	✓	✓		✓				NA			
NBC3	D	✓	✓	✓	✓					✓	✓	✓	✓	✓				NA			
SBC1	D	✓	✓			✓								*	*	*	*	NA			
SBC2	D	✓	✓	✓		✓								*	*	*	*	NA			
SBC3	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	NA			
WBC1	D					✓				✓	✓	✓	✓	*	*	*	*	✓			
WBC2	D	✓								✓	✓	✓	✓	*	*	*	*	✓	✓		
WBC3	D	✓	✓			✓				✓	✓	✓	✓	*	*	*	*	✓	✓		
EBC1	N	✓	✓	✓						✓	✓	✓		*	*	*	*	✓			
EBC2	N	✓	✓	✓						✓	✓	✓		*	*	*	*	✓			
EBC3	N	✓	✓	✓						✓	✓	✓		*	*	*	*	✓			
NBC1	N	✓				✓	✓							*	*	*	*	NA			
NBC2	N	✓				✓	✓							✓	✓			NA			
NBC3	N					✓	✓	✓						✓				NA			
SBC1	N					✓	✓			✓	✓	✓		*	*	*	*	NA			
SBC2	N					✓	✓							*	*	*	*	NA			
SBC3	N					✓	✓							*	*	*	*	NA			
WBC1	N	✓				✓	✓			✓	✓	✓		*	*	*	*	✓			
WBC2	N	✓	✓	✓	✓	✓	✓			*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N					✓	✓			✓	✓	✓	✓	*	*	*	*				

* Indicates Insufficient Data

Table B.13 Difference between Loop Detector and Video Detector Turn Off Times (Noblesville, Indiana, March 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D					✓				*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC2	D	✓				✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC3	D	✓				✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
NBC1	D	✓				✓	✓			*	*	*	*	✓	✓			NA			
NBC2	D	✓	✓			✓	✓			*	*	*	*	✓	✓			NA			
NBC3	D	✓	✓			✓	✓			*	*	*	*	✓	✓	✓		NA			
SBC1	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓			NA			
SBC2	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		NA			
SBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓			NA			
WBC1	D	*	*	*	*	✓	✓			*	*	*	*	*	*	*	*	✓	✓	✓	✓
WBC2	D	*	*	*	*	✓	✓	✓		*	*	*	*	*	*	*	*	✓	✓	✓	✓
WBC3	D	*	*	*	*	✓	✓	✓		*	*	*	*	*	*	*	*	✓	✓	✓	✓
EBC1	N	✓				✓				*	*	*	*	✓	✓			✓	✓		
EBC2	N	✓				✓				*	*	*	*	✓	✓			✓	✓		
EBC3	N	✓				✓				*	*	*	*	✓	✓	✓		✓	✓		
NBC1	N					✓				*	*	*	*	✓				NA			
NBC2	N					✓	✓			*	*	*	*	✓				NA			
NBC3	N					✓	✓			*	*	*	*	✓				NA			
SBC1	N	*	*	*	*	✓				*	*	*	*					NA			
SBC2	N	*	*	*	*	✓				*	*	*	*	✓				NA			
SBC3	N	*	*	*	*	✓				*	*	*	*	✓				NA			
WBC1	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
WBC2	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		*	*	*	*
WBC3	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	

* Indicates Insufficient Data

Appendix C. Results – Noblesville, Indiana, April 5th, 2005

a) L1V0 Discrepancy Graph Example

b) L0V1 Discrepancy Graph Example

c) Discrepancy in Turn On Times Histogram Example

d) Discrepancy in Turn Off Times Histogram Example

Figure C.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends

a) Precipitation (Inches)

b) Wind Speed (Knots)

Figure C.2 Weather at Eagle Creek Airpark (Indianapolis, IN) During April 5th, 2005 Noblesville Testing Period

c) Temperature (Fahrenheit)

d) Sky Cover (%)

Figure C.2 (continued): Weather at Eagle Creek Airpark (Indianapolis, IN) During April 5th, 2005 Noblesville Testing Period

a) L1V0 Camera 3

Not included in test

d) L0V1 Camera 3

Not included in test

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure C.3 Noblesville Northbound Through-Right Movement (Phase 2), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through

a) L1V0 Camera 3

Not included in test

d) L0V1 Camera 3

Not included in test

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure C.4 Noblesville Northbound Left Turn Movement (Phase 5), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3

a) L1V0 Camera 3

d) L0V1 Camera 3

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure C.5 Noblesville Southbound Through-Right Movement (Phase 6), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through

a) L1V0 Camera 3

d) L0V1 Camera 3

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure C.6 Noblesville Southbound Left Turn Movement (Phase 1), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3

Figure C.7 Noblesville Eastbound Through-Right Movement (Phase 4), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3

Figure C.8 Noblesville Eastbound Left-Turn Movement (Phase 7), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3

a) L1V0 Camera 3

d) L0V1 Camera 3

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure C.9 Noblesville Westbound Through-Right Movement (Phase 8), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through

a) L1V0 Camera 3

d) L0V1 Camera 3

b) L1V0 Camera 2

e) L0V1 Camera 2

c) L1V0 Camera 1

f) L0V1 Camera 1

Figure C.10 Noblesville Westbound Left-Turn Movement (Phase 3), 12:00 AM April 5th – 12:00 AM April 6th L1V0 and L0V1 Graphs for Cameras 1 through 3

a) Count of Missed Detections Longer than 5 Seconds

b) Count of False Detections Longer than 5 Seconds

Figure C.11 Tabulation of Discrepancies Longer than 5 Seconds for All Approaches (April 5th, 2005, Noblesville, Indiana)

a) Count of Missed Detections Longer than 10 Seconds

b) Count of False Detections Longer than 10 Seconds

Figure C.12 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (April 5th, 2005, Noblesville, Indiana)

a) Count of Missed Detections Longer than 20 Seconds

b) Count of False Detections Longer than 20 Seconds

Figure C.13 Tabulation of Discrepancies Longer than 20 Seconds for All Approaches (April 5th, 2005, Noblesville, Indiana)

Table C.1 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (Noblesville, Indiana, April 5th, 2005)

Φ	Cam1			Cam2			Cam3			Loop		
	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2				NA	NA	NA						
3	✓			✓			✓	✓				
4	✓	✓		✓	✓		✓	✓				
5	✓			NA	NA	NA						
6	✓			✓	✓		✓	✓				
7												
8	✓	✓		✓	✓		✓	✓				

a) Missed Detections

Φ	Cam1			Cam2			Cam3			Loop		
	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2	✓			NA	NA	NA	✓					
3	✓	✓	✓	✓	✓	✓	✓	✓	✓			
4	✓	✓	✓	✓	✓	✓	✓	✓	✓			
5	✓	✓	✓	NA	NA	NA	✓	✓	✓			
6	✓											
7	✓	✓	✓	✓	✓	✓	✓	✓	✓			
8	✓	✓	✓	✓	✓	✓	✓	✓	✓			

b) False Detections

✓ - Indicates that detector had a statistically significant larger number of errors than detector used for comparison

Not included in test

a) On Time Histogram Camera 1
(Day)

c) On Time Histogram Camera 2
(Day)

Not included in test

b) On Time Histogram Camera 1
(Night)

d) On Time Histogram Camera 2
(Night)

e) On Time Histogram Camera 3
(Day)

f) On Time Histogram Camera 3
(Night)

Figure C.14 On Time Histograms for Three Cameras. Noblesville Northbound Through-Right Movement (Phase 2), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1
(Day)

Not included in test

b) Off Time Histogram Camera 1
(Night)

Not included in test

e) Off Time Histogram Camera 3
(Day)

f) Off Time Histogram Camera 3
(Night)

c) Off Time Histogram Camera 2
(Day)

d) Off Time Histogram Camera 2
(Night)

Figure C.15 Off Time Histograms for Three Cameras. Noblesville Northbound Through-Right Movement (Phase 2), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) On Time Histogram Camera 1
(Day)

c) On Time Histogram Camera 2
(Day)

b) On Time Histogram Camera 1
(Night)

d) On Time Histogram Camera 2
(Night)

e) On Time Histogram Camera 3
(Day)

f) On Time Histogram Camera 3
(Night)

Figure C.16 On Time Histograms for Three Cameras. Noblesville Southbound Through-Right Movement (Phase 6), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure C.17 Off Time Histograms for Three Cameras. Noblesville Southbound Through-Right Movement (Phase 6), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) On Time Histogram Camera 1
(Day)

c) On Time Histogram Camera 2
(Day)

b) On Time Histogram Camera 1
(Night)

d) On Time Histogram Camera 2
(Night)

e) On Time Histogram Camera 3
(Day)

f) On Time Histogram Camera 3
(Night)

Figure C.18 On Time Histograms for Three Cameras. Noblesville Eastbound Through-Right Movement (Phase 4), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure C.19 Off Time Histograms for Three Cameras. Noblesville Eastbound Through-Right Movement (Phase 4), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure C.20 On Time Histograms for Three Cameras. Noblesville Westbound Through-Right Movement (Phase 8), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure C.21 Off Time Histograms for Three Cameras. Noblesville Westbound Through-Right Movement (Phase 8), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Day: 8:00 AM to 12:00 PM

b) Day: 12:00 PM to 4:00 PM

c) Night: 12:00 AM to 4:00 AM

d) Night 8:00 PM to 12:00 AM

e) Transition: 4:00 AM to 8:00 AM

e) Transition: 4:00 PM to 8:00 PM

Figure C.22 On Time Histograms for Noblesville Eastbound Camera 1 Through-Right Movement (Phase 4), (April 5th, 2005)

a) Day: 8:00 AM to 12:00 PM

b) Day: 12:00 PM to 4:00 PM

c) Night: 12:00 AM to 4:00 AM

d) Night 8:00 PM to 12:00 AM

e) Transition: 4:00 AM to 8:00 AM

e) Transition: 4:00 PM to 8:00 PM

Figure C.23 Off Time Histograms for Noblesville Eastbound Camera 1 Through-Right Movement (Phase 4), (April 5th, 2005)

Table C.2 Difference between Loop Detector and Video Detector Turn On Times
During Red Through Phase (Noblesville, Indiana, April 5th, 2005, Day Period:
12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	2.6	3.5	3.0	107	2.27	7.7	6.2	4.7	1.8	✓	✓	✓	
EBC2	D	3.0	1.1	3.0	97	2.28	26.9	22.4	18.0	9.1	✓	✓	✓	✓
EBC3	D	3.2	0.8	3.2	104	2.27	41.4	34.9	28.5	15.7	✓	✓	✓	✓
NBC1	D	2.6	0.6	2.6	112	2.27	48.8	39.5	30.3	11.7	✓	✓	✓	✓
NBC2	D	Not included in test												
NBC3	D	2.7	0.7	2.8	105	2.27	38.6	31.4	24.2	9.8	✓	✓	✓	✓
SBC1	D	2.7	2.6	2.5	116	2.27	10.9	8.9	6.9	2.8	✓	✓	✓	✓
SBC2	D	2.9	1.6	2.7	115	2.27	19.5	16.2	12.8	6.2	✓	✓	✓	✓
SBC3	D	3.8	3.8	3.3	114	2.27	10.7	9.3	7.9	5.1	✓	✓	✓	✓
WBC1	D	2.7	2.1	3.2	115	2.27	13.9	11.3	8.7	3.5	✓	✓	✓	✓
WBC2	D	3.2	2.5	3.9	117	2.27	13.5	11.4	9.3	5.0	✓	✓	✓	✓
WBC3	D	2.8	4.0	3.7	118	2.27	7.6	6.3	4.9	2.2	✓	✓	✓	
EBC1	N	1.0	1.7	1.0	188	2.26	8.4	4.4	0.3	¹	✓	✓		
EBC2	N	1.4	1.3	1.3	171	2.26	13.4	8.5	3.5	¹	✓	✓	✓	
EBC3	N	0.1	2.7	0.3	183	2.26	0.7	¹	¹	¹				
NBC1	N	1.4	0.6	1.5	149	2.26	29.5	19.2	9.0	¹	✓	✓	✓	
NBC2	N	Not included in test												
NBC3	N	0.7	1.6	1.0	142	2.27	5.4	1.6	¹	¹	✓			
SBC1	N	0.0	0.8	0.0	128	2.27	0.1	¹	¹	¹				
SBC2	N	0.1	0.9	0.0	126	2.27	0.7	¹	¹	¹				
SBC3	N	0.5	0.8	0.5	131	2.27	6.4	¹	¹	¹	✓			
WBC1	N	1.5	1.0	1.5	131	2.27	16.1	10.5	5.0	¹	✓	✓	✓	
WBC2	N	1.4	2.2	1.6	131	2.27	7.3	4.6	2.0	¹	✓	✓		
WBC3	N	0.5	5.6	1.2	132	2.27	1.0	¹	¹	¹				

¹ T Statistic is out of range

Table C.3 Difference between Loop Detector and Video Detector Turn On Times During Green Through Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.4	0.2	0.4	227	2.26	27.0	¹	¹	¹	✓			
EBC2	D	0.5	0.3	0.5	200	2.26	24.2	0.9	¹	¹	✓			
EBC3	D	0.6	0.3	0.5	211	2.26	31.1	4.1	¹	¹	✓	✓		
NBC1	D	0.2	0.1	0.2	716	2.25	36.4	¹	¹	¹	✓			
NBC2	D	Not included in test												
NBC3	D	0.4	0.3	0.4	591	2.25	35.6	¹	¹	¹	✓			
SBC1	D	0.2	0.2	0.2	271	2.25	17.2	¹	¹	¹	✓			
SBC2	D	0.5	0.3	0.5	226	2.26	26.4	0.3	¹	¹	✓			
SBC3	D	0.6	0.2	0.6	214	2.26	40.4	9.3	¹	¹	✓	✓		
WBC1	D	0.5	0.2	0.5	229	2.26	36.3	1.8	¹	¹	✓			
WBC2	D	0.9	0.4	0.9	195	2.26	31.4	13.6	¹	¹	✓	✓		
WBC3	D	0.8	0.6	0.8	195	2.26	18.3	6.3	¹	¹	✓	✓		
EBC1	N	-0.8	0.6	-0.9	141	2.27	16.2	6.6	¹	¹	✓	✓		
EBC2	N	-0.4	0.8	-0.2	145	2.27	5.7	¹	¹	¹	✓			
EBC3	N	-1.2	1.1	-1.2	129	2.27	12.6	7.5	2.4	¹	✓	✓	✓	
NBC1	N	-0.6	0.5	-0.5	426	2.25	26.2	4.7	¹	¹	✓	✓		
NBC2	N	Not included in test												
NBC3	N	-0.8	0.5	-0.7	387	2.25	30.4	11.0	¹	¹	✓	✓		
SBC1	N	-1.2	0.4	-1.2	205	2.26	42.9	24.7	6.5	¹	✓	✓	✓	
SBC2	N	-1.0	0.4	-1.0	203	2.26	38.3	19.4	0.5	¹	✓	✓		
SBC3	N	-0.7	0.4	-0.7	210	2.26	24.6	7.7	¹	¹	✓	✓		
WBC1	N	-0.5	0.4	-0.5	76	2.29	11.1	1.0	¹	¹	✓			
WBC2	N	-0.4	0.6	-0.4	74	2.29	6.5	¹	¹	¹	✓			
WBC3	N	-0.5	0.6	-0.3	69	2.29	7.3	¹	¹	¹	✓			

¹ T Statistic is out of range

Table C.4 Difference between Loop Detector and Video Detector Turn Off Times
During Red Through Phase (Noblesville, Indiana, April 5th, 2005, Day Period:
12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.2	1.2	0.2	40	2.33	1.2	¹	¹	¹				
EBC2	D	0.2	1.1	0.5	35	2.35	1.3	¹	¹	¹				
EBC3	D	0.3	1.0	0.6	38	2.34	2.0	¹	¹	¹				
NBC1	D	0.3	0.4	0.3	36	2.34	3.5	¹	¹	¹	✓			
NBC2	D	Not included in test												
NBC3	D	0.9	0.5	0.9	32	2.36	9.1	3.8	¹	¹	✓	✓		
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	-0.9	2.6	-0.9	88	2.28	3.2	1.4	¹	¹	✓			
EBC2	N	-1.1	2.6	-0.7	74	2.29	3.6	1.9	0.3	¹	✓			
EBC3	N	-0.6	2.7	-0.4	90	2.28	2.2	0.5	¹	¹				
NBC1	N	-0.1	0.7	0.1	42	2.33	0.5	¹	¹	¹				
NBC2	N	Not included in test												
NBC3	N	0.7	1.0	0.8	38	2.34	4.5	1.3	¹	¹	✓			
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*

¹ T Statistic is out of range

* Indicates Insufficient Data

Table C.5 Difference between Loop Detector and Video Detector Turn Off Times During Green Through Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.6	0.5	0.6	301	2.25	20.4	3.5	¹	¹	✓	✓		
EBC2	D	0.9	0.6	0.8	261	2.25	27.1	12.5	¹	¹	✓	✓		
EBC3	D	0.8	0.5	0.8	281	2.25	27.4	11.0	¹	¹	✓	✓		
NBC1	D	0.5	0.3	0.5	793	2.25	47.2	0.9	¹	¹	✓			
NBC2	D	Not included in test												
NBC3	D	0.9	0.3	0.9	661	2.25	75.8	33.2	¹	¹	✓	✓		
SBC1	D	0.6	0.4	0.6	374	2.25	30.0	4.6	¹	¹	✓	✓		
SBC2	D	1.0	0.3	1.0	327	2.25	49.9	24.0	¹	¹	✓	✓		
SBC3	D	1.0	0.4	1.0	315	2.25	45.3	23.5	1.6	¹	✓	✓		
WBC1	D	1.0	0.5	0.9	338	2.25	37.7	19.7	1.7	¹	✓	✓		
WBC2	D	1.5	0.6	1.3	298	2.25	41.6	27.9	14.2	¹	✓	✓	✓	
WBC3	D	1.4	0.6	1.3	301	2.25	41.7	27.2	12.7	¹	✓	✓	✓	
EBC1	N	0.6	1.0	0.7	250	2.26	9.7	1.7	¹	¹	✓			
EBC2	N	0.9	0.9	0.9	247	2.26	15.5	6.9	¹	¹	✓	✓		
EBC3	N	0.9	1.0	0.9	231	2.26	14.8	6.8	¹	¹	✓	✓		
NBC1	N	0.7	0.4	0.7	539	2.25	35.8	9.8	¹	¹	✓	✓		
NBC2	N	Not included in test												
NBC3	N	0.9	0.5	0.8	500	2.25	42.7	19.9	¹	¹	✓	✓		
SBC1	N	0.9	0.5	0.7	330	2.25	31.8	13.8	¹	¹	✓	✓		
SBC2	N	1.1	0.6	0.9	327	2.25	31.7	17.1	2.4	¹	✓	✓	✓	
SBC3	N	1.2	0.6	0.9	334	2.25	36.0	20.7	5.3	¹	✓	✓	✓	
WBC1	N	1.2	0.6	1.2	189	2.26	29.9	17.5	5.2	¹	✓	✓	✓	
WBC2	N	1.6	0.6	1.5	187	2.26	35.6	24.3	13.0	¹	✓	✓	✓	
WBC3	N	1.5	0.5	1.5	182	2.26	37.4	24.9	12.4	¹	✓	✓	✓	

¹ T Statistic is out of range

Not included in test

a) On Time Histogram Camera 1
(Day)

c) On Time Histogram Camera 2
(Day)

Not included in test

b) On Time Histogram Camera 1
(Night)

d) On Time Histogram Camera 2
(Night)

e) On Time Histogram Camera 3
(Day)

f) On Time Histogram Camera 3
(Night)

Figure C.24 On Time Histograms for Four Cameras. Noblesville Northbound Left-Turn Movement (Phase 5), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1
(Day)

Not included in test

c) Off Time Histogram Camera 2
(Day)

b) Off Time Histogram Camera 1
(Night)

Not included in test

d) Off Time Histogram Camera 2
(Night)

e) Off Time Histogram Camera 3
(Day)

f) Off Time Histogram Camera 3
(Night)

Figure C.25 Off Time Histograms for Four Cameras. Noblesville Northbound Left-Turn Movement (Phase 5), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) On Time Histogram Camera 1
(Day)

c) On Time Histogram Camera 2
(Day)

b) On Time Histogram Camera 1
(Night)

d) On Time Histogram Camera 2
(Night)

e) On Time Histogram Camera 3
(Day)

f) On Time Histogram Camera 3
(Night)

Figure C.26 On Time Histograms for Four Cameras. Noblesville Southbound Left-Turn Movement (Phase 1), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1
(Day)

c) Off Time Histogram Camera 2
(Day)

b) Off Time Histogram Camera 1
(Night)

d) Off Time Histogram Camera 2
(Night)

e) Off Time Histogram Camera 3
(Day)

f) Off Time Histogram Camera 3
(Night)

Figure C.27 Off Time Histograms for Four Cameras. Noblesville Southbound Left-Turn Movement (Phase 1), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure C.28 On Time Histograms for Four Cameras. Noblesville Eastbound Left-Turn Movement (Phase 7), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure C.29 Off Time Histograms for Four Cameras. Noblesville Eastbound Left-Turn Movement (Phase 7), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure C.30 On Time Histograms for Four Cameras. Noblesville Westbound Left-Turn Movement (Phase 3), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1 (Day)

c) Off Time Histogram Camera 2 (Day)

b) Off Time Histogram Camera 1 (Night)

d) Off Time Histogram Camera 2 (Night)

e) Off Time Histogram Camera 3 (Day)

f) Off Time Histogram Camera 3 (Night)

Figure C.31 Off Time Histograms for Four Cameras. Noblesville Westbound Left-Turn Movement (Phase 3), (April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure C.32 On Time Histograms for Noblesville Eastbound Camera 1 Left-Turn Movement (Phase 7), (April 5th, 2005)

Figure C.33 Off Time Histograms for Noblesville Eastbound Camera 1 Left-Turn Movement (Phase 7), (April 5th, 2005)

Table C.6 Difference between Loop Detector and Video Detector Turn On Times During Red Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.2	10.7	2.7	94	2.28	0.2	¹	¹	¹				
EBC2	D	0.0	11.3	3.0	96	2.28	0.0	¹	¹	¹				
EBC3	D	1.1	9.3	3.0	95	2.28	1.1	0.6	0.1	¹				
NBC1	D	2.9	0.3	2.9	108	2.27	87.7	72.8	57.8	27.9	✓	✓	✓	✓
NBC2	D	Not included in test												
NBC3	D	3.2	0.5	3.2	106	2.27	68.3	57.6	46.9	25.5	✓	✓	✓	✓
SBC1	D	3.3	0.8	3.1	87	2.28	39.8	33.8	27.7	15.6	✓	✓	✓	✓
SBC2	D	3.1	4.0	3.4	87	2.28	7.3	6.1	5.0	2.6	✓	✓	✓	✓
SBC3	D	3.8	0.5	3.7	87	2.28	65.6	57.0	48.4	31.1	✓	✓	✓	✓
WBC1	D	3.5	0.4	3.4	60	2.30	62.8	53.8	44.8	26.8	✓	✓	✓	✓
WBC2	D	3.8	0.7	3.8	60	2.30	40.9	35.6	30.3	19.6	✓	✓	✓	✓
WBC3	D	4.3	1.0	4.2	57	2.30	31.7	28.0	24.3	16.9	✓	✓	✓	✓
EBC1	N	0.9	0.6	1.0	67	2.29	11.9	5.1	¹	¹	✓	✓		
EBC2	N	1.3	0.6	1.3	67	2.29	17.1	10.4	3.7	¹	✓	✓	✓	
EBC3	N	1.3	0.6	1.4	68	2.29	18.9	11.8	4.6	¹	✓	✓	✓	
NBC1	N	0.9	0.8	1.0	116	2.27	12.4	5.5	¹	¹	✓	✓		
NBC2	N	Not included in test												
NBC3	N	1.3	1.0	1.4	116	2.27	13.9	8.4	2.9	¹	✓	✓	✓	
SBC1	N	-0.9	14.1	1.7	32	2.36	0.4	0.2	¹	¹				
SBC2	N	-3.5	26.4	2.1	32	2.36	0.7	0.6	0.5	0.3				
SBC3	N	-1.4	23.0	2.7	32	2.36	0.4	0.2	0.1	¹				
WBC1	N	1.6	0.8	1.8	88	2.28	19.7	13.6	7.5	¹	✓	✓	✓	
WBC2	N	2.0	1.5	1.9	87	2.28	12.3	9.2	6.1	¹	✓	✓	✓	
WBC3	N	2.3	0.9	2.4	90	2.28	24.5	19.2	13.9	3.4	✓	✓	✓	✓

* Indicates Insufficient Data

¹ T Statistic is out of range

Table C.7 Difference between Loop Detector and Video Detector Turn On Times
During Protected Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day
Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	D	0.5	0.3	0.5	85	2.28	14.7	¹	¹	¹	✓			
NBC2	D	Not included in test												
NBC3	D	0.7	0.3	0.6	50	2.31	17.4	4.3	¹	¹	✓	✓		
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	Not included in test												
NBC3	N	-0.5	0.5	-0.4	31	2.36	5.6	¹	¹	¹	✓			
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*

* Indicates Insufficient Data

¹ T Statistic is out of range

Table C.8 Difference between Loop Detector and Video Detector Turn On Times
During Permitted Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day
Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.0	0.9	0.2	94	2.28	0.4	¹	¹	¹				
EBC2	D	0.2	1.1	0.3	90	2.28	1.9	¹	¹	¹				
EBC3	D	0.4	0.3	0.4	91	2.28	11.3	¹	¹	¹	✓			
NBC1	D	Protected Left Turn Only												
NBC2	D	Not included in test												
NBC3	D	Protected Left Turn Only												
SBC1	D	Protected Left Turn Only												
SBC2	D	Protected Left Turn Only												
SBC3	D	Protected Left Turn Only												
WBC1	D	0.7	0.3	0.7	89	2.28	22.2	6.5	¹	¹	✓	✓		
WBC2	D	0.9	0.9	1.0	93	2.28	9.8	4.4	¹	¹	✓	✓		
WBC3	D	1.3	0.4	1.3	87	2.28	29.9	18.4	7.0	¹	✓	✓	✓	
EBC1	N	-1.3	0.6	-1.0	59	2.30	16.4	9.9	3.5	¹	✓	✓	✓	
EBC2	N	-1.1	1.0	-0.9	61	2.30	8.0	4.2	0.4	¹	✓	✓		
EBC3	N	-0.9	1.0	-0.7	60	2.30	7.2	3.4	¹	¹	✓	✓		
NBC1	N	Protected Left Turn Only												
NBC2	N	Not included in test												
NBC3	N	Protected Left Turn Only												
SBC1	N	Protected Left Turn Only												
SBC2	N	Protected Left Turn Only												
SBC3	N	Protected Left Turn Only												
WBC1	N	-0.7	0.7	-0.7	42	2.33	6.3	1.5	¹	¹	✓			
WBC2	N	-0.4	0.6	-0.4	44	2.32	4.2	¹	¹	¹	✓			
WBC3	N	0.0	0.5	-0.1	45	2.32	0.4	¹	¹	¹				

¹ T Statistic is out of range

Table C.9 Difference between Loop Detector and Video Detector Turn Off Times
During Red Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period:
12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	D	Not included in test												
NBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	Not included in test												
NBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*

* Indicates Insufficient Data

¹ T Statistic is out of range

Table C.10 Difference between Loop Detector and Video Detector Turn Off Times During Protected Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	1.4	0.4	1.4	93	2.28	33.3	21.3	9.4	¹	✓	✓	✓	
EBC2	D	1.8	0.4	1.7	90	2.28	43.0	30.8	18.6	¹	✓	✓	✓	
EBC3	D	1.7	0.4	1.7	91	2.28	38.7	27.4	16.1	¹	✓	✓	✓	
NBC1	D	0.4	0.5	0.5	178	2.26	12.0	¹	¹	¹	✓			
NBC2	D	Not included in test												
NBC3	D	1.1	0.2	1.1	140	2.27	58.4	31.6	4.8	¹	✓	✓	✓	
SBC1	D	0.9	0.4	0.9	88	2.28	18.5	8.1	¹	¹	✓	✓		
SBC2	D	1.3	0.4	1.3	86	2.28	31.7	19.4	7.1	¹	✓	✓	✓	
SBC3	D	1.3	0.4	1.3	86	2.28	34.8	21.8	8.8	¹	✓	✓	✓	
WBC1	D	1.4	0.8	1.4	56	2.30	13.3	8.6	3.9	¹	✓	✓	✓	
WBC2	D	1.6	0.5	1.8	50	2.31	21.3	14.8	8.3	¹	✓	✓	✓	
WBC3	D	1.7	0.4	1.6	50	2.31	27.5	19.3	11.1	¹	✓	✓	✓	
EBC1	N	1.4	0.5	1.4	73	2.29	23.7	15.0	6.3	¹	✓	✓	✓	
EBC2	N	1.6	0.4	1.7	74	2.29	31.0	21.4	11.9	¹	✓	✓	✓	
EBC3	N	1.7	0.4	1.7	72	2.29	32.0	22.5	12.9	¹	✓	✓	✓	
NBC1	N	0.7	0.4	0.7	135	2.27	20.0	6.2	¹	¹	✓	✓		
NBC2	N	Not included in test												
NBC3	N	1.0	0.4	0.9	136	2.27	29.7	14.1	¹	¹	✓	✓		
SBC1	N	0.4	0.3	0.5	33	2.35	8.3	¹	¹	¹	✓			
SBC2	N	0.6	0.2	0.6	33	2.35	13.3	1.5	¹	¹	✓			
SBC3	N	0.6	0.3	0.6	33	2.35	10.6	1.1	¹	¹	✓			
WBC1	N	1.6	0.4	1.6	86	2.28	33.9	23.1	12.3	¹	✓	✓	✓	
WBC2	N	1.9	0.4	1.9	85	2.28	46.6	34.2	21.8	¹	✓	✓	✓	
WBC3	N	1.7	0.4	1.7	87	2.28	38.6	27.3	16.1	¹	✓	✓	✓	

¹ T Statistic is out of range

Table C.11 Difference between Loop Detector and Video Detector Turn Off Times During Permitted Left-Turn Phase (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	2.5	2.6	1.6	97	2.28	9.3	7.4	5.5	1.7	✓	✓	✓	
EBC2	D	2.8	3.4	1.8	95	2.28	8.1	6.7	5.3	2.4	✓	✓	✓	✓
EBC3	D	3.4	4.6	2.1	94	2.28	7.1	6.1	5.0	2.9	✓	✓	✓	✓
NBC1	D	Protected Left Turn Only												
NBC2	D	Not included in test												
NBC3	D	Protected Left Turn Only												
SBC1	D	Protected Left Turn Only												
SBC2	D	Protected Left Turn Only												
SBC3	D	Protected Left Turn Only												
WBC1	D	3.5	3.4	2.7	82	2.28	9.4	8.0	6.7	4.0	✓	✓	✓	✓
WBC2	D	3.7	3.0	2.8	82	2.28	11.2	9.7	8.2	5.2	✓	✓	✓	✓
WBC3	D	3.6	3.1	2.8	79	2.29	10.4	8.9	7.5	4.6	✓	✓	✓	✓
EBC1	N	1.7	1.8	1.3	53	2.31	7.0	4.9	2.8	¹	✓	✓	✓	
EBC2	N	1.8	1.7	1.5	57	2.30	8.1	5.9	3.7	¹	✓	✓	✓	
EBC3	N	1.9	1.8	1.6	55	2.31	7.8	5.8	3.8	¹	✓	✓	✓	
NBC1	N	Protected Left Turn Only												
NBC2	N	Not included in test												
NBC3	N	Protected Left Turn Only												
SBC1	N	Protected Left Turn Only												
SBC2	N	Protected Left Turn Only												
SBC3	N	Protected Left Turn Only												
WBC1	N	2.6	2.6	1.9	46	2.32	6.9	5.6	4.3	1.7	✓	✓	✓	
WBC2	N	2.7	2.1	2.0	45	2.32	8.8	7.2	5.5	2.3	✓	✓	✓	
WBC3	N	2.3	1.9	1.7	50	2.31	8.6	6.7	4.8	1.0	✓	✓	✓	

¹ T Statistic is out of range

Table C.12 Difference between Loop Detector and Video Detector Turn On Times (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

		Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
Camera	Time of Day	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓		✓								*	*	*	*				
EBC2	D	✓	✓	✓	✓	✓								*	*	*	*				
EBC3	D	✓	✓	✓	✓	✓	✓							*	*	*	*	✓			
NBC1	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓				Protected only			
NBC2	D	Not included in test																			
NBC3	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓			Protected only			
SBC1	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	*	*	*	*	Protected only			
SBC2	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	*	*	*	*	Protected only			
SBC3	D	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	*	*	*	*	Protected only			
WBC1	D	✓	✓	✓	✓	✓				✓	✓	✓	✓	*	*	*	*	✓	✓		
WBC2	D	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	*	*	*	*	✓	✓		
WBC3	D	✓	✓	✓		✓	✓			✓	✓	✓	✓	*	*	*	*	✓	✓	✓	
EBC1	N	✓	✓			✓	✓			✓	✓			*	*	*	*	✓	✓	✓	
EBC2	N	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	✓	✓		
EBC3	N					✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓		
NBC1	N	✓	✓	✓		✓	✓			✓	✓			*	*	*	*	Protected only			
NBC2	N	Not included in test																			
NBC3	N	✓				✓	✓			✓	✓	✓		✓				Protected only			
SBC1	N					✓	✓	✓						*	*	*	*	Protected only			
SBC2	N					✓	✓							*	*	*	*	Protected only			
SBC3	N	✓				✓	✓							*	*	*	*	Protected only			
WBC1	N	✓	✓	✓						✓	✓	✓		*	*	*	*	✓			
WBC2	N	✓	✓							✓	✓	✓		*	*	*	*	✓			
WBC3	N									✓	✓	✓	✓	*	*	*	*				

* Indicates Insufficient Data

Table C.13 Difference between Loop Detector and Video Detector Turn Off Times (Noblesville, Indiana, April 5th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

		Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
Camera	Time of Day	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D					✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC2	D					✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
EBC3	D					✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
NBC1	D	✓				✓				*	*	*	*	✓				Protected only			
NBC2	D	Not included in test																			
NBC3	D	✓	✓			✓	✓			*	*	*	*	✓	✓	✓		Protected only			
SBC1	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓			Protected only			
SBC2	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		Protected only			
SBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		Protected only			
WBC1	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
WBC2	D	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	✓
WBC3	D	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	✓
EBC1	N	✓				✓				*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC2	N	✓				✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC3	N					✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
NBC1	N					✓	✓			*	*	*	*	✓	✓			Protected only			
NBC2	N	Not included in test																			
NBC3	N	✓				✓	✓			*	*	*	*	✓	✓			Protected only			
SBC1	N	*	*	*	*	✓	✓			*	*	*	*	✓				Protected only			
SBC2	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓				Protected only			
SBC3	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓				Protected only			
WBC1	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
WBC2	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
WBC3	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	

* Indicates Insufficient Data

Appendix D. Results – West Lafayette, Indiana, January 25th, 2005

a) L1V0 Discrepancy Graph Example

b) L0V1 Discrepancy Graph Example

c) Discrepancy in Turn On Times Histogram Example

d) Discrepancy in Turn Off Times Histogram Example

Figure D.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends

a) Precipitation (Inches)

b) Wind Speed (Knots)

Figure D.2 Weather at Purdue University Airport (West Lafayette, IN) During January 25th, 2005 West Lafayette Testing Period

c) Temperature (Fahrenheit)

d) Sky Cover (%)

Figure D.2 (continued): Weather at Purdue University Airport (West Lafayette, IN)
During January 25th, 2005 West Lafayette Testing Period

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure D.3 West Lafayette Northbound Through-Right Movement (Phase 2), 12:00 AM January 25th – 12:00 AM January 26th L1V0 and L0V1 Graphs for Cameras 1 through 4

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure D.4 West Lafayette Northbound Left-Turn Movement (Phase 5), 12:00 AM January 25th – 12:00 AM January 26th L1V0 and L0V1 Graphs for Cameras 1 through 4

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure D.5 West Lafayette Southbound Through-Right Movement (Phase 6),
12:00 AM January 25th – 12:00 AM January 26th L1V0 and L0V1 Graphs for
Cameras 1 through 4

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure D.6 West Lafayette Southbound Left-Turn Movement (Phase 1), 12:00 AM January 25th – 12:00 AM January 26th L1V0 and L0V1 Graphs for Cameras 1 through 4

Figure D.7 West Lafayette Eastbound Through-Right Movement (Phase 4), 12:00 AM January 25th – 12:00 AM January 26th L1V0 and L0V1 Graphs for Cameras 1 through 4

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure D.8 West Lafayette Eastbound Left-Turn Movement (Phase 7), 12:00 AM January 25th – 12:00 AM January 26th L1V0 and L0V1 Graphs for Cameras 1 through 4

Figure D.9 West Lafayette Westbound Through-Right Movement (Phase 8), 12:00 AM January 25th – 12:00 AM January 26th L1V0 and L0V1 Graphs for Cameras 1 through 4

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure D.10 West Lafayette Westbound Left-Turn Movement (Phase 3), 12:00 AM January 25th – 12:00 AM January 26th L1V0 and L0V1 Graphs for Cameras 1 through 4

a) Count of Missed Detections Longer than 5 Seconds

b) Count of False Detections Longer than 5 Seconds

Figure D.11 Tabulation of Discrepancies Longer than 5 Seconds for All Approaches (January 25th, 2005, West Lafayette, Indiana)

a) Count of Missed Detections Longer than 10 Seconds

b) Count of False Detections Longer than 10 Seconds

Figure D.12 Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (January 25th, 2005, West Lafayette, Indiana)

a) Count of Missed Detections Longer than 20 Seconds

b) Count of False Detections Longer than 20 Seconds

Figure D.13 Tabulation of Discrepancies Longer than 20 Seconds for All Approaches (January 25th, 2005, West Lafayette, Indiana)

Table D.1 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (West Lafayette, Indiana, January 25th, 2005)

	Cam1			Cam2			Cam3			Cam4			Loop		
Φ	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1															
2										✓	✓				
3				✓											
4										✓					
5	✓			✓						✓	✓	✓			
6															
7															
8				✓	✓		✓	✓		✓					

a) Missed Detections

	Cam1			Cam2			Cam3			Cam4			Loop		
Φ	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
6	✓			✓	✓	✓	✓	✓		✓	✓	✓			
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			

b) False Detections

✓ - Indicates that detector had a statistically significant larger number of errors than detector used for comparison

Figure D.14 On Time Histograms for Four Cameras. West Lafayette Northbound Through-Right Movement (Phase 2), (January 25th, 2004, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.15 Off Time Histograms for Four Cameras. West Lafayette Northbound Through-Right Movement (Phase 2), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.16 On Time Histograms for Four Cameras. West Lafayette Southbound Through-Right Movement (Phase 6), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.17 Off Time Histograms for Four Cameras. West Lafayette Southbound Through-Right Movement (Phase 6), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.18 On Time Histograms for Four Cameras. West Lafayette Eastbound Through-Right Movement (Phase 4), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.19 Off Time Histograms for Four Cameras. West Lafayette Eastbound Through-Right Movement (Phase 4), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.20 On Time Histograms for Four Cameras. West Lafayette Westbound Through-Right Movement (Phase 8), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1
(Day)

c) Off Time Histogram Camera 2
(Day)

b) Off Time Histogram Camera 1
(Night)

d) Off Time Histogram Camera 2
(Night)

e) Off Time Histogram Camera 3
(Day)

g) Off Time Histogram Camera 4
(Day)

f) Off Time Histogram Camera 3
(Night)

h) Off Time Histogram Camera 4
(Night)

Figure D.21 Off Time Histograms for Four Cameras. West Lafayette Westbound Through-Right Movement (Phase 8), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.22 On Time Histograms for West Lafayette Northbound Camera 1 Through-Right Movement (Phase 2), (January 25th, 2005)

Figure D.23 On Time Histograms for West Lafayette Northbound Camera 4 Through-Right Movement (Phase 2), (January 25th, 2005)

Figure D.24 Off Time Histograms for West Lafayette Northbound Camera 1 Through-Right Movement (Phase 2), (January 25th, 2005)

Figure D.25 Off Time Histograms for West Lafayette Northbound Camera 4 Through-Right Movement (Phase 2), (January 25th, 2005)

Table D.2 Difference between Loop Detector and Video Detector Turn On Times
During Red Through Phase (West Lafayette, Indiana, January 25, 2005, Day
Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	2.0	0.6	2.0	178	2.26	42.4	31.7	20.9	¹	✓	✓	✓	
EBC2	D	2.0	1.7	2.3	163	2.26	15.5	11.7	7.9	0.3	✓	✓	✓	
EBC3	D	1.7	1.1	1.8	165	2.26	18.9	13.3	7.6	¹	✓	✓	✓	
EBC4	D	1.6	1.4	1.7	196	2.26	16.5	11.4	6.3	¹	✓	✓	✓	
NBC1	D	0.4	6.3	1.4	137	2.27	0.7	¹	¹	¹				
NBC2	D	0.5	6.1	1.5	142	2.27	0.9	¹	¹	¹				
NBC3	D	0.8	2.3	1.4	138	2.27	4.3	1.7	¹	¹	✓			
NBC4	D	0.8	7.2	1.9	143	2.27	1.3	0.5	¹	¹				
SBC1	D	1.9	1.4	2.0	148	2.26	17.0	12.6	8.2	¹	✓	✓	✓	
SBC2	D	2.5	3.5	2.4	139	2.27	8.5	6.8	5.1	1.7	✓	✓	✓	
SBC3	D	2.0	0.6	2.0	141	2.27	41.8	31.2	20.5	¹	✓	✓	✓	
SBC4	D	2.3	1.3	2.3	146	2.26	20.7	16.1	11.6	2.5	✓	✓	✓	✓
WBC1	D	1.2	2.5	1.5	152	2.26	5.7	3.3	0.9	¹	✓	✓		
WBC2	D	1.4	3.2	2.0	146	2.26	5.5	3.6	1.7	¹	✓	✓		
WBC3	D	0.5	1.1	0.4	155	2.26	5.9	0.5	¹	¹	✓			
WBC4	D	-0.1	3.9	0.1	159	2.26	0.3	¹	¹	¹				
EBC1	N	0.0	1.5	0.3	177	2.26	0.1	¹	¹	¹				
EBC2	N	-1.1	4.2	0.0	154	2.26	3.3	1.8	0.3	¹	✓			
EBC3	N	-0.9	1.8	-0.5	161	2.26	6.7	3.1	¹	¹	✓	✓		
EBC4	N	-0.1	4.0	0.5	194	2.26	0.3	¹	¹	¹				
NBC1	N	0.0	1.2	0.1	166	2.26	0.1	¹	¹	¹				
NBC2	N	-0.4	2.0	-0.1	162	2.26	2.7	¹	¹	¹	✓			
NBC3	N	-0.6	0.9	-0.4	158	2.26	8.5	1.6	¹	¹	✓			
NBC4	N	1.4	0.7	1.5	174	2.26	26.3	16.8	7.2	¹	✓	✓	✓	
SBC1	N	0.2	0.6	0.3	165	2.26	3.4	¹	¹	¹	✓			
SBC2	N	0.5	0.7	0.5	170	2.26	10.3	0.5	¹	¹	✓			
SBC3	N	0.0	0.8	0.1	165	2.26	0.7	¹	¹	¹				
SBC4	N	2.0	2.1	2.2	174	2.26	12.5	9.3	6.1	¹	✓	✓	✓	
WBC1	N	0.7	0.8	0.6	164	2.26	11.3	3.5	¹	¹	✓	✓		
WBC2	N	0.6	1.9	0.5	169	2.26	3.9	0.5	¹	¹	✓			
WBC3	N	-0.5	2.2	-0.9	169	2.26	3.1	0.2	¹	¹	✓			
WBC4	N	0.5	1.6	0.4	174	2.26	4.1	0.1	¹	¹	✓			

* Indicates Insufficient Data

¹ T Statistic is out of range

Table D.3 Difference between Loop Detector and Video Detector Turn On Times During Green Through Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.5	0.3	0.5	360	2.25	37.4	0.2	1	1	✓			
EBC2	D	0.9	0.3	0.9	303	2.25	51.0	22.3	1	1	✓	✓		
EBC3	D	0.5	0.6	0.6	288	2.25	15.4	0.9	1	1	✓			
EBC4	D	0.5	0.2	0.5	425	2.25	49.4	1.8	1	1	✓			
NBC1	D	0.1	0.2	0.0	405	2.25	5.1	1	1	1	✓			
NBC2	D	0.3	0.3	0.3	384	2.25	15.6	1	1	1	✓			
NBC3	D	0.1	0.3	0.1	319	2.25	6.3	1	1	1	✓			
NBC4	D	0.5	0.3	0.5	455	2.25	37.8	1	1	1	✓			
SBC1	D	0.4	0.2	0.4	253	2.25	28.3	1	1	1	✓			
SBC2	D	0.7	1.0	0.4	71	2.29	6.1	2.0	1	1	✓			
SBC3	D	0.4	0.2	0.4	202	2.26	30.8	1	1	1	✓			
SBC4	D	0.8	0.2	0.8	272	2.25	77.9	26.6	1	1	✓	✓		
WBC1	D	0.6	0.5	0.6	129	2.27	13.5	2.1	1	1	✓			
WBC2	D	2.1	1.3	2.2	21	2.42	7.6	5.8	4.1	0.5	✓	✓	✓	
WBC3	D	0.7	0.4	0.8	68	2.29	13.4	4.0	1	1	✓	✓		
WBC4	D	0.5	0.7	0.6	136	2.27	8.1	1	1	1	✓			
EBC1	N	-0.9	0.5	-0.9	287	2.25	29.1	12.8	1	1	✓	✓		
EBC2	N	-1.3	1.1	-1.0	252	2.25	18.5	11.2	3.9	1	✓	✓	✓	
EBC3	N	-1.5	1.1	-1.3	254	2.25	21.7	14.4	7.1	1	✓	✓	✓	
EBC4	N	-0.4	0.5	-0.3	345	2.25	12.5	1	1	1	✓			
NBC1	N	-0.7	0.4	-0.6	217	2.26	25.1	7.1	1	1	✓	✓		
NBC2	N	-0.9	0.6	-0.8	194	2.26	22.1	9.9	1	1	✓	✓		
NBC3	N	-1.1	0.7	-1.0	194	2.26	22.4	12.3	2.2	1	✓	✓		
NBC4	N	0.3	0.3	0.4	292	2.25	18.3	1	1	1	✓			
SBC1	N	-0.6	0.4	-0.6	87	2.28	14.4	2.3	1	1	✓	✓		
SBC2	N	0.9	0.5	0.9	64	2.30	13.2	5.7	1	1	✓	✓		
SBC3	N	-0.6	0.4	-0.6	76	2.29	12.1	2.4	1	1	✓	✓		
SBC4	N	0.6	0.2	0.6	119	2.27	40.7	8.1	1	1	✓	✓		
WBC1	N	-0.8	0.7	-0.8	117	2.27	13.0	4.9	1	1	✓	✓		
WBC2	N	0.8	0.6	0.8	79	2.29	12.1	4.1	1	1	✓	✓		
WBC3	N	-0.3	0.7	-0.3	93	2.28	5.0	1	1	1	✓			
WBC4	N	-0.3	0.5	-0.3	124	2.27	6.9	1	1	1	✓			

* Indicates Insufficient Data

¹ T Statistic is out of range

Table D.4 Difference between Loop Detector and Video Detector Turn Off Times
During Red Through Phase (West Lafayette, Indiana, January 25, 2005, Day
Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	1.4	1.2	1.3	76	2.29	9.6	6.0	2.5	¹	✓	✓	✓	
EBC2	D	2.4	1.7	2.1	64	2.30	11.4	9.0	6.6	1.8	✓	✓	✓	
EBC3	D	1.7	1.2	1.7	69	2.29	12.2	8.7	5.2	¹	✓	✓	✓	
EBC4	D	0.7	1.1	0.5	93	2.28	6.1	1.6	¹	¹	✓			
NBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	1.2	0.4	1.2	58	2.30	21.4	12.7	3.9	¹	✓	✓	✓	
EBC2	N	1.8	1.3	1.5	35	2.35	7.9	5.7	3.5	¹	✓	✓	✓	
EBC3	N	1.6	0.8	1.4	50	2.31	14.7	10.0	5.3	¹	✓	✓	✓	
EBC4	N	0.9	0.7	0.9	63	2.30	10.7	4.9	¹	¹	✓	✓		
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	0.9	0.3	1.0	44	2.32	20.2	9.3	¹	¹	✓	✓		
WBC2	N	0.2	1.6	0.4	43	2.32	0.8	¹	¹	¹				
WBC3	N	0.5	1.3	0.9	47	2.32	2.7	0.1	¹	¹	✓			
WBC4	N	0.4	0.6	0.5	55	2.31	4.6	¹	¹	¹	✓			

* Indicates Insufficient Data

¹ T Statistic is out of range

Table D.5 Difference between Loop Detector and Video Detector Turn Off Times During Green Through Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.7	0.4	0.6	469	2.25	38.5	9.3	¹	¹	✓	✓		
EBC2	D	1.1	0.5	1.0	406	2.25	49.3	27.5	5.7	¹	✓	✓	✓	
EBC3	D	1.2	0.4	1.2	391	2.25	53.6	31.6	9.5	¹	✓	✓	✓	
EBC4	D	0.1	0.3	0.1	536	2.25	6.1	¹	¹	¹	✓			
NBC1	D	0.4	0.4	0.4	527	2.25	22.5	¹	¹	¹	✓			
NBC2	D	0.7	0.4	0.6	499	2.25	32.9	8.1	¹	¹	✓	✓		
NBC3	D	1.0	0.7	0.9	431	2.25	31.7	15.8	¹	¹	✓	✓		
NBC4	D	0.1	0.4	0.1	588	2.25	7.8	¹	¹	¹	✓			
SBC1	D	0.5	0.4	0.4	390	2.25	23.7	¹	¹	¹	✓			
SBC2	D	0.4	1.3	1.0	214	2.26	4.2	¹	¹	¹	✓			
SBC3	D	1.0	0.5	0.9	335	2.25	34.4	16.3	¹	¹	✓	✓		
SBC4	D	0.4	0.3	0.4	416	2.25	29.7	¹	¹	¹	✓			
WBC1	D	0.3	0.6	0.3	254	2.25	8.2	¹	¹	¹	✓			
WBC2	D	0.6	0.9	0.6	147	2.26	7.6	1.1	¹	¹	✓			
WBC3	D	1.1	1.0	0.9	190	2.26	14.9	7.9	0.8	¹	✓	✓		
WBC4	D	0.1	0.5	0.1	263	2.25	2.6	¹	¹	¹	✓			
EBC1	N	0.6	0.4	0.5	409	2.25	33.3	5.1	¹	¹	✓	✓		
EBC2	N	1.2	1.1	0.9	375	2.25	22.5	13.3	4.1	¹	✓	✓	✓	
EBC3	N	1.2	0.6	1.0	374	2.25	40.2	23.6	7.1	¹	✓	✓	✓	
EBC4	N	0.2	0.6	0.0	476	2.25	6.8	¹	¹	¹	✓			
NBC1	N	0.4	0.4	0.4	373	2.25	21.4	¹	¹	¹	✓			
NBC2	N	0.7	0.5	0.6	350	2.25	23.1	5.6	¹	¹	✓	✓		
NBC3	N	0.8	0.4	0.8	347	2.25	36.6	14.8	¹	¹	✓	✓		
NBC4	N	0.1	0.4	0.1	459	2.25	4.3	¹	¹	¹	✓			
SBC1	N	0.8	0.5	0.8	254	2.25	27.7	10.6	¹	¹	✓	✓		
SBC2	N	1.0	0.6	1.0	235	2.26	24.5	12.6	0.6	¹	✓	✓		
SBC3	N	1.3	0.5	1.3	242	2.26	37.6	22.9	8.2	¹	✓	✓	✓	
SBC4	N	0.4	0.4	0.3	293	2.25	14.3	¹	¹	¹	✓			
WBC1	N	0.4	0.3	0.4	240	2.26	16.6	¹	¹	¹	✓			
WBC2	N	0.4	0.4	0.4	214	2.26	16.7	¹	¹	¹	✓			
WBC3	N	0.7	0.3	0.6	216	2.26	27.6	6.6	¹	¹	✓	✓		
WBC4	N	-0.1	0.7	0.0	250	2.26	1.6	¹	¹	¹				

¹ T Statistic is out of range

Figure D.26 On Time Histograms for Four Cameras. West Lafayette Northbound Left-Turn Movement (Phase 5), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.27 Off Time Histograms for Four Cameras. West Lafayette Northbound Left-Turn Movement (Phase 5), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.28 On Time Histograms for Four Cameras. West Lafayette Southbound Left-Turn Movement (Phase 1), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.29 Off Time Histograms for Four Cameras. West Lafayette Southbound Left-Turn Movement (Phase 1), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) On Time Histogram Camera 1
(Day)

c) On Time Histogram Camera 2
(Day)

b) On Time Histogram Camera 1
(Night)

d) On Time Histogram Camera 2
(Night)

e) On Time Histogram Camera 3
(Day)

g) On Time Histogram Camera 4
(Day)

f) On Time Histogram Camera 3
(Night)

h) On Time Histogram Camera 4
(Night)

Figure D.30 On Time Histograms for Four Cameras. West Lafayette Eastbound Left-Turn Movement (Phase 7), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.31 Off Time Histograms for Four Cameras. West Lafayette Eastbound Left-Turn Movement (Phase 7), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.32 On Time Histograms for Four Cameras. West Lafayette Westbound Left-Turn Movement (Phase 3), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1 (Day)

c) Off Time Histogram Camera 2 (Day)

b) Off Time Histogram Camera 1 (Night)

d) Off Time Histogram Camera 2 (Night)

e) Off Time Histogram Camera 3 (Day)

g) Off Time Histogram Camera 4 (Day)

f) Off Time Histogram Camera 3 (Night)

h) Off Time Histogram Camera 4 (Night)

Figure D.33 Off Time Histograms for Four Cameras. West Lafayette Westbound Left-Turn Movement (Phase 3), (January 25th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure D.34 On Time Histograms for West Lafayette Northbound Camera 1 Left-Turn Movement (Phase 5), (January 25th, 2005)

Figure D.35 On Time Histograms for West Lafayette Northbound Camera 4 Left-Turn Movement (Phase 5), (January 25th, 2005)

Figure D.36 Off Time Histograms for West Lafayette Northbound Camera 1 Left-Turn Movement (Phase 5), (January 25th, 2005)

Figure D.37 Off Time Histograms for West Lafayette Northbound Camera 4 Left-Turn Movement (Phase 5), (January 25th, 2005)

Table D.6 Difference between Loop Detector and Video Detector Turn On Times During Red Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.9	4.7	2.0	122	2.27	2.2	1.0	¹	¹				
EBC2	D	1.4	3.8	2.3	121	2.27	4.1	2.7	1.2	¹	✓	✓		
EBC3	D	0.2	6.2	1.7	119	2.27	0.4	¹	¹	¹				
EBC4	D	0.7	5.0	1.4	119	2.27	1.5	0.4	¹	¹				
NBC1	D	1.1	3.7	1.9	111	2.27	3.2	1.8	0.4	¹	✓			
NBC2	D	0.1	9.0	2.2	111	2.27	0.2	¹	¹	¹				
NBC3	D	1.5	5.5	2.0	105	2.27	2.8	1.9	0.9	¹	✓			
NBC4	D	0.3	9.0	1.9	106	2.27	0.4	¹	¹	¹				
SBC1	D	-3.4	10.1	1.8	96	2.28	3.3	2.8	2.4	1.4	✓	✓	✓	
SBC2	D	1.3	7.4	2.8	83	2.28	1.6	0.9	0.3	¹				
SBC3	D	-3.6	10.6	1.8	97	2.28	3.4	2.9	2.5	1.5	✓	✓	✓	
SBC4	D	1.4	5.2	2.0	85	2.28	2.5	1.7	0.8	¹	✓			
WBC1	D	2.8	6.4	3.7	81	2.28	3.9	3.2	2.5	1.1	✓	✓	✓	
WBC2	D	3.5	3.0	3.8	81	2.28	10.6	9.1	7.6	4.6	✓	✓	✓	✓
WBC3	D	2.5	1.7	2.8	81	2.28	12.9	10.3	7.7	2.5	✓	✓	✓	✓
WBC4	D	1.3	8.0	2.6	83	2.28	1.5	0.9	0.4	¹				
EBC1	N	0.5	1.0	0.6	110	2.27	4.8	¹	¹	¹	✓			
EBC2	N	1.7	0.4	1.8	115	2.27	45.8	32.4	19.0	¹	✓	✓	✓	
EBC3	N	-0.1	0.6	-0.1	107	2.27	1.3	¹	¹	¹				
EBC4	N	0.8	0.3	0.8	114	2.27	25.9	9.5	¹	¹	✓	✓		
NBC1	N	-0.7	3.4	0.1	140	2.27	2.6	0.8	¹	¹	✓			
NBC2	N	0.7	0.7	0.8	137	2.27	11.6	3.8	¹	¹	✓	✓		
NBC3	N	-0.4	1.2	-0.4	133	2.27	3.4	¹	¹	¹	✓			
NBC4	N	1.6	0.6	1.8	134	2.27	34.2	23.8	13.4	¹	✓	✓	✓	
SBC1	N	0.7	1.0	0.6	78	2.29	5.6	1.3	¹	¹	✓			
SBC2	N	1.9	0.5	1.8	77	2.29	35.6	26.1	16.7	¹	✓	✓	✓	
SBC3	N	0.7	0.8	0.8	77	2.29	7.6	2.2	¹	¹	✓			
SBC4	N	1.7	2.8	1.8	80	2.28	5.4	3.8	2.2	¹	✓	✓		
WBC1	N	-2.3	14.6	1.8	45	2.32	1.0	0.8	0.6	0.1				
WBC2	N	3.0	3.5	2.3	41	2.33	5.5	4.6	3.7	1.8	✓	✓	✓	
WBC3	N	-0.2	2.3	0.0	45	2.32	0.6	¹	¹	¹				
WBC4	N	-0.2	7.0	1.3	43	2.32	0.2	¹	¹	¹				

¹ T Statistic is out of range

Table D.7 Difference between Loop Detector and Video Detector Turn On Times During Protected Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.5	0.2	0.5	47	2.32	14.0	¹	1	1	✓			
EBC2	D	0.8	0.2	0.8	36	2.34	29.7	10.6	1	1	✓	✓		
EBC3	D	0.5	0.3	0.5	36	2.34	10.4	¹	1	1	✓			
EBC4	D	0.4	0.2	0.4	57	2.30	14.9	1	1	1	✓			
NBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	D	0.7	0.2	0.6	31	2.36	16.7	5.5	1	1	✓	✓		
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	-0.5	0.5	-0.5	49	2.31	7.3	1	1	1	✓			
EBC2	N	0.5	0.3	0.5	50	2.31	9.6	1	1	1	✓			
EBC3	N	-1.0	0.6	-1.0	43	2.32	10.9	5.6	0.3	1	✓	✓		
EBC4	N	0.0	0.2	0.0	58	2.30	0.9	¹	1	1				
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	-0.3	0.4	-0.3	31	2.36	4.0	1	1	1	✓			
NBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	N	0.5	0.2	0.5	35	2.35	13.2	1	1	1	✓			
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*

* Indicates Insufficient Data

¹ T Statistic is out of range

Table D.8 Difference between Loop Detector and Video Detector Turn On Times During Permitted Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.5	0.4	0.5	128	2.27	13.5	0.1	¹	¹	✓			
EBC2	D	0.9	0.2	0.9	128	2.27	44.8	19.1	¹	¹	✓	✓		
EBC3	D	0.4	0.7	0.4	113	2.27	5.3	¹	¹	¹	✓			
EBC4	D	0.4	0.3	0.4	145	2.27	17.6	¹	¹	¹	✓			
NBC1	D	0.4	0.4	0.3	146	2.26	13.1	¹	¹	¹	✓			
NBC2	D	0.7	0.5	0.6	144	2.27	16.2	4.3	¹	¹	✓	✓		
NBC3	D	0.6	0.3	0.5	121	2.27	18.7	2.8	¹	¹	✓	✓		
NBC4	D	0.9	1.0	0.8	142	2.27	10.5	4.7	¹	¹	✓	✓		
SBC1	D	0.3	0.9	0.5	62	2.30	2.9	¹	¹	¹	✓			
SBC2	D	1.9	1.6	2.6	40	2.33	7.7	5.7	3.8	¹	✓	✓	✓	
SBC3	D	0.2	0.9	0.5	63	2.30	1.8	¹	¹	¹				
SBC4	D	0.5	1.7	0.8	64	2.30	2.5	0.1	¹	¹	✓			
WBC1	D	0.9	0.4	0.9	39	2.33	16.8	7.9	¹	¹	✓	✓		
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	D	1.2	0.4	1.3	36	2.34	17.4	10.4	3.4	¹	✓	✓	✓	
EBC1	N	-0.6	0.4	-0.6	142	2.27	16.4	3.1	¹	¹	✓	✓		
EBC2	N	0.4	0.3	0.5	151	2.26	21.0	¹	¹	¹	✓			
EBC3	N	-1.1	0.5	-1.0	134	2.27	23.6	12.6	1.6	¹	✓	✓		
EBC4	N	0.0	0.2	0.0	167	2.26	0.0	¹	¹	¹				
NBC1	N	-0.9	0.5	-0.8	87	2.28	17.6	8.0	¹	¹	✓	✓		
NBC2	N	-0.3	0.4	-0.4	90	2.28	8.3	¹	¹	¹	✓			
NBC3	N	-1.1	0.7	-1.0	84	2.28	15.7	8.8	2.0	¹	✓	✓		
NBC4	N	0.5	0.2	0.5	107	2.27	27.9	1.8	¹	¹	✓			
SBC1	N	-0.9	0.6	-0.9	30	2.36	8.0	3.5	¹	¹	✓	✓		
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	-0.8	0.6	-0.8	30	2.36	7.3	2.9	¹	¹	✓	✓		
SBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*

¹ T Statistic is out of range

* Indicates Insufficient Data

Table D.9 Difference between Loop Detector and Video Detector Turn Off Times
During Red Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day
Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*

* Indicates Insufficient Data

¹ T Statistic is out of range

Table D.10 Difference between Loop Detector and Video Detector Turn Off Times During Protected Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.8	0.5	0.8	161	2.26	18.5	6.8	¹	¹	✓	✓		
EBC2	D	1.3	0.5	1.3	148	2.26	35.3	22.0	8.6	¹	✓	✓	✓	
EBC3	D	1.3	0.5	1.2	151	2.26	29.1	17.7	6.3	¹	✓	✓	✓	
EBC4	D	0.3	0.6	0.3	174	2.26	7.2	¹	¹	¹	✓			
NBC1	D	1.0	0.5	1.0	132	2.27	24.1	11.9	¹	¹	✓	✓		
NBC2	D	1.3	0.4	1.3	124	2.27	34.5	21.3	8.2	¹	✓	✓	✓	
NBC3	D	1.8	0.6	1.8	123	2.27	32.3	23.3	14.4	¹	✓	✓	✓	
NBC4	D	0.5	0.5	0.4	137	2.27	12.1	¹	¹	¹	✓			
SBC1	D	1.1	1.4	0.9	78	2.29	6.5	3.5	0.4	¹	✓	✓		
SBC2	D	0.9	1.2	1.0	57	2.30	5.5	2.4	¹	¹	✓	✓		
SBC3	D	1.4	1.3	1.4	75	2.29	9.1	5.9	2.6	¹	✓	✓	✓	
SBC4	D	0.9	1.2	1.0	79	2.29	7.1	3.3	¹	¹	✓	✓		
WBC1	D	0.8	0.7	0.9	63	2.30	8.8	3.3	¹	¹	✓	✓		
WBC2	D	1.0	0.9	0.9	56	2.30	8.5	4.3	0.2	¹	✓	✓		
WBC3	D	1.4	0.9	1.2	55	2.31	12.1	7.8	3.5	¹	✓	✓	✓	
WBC4	D	0.9	0.6	0.9	63	2.30	11.1	4.7	¹	¹	✓	✓		
EBC1	N	0.5	0.4	0.5	157	2.26	14.1	¹	¹	¹	✓			
EBC2	N	0.8	0.5	0.9	159	2.26	22.2	8.8	¹	¹	✓	✓		
EBC3	N	1.0	0.4	1.0	150	2.26	31.3	16.4	1.5	¹	✓	✓		
EBC4	N	0.1	0.5	0.0	174	2.26	2.3	¹	¹	¹	✓			
NBC1	N	0.5	0.5	0.5	144	2.27	11.9	0.1	¹	¹	✓			
NBC2	N	0.8	0.4	0.8	150	2.26	25.8	9.9	¹	¹	✓	✓		
NBC3	N	1.1	0.4	1.0	140	2.27	31.9	17.1	2.2	¹	✓	✓		
NBC4	N	0.2	0.7	0.4	159	2.26	3.8	¹	¹	¹	✓			
SBC1	N	0.7	0.5	0.8	58	2.30	9.6	2.4	¹	¹	✓	✓		
SBC2	N	0.6	0.2	0.6	58	2.30	20.1	3.0	¹	¹	✓	✓		
SBC3	N	1.2	0.4	1.3	58	2.30	23.2	13.8	4.3	¹	✓	✓	✓	
SBC4	N	0.7	0.4	0.8	61	2.30	14.4	4.1	¹	¹	✓	✓		
WBC1	N	0.5	0.4	0.5	33	2.35	6.1	¹	¹	¹	✓			
WBC2	N	0.4	0.5	0.5	33	2.35	5.1	¹	¹	¹	✓			
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	0.5	0.4	0.5	32	2.36	6.7	¹	¹	¹	✓			

¹ T Statistic is out of range

Table D.11 Difference between Loop Detector and Video Detector Turn Off Times During Permitted Left-Turn Phase (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	1.6	1.7	1.2	126	2.27	10.3	7.1	3.9	¹	✓	✓	✓	
EBC2	D	2.0	1.7	1.5	124	2.27	13.3	9.9	6.6	¹	✓	✓	✓	
EBC3	D	3.1	2.9	1.9	104	2.27	10.9	9.1	7.3	3.8	✓	✓	✓	✓
EBC4	D	0.2	0.5	0.3	142	2.27	5.1	¹	¹	¹	✓			
NBC1	D	1.0	2.1	0.6	152	2.26	5.8	2.9	¹	¹	✓	✓		
NBC2	D	1.2	2.1	1.0	145	2.27	7.0	4.1	1.3	¹	✓	✓		
NBC3	D	3.3	2.9	2.0	111	2.27	12.1	10.3	8.5	4.8	✓	✓	✓	✓
NBC4	D	0.5	3.6	0.3	135	2.27	1.6	¹	¹	¹				
SBC1	D	3.2	3.7	1.8	83	2.28	7.8	6.6	5.3	2.9	✓	✓	✓	✓
SBC2	D	2.2	2.3	1.4	59	2.30	7.2	5.6	3.9	0.7	✓	✓	✓	
SBC3	D	3.6	3.3	2.6	77	2.29	9.5	8.2	6.9	4.2	✓	✓	✓	✓
SBC4	D	2.2	2.5	1.3	79	2.29	7.7	6.0	4.2	0.7	✓	✓	✓	
WBC1	D	2.2	3.0	1.2	66	2.29	6.1	4.7	3.3	0.6	✓	✓	✓	
WBC2	D	2.2	2.7	1.3	49	2.31	5.5	4.2	3.0	0.4	✓	✓	✓	
WBC3	D	3.0	3.0	1.7	54	2.31	7.4	6.2	5.0	2.6	✓	✓	✓	✓
WBC4	D	1.8	2.1	0.9	65	2.30	6.9	5.0	3.1	¹	✓	✓	✓	
EBC1	N	0.8	1.2	0.6	150	2.26	8.5	3.4	¹	¹	✓	✓		
EBC2	N	1.1	1.2	0.9	150	2.26	10.7	5.7	0.8	¹	✓	✓		
EBC3	N	2.1	2.3	1.4	135	2.27	10.4	7.9	5.4	0.4	✓	✓	✓	
EBC4	N	-0.2	0.8	-0.1	170	2.26	3.0	¹	¹	¹	✓			
NBC1	N	0.9	1.2	0.6	107	2.27	7.9	3.6	¹	¹	✓	✓		
NBC2	N	0.9	1.3	0.8	110	2.27	7.4	3.3	¹	¹	✓	✓		
NBC3	N	2.6	2.0	2.0	95	2.28	12.5	10.1	7.7	2.9	✓	✓	✓	✓
NBC4	N	0.1	0.8	0.1	126	2.27	2.0	¹	¹	¹				
SBC1	N	0.9	0.9	0.8	50	2.31	7.1	3.2	¹	¹	✓	✓		
SBC2	N	0.7	0.3	0.6	48	2.32	14.5	3.7	¹	¹	✓	✓		
SBC3	N	2.4	3.1	1.7	47	2.32	5.4	4.3	3.2	1.0	✓	✓	✓	
SBC4	N	1.2	1.7	0.9	47	2.32	4.8	2.9	0.9	¹	✓	✓		
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*

* Indicates Insufficient Data

¹ T Statistic is out of range

Table D.12 Difference between Loop Detector and Video Detector Turn On Times (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓		✓								✓				✓			
EBC2	D	✓	✓	✓		✓	✓			✓	✓			✓	✓			✓	✓		
EBC3	D	✓	✓	✓		✓								✓				✓			
EBC4	D	✓	✓	✓		✓								✓				✓			
NBC1	D					✓				✓				*	*	*	*	✓			
NBC2	D					✓								*	*	*	*	✓	✓		
NBC3	D	✓				✓				✓				*	*	*	*	✓	✓		
NBC4	D					✓								✓	✓			✓			
SBC1	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	✓			
SBC2	D	✓	✓	✓		✓								*	*	*	*	✓	✓	✓	
SBC3	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*				
SBC4	D	✓	✓	✓	✓	✓	✓			✓				*	*	*	*	✓			
WBC1	D	✓	✓			✓				✓	✓	✓		*	*	*	*	✓	✓		
WBC2	D	✓	✓			✓	✓	✓		✓	✓	✓	✓	*	*	*	*	*	*	*	*
WBC3	D	✓				✓	✓			✓	✓	✓	✓	*	*	*	*	*	*	*	*
WBC4	D					✓								*	*	*	*	✓	✓	✓	
EBC1	N					✓	✓			✓				✓				✓	✓		
EBC2	N	✓				✓	✓	✓		✓	✓	✓		✓				✓			
EBC3	N	✓	✓			✓	✓	✓						✓	✓			✓	✓		
EBC4	N					✓				✓	✓										
NBC1	N					✓	✓			✓				*	*	*	*	✓	✓		
NBC2	N	✓				✓	✓			✓	✓			✓				✓			
NBC3	N	✓				✓	✓			✓				*	*	*	*	✓	✓		
NBC4	N	✓	✓	✓		✓				✓	✓	✓		✓				✓			
SBC1	N	✓				✓	✓			✓				*	*	*	*	✓	✓		
SBC2	N	✓				✓	✓			✓	✓	✓		*	*	*	*	*	*	*	*
SBC3	N					✓	✓			✓				*	*	*	*	✓	✓		
SBC4	N	✓	✓	✓		✓	✓			✓	✓			*	*	*	*	*	*	*	*
WBC1	N	✓	✓			✓	✓							*	*	*	*	*	*	*	*
WBC2	N	✓				✓	✓			✓	✓	✓		*	*	*	*	*	*	*	*
WBC3	N	✓				✓								*	*	*	*	*	*	*	*
WBC4	N	✓				✓								*	*	*	*	*	*	*	*

* Indicates Insufficient Data

Table D.13 Difference between Loop Detector and Video Detector Turn Off Times (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓		✓	✓			*	*	*	*	✓	✓			✓	✓	✓	
EBC2	D	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC3	D	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	✓
EBC4	D	✓				✓				*	*	*	*	✓				✓			
NBC1	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓		
NBC2	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓		
NBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
NBC4	D	*	*	*	*	✓				*	*	*	*	✓							
SBC1	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	✓
SBC2	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
SBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
SBC4	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
WBC1	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
WBC2	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
WBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	✓
WBC4	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
EBC1	N	✓	✓	✓		✓	✓			*	*	*	*	✓				✓	✓		
EBC2	N	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓			✓	✓		
EBC3	N	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓			✓	✓	✓	
EBC4	N	✓	✓			✓				*	*	*	*	✓				✓			
NBC1	N	*	*	*	*	✓				*	*	*	*	✓				✓	✓		
NBC2	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓		
NBC3	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓	✓	✓
NBC4	N	*	*	*	*	✓				*	*	*	*	✓							
SBC1	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓		
SBC2	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓		
SBC3	N	*	*	*	*	✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
SBC4	N	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓		
WBC1	N	✓	✓			✓				*	*	*	*	✓				*	*	*	*
WBC2	N					✓				*	*	*	*	✓				*	*	*	*
WBC3	N	✓				✓	✓			*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	✓								*	*	*	*	✓				*	*	*	*

* Indicates Insufficient Data

Table D.14 Chi-Squared Goodness of Fit Test between Day and Night On-Time Histograms (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	On-Times			
	Northbound	Southbound	Eastbound	Westbound
Cam1	2825.8	144.2	9438.7	734.5
Cam2	4531.2	212.2	6688.6	112.6
Cam3	2749.2	525.0	6880.7	781.6
Cam4	638.7	216.1	3264.0	376.9

Table D.15 Chi-Squared Goodness of Fit Test between Day and Night Off-Time Histograms (West Lafayette, Indiana, January 25, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Off-Times			
	Northbound	Southbound	Eastbound	Westbound
Cam1	28.9	359.8	64.4	153.5
Cam2	116.9	274.2	121.5	707.9
Cam3	164.6	165.5	140.2	135.1
Cam4	162.9	671.2	266.1	95.1

Appendix E. Results – West Lafayette, Indiana, January 20th, 2005

a) L1V0 Discrepancy Graph Example

b) L0V1 Discrepancy Graph Example

c) Discrepancy in Turn On Times Histogram Example

d) Discrepancy in Turn Off Times Histogram Example

Figure E.1 Example L1V0, L0V1 graphs and On-Time, Off Time Histograms with Legends

a) Precipitation (Inches)

b) Wind Speed (Knots)

Figure E.2 Weather at Purdue University Airport (West Lafayette, IN) During January 20th, 2005 West Lafayette Testing Period

c) Temperature (Fahrenheit)

d) Sky Cover (%)

Figure E.2 (continued): Weather at Purdue University Airport (West Lafayette, IN)
During January 20th, 2005 West Lafayette Testing Period

Figure E.3 West Lafayette Northbound Through-Right Movement (Phase 2), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure E.4 West Lafayette Northbound Left-Turn Movement (Phase 5), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4

Not Included in Test

a) L1V0 Camera 4

Not Included in Test

c) L1V0 Camera 3

Not Included in Test

e) L1V0 Camera 2

Not Included in Test

g) L1V0 Camera 1

Not Included in Test

b) L0V1 Camera 4

Not Included in Test

d) L0V1 Camera 3

Not Included in Test

f) L0V1 Camera 2

Not Included in Test

h) L0V1 Camera 1

Figure E.5 West Lafayette Southbound Through-Right Movement (Phase 6),
12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for
Cameras 1 through 4

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure E.6 West Lafayette Southbound Left-Turn Movement (Phase 1), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4

Figure E.7 West Lafayette Eastbound Through-Right Movement (Phase 4), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure E.8 West Lafayette Eastbound Left-Turn Movement (Phase 7), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4

Figure E.9 West Lafayette Westbound Through-Right Movement (Phase 8), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4

a) L1V0 Camera 4

b) L0V1 Camera 4

c) L1V0 Camera 3

d) L0V1 Camera 3

e) L1V0 Camera 2

f) L0V1 Camera 2

g) L1V0 Camera 1

h) L0V1 Camera 1

Figure E.10 West Lafayette Westbound Left-Turn Movement (Phase 3), 12:00 AM January 20th – 12:00 AM January 21st L1V0 and L0V1 Graphs for Cameras 1 through 4

a) Count of Missed Detections Longer than 5 Seconds

b) Count of False Detections Longer than 5 Seconds

Figure E.11: Tabulation of Discrepancies Longer than 5 Seconds for All Approaches (January 20, 2005, West Lafayette, Indiana)

a) Count of Missed Detections Longer than 10 Seconds

b) Count of False Detections Longer than 10 Seconds

Figure E.12: Tabulation of Discrepancies Longer than 10 Seconds for All Approaches (January 20, 2005, West Lafayette, Indiana)

a) Count of Missed Detections Longer than 20 Seconds

b) Count of False Detections Longer than 20 Seconds

Figure E.13: Tabulation of Discrepancies Longer than 20 Seconds for All Approaches (January 20, 2005, West Lafayette, Indiana)

Table E.1 Table of Statistically Significant Difference between Number of Missed Detections and False Detections between Loop Detector and Video Detector (West Lafayette, Indiana, January 20, 2005)

	Cam1			Cam2			Cam3			Cam4			Loop		
Φ	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1										✓					
2															
3				✓	✓										
4															
5										✓	✓				
6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	✓			✓	✓		✓			✓					
8				✓	✓	✓	✓								

a) Missed Detections

	Cam1			Cam2			Cam3			Cam4			Loop		
Φ	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s	5s	10s	20s
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
3	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
8	✓			✓	✓		✓	✓		✓					

b) False Detections

✓ - Indicates that detector had a statistically significant larger number of errors than detector used for comparison

Figure E.14 On Time Histograms for Four Cameras. West Lafayette Northbound Through-Right Movement (Phase 2), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.15 Off Time Histograms for Four Cameras. West Lafayette Northbound Through-Right Movement (Phase 2), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Not Included in Test	Not Included in Test
a) On Time Histogram Camera 1 (Day)	c) On Time Histogram Camera 2 (Day)
Not Included in Test	Not Included in Test
b) On Time Histogram Camera 1 (Night)	d) On Time Histogram Camera 2 (Night)
Not Included in Test	Not Included in Test
e) On Time Histogram Camera 3 (Day)	g) On Time Histogram Camera 4 (Day)
Not Included in Test	Not Included in Test
f) On Time Histogram Camera 3 (Night)	h) On Time Histogram Camera 4 (Night)

Figure E.16 On Time Histograms for Four Cameras. West Lafayette Southbound Through-Right Movement (Phase 6), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Not Included in Test	Not Included in Test
a) Off Time Histogram Camera 1 (Day)	c) Off Time Histogram Camera 2 (Day)
Not Included in Test	Not Included in Test
b) Off Time Histogram Camera 1 (Night)	d) Off Time Histogram Camera 2 (Night)
Not Included in Test	Not Included in Test
e) Off Time Histogram Camera 3 (Day)	g) Off Time Histogram Camera 4 (Day)
Not Included in Test	Not Included in Test
f) Off Time Histogram Camera 3 (Night)	h) Off Time Histogram Camera 4 (Night)

Figure E.17 Off Time Histograms for Four Cameras. West Lafayette Southbound Through-Right Movement (Phase 6), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.18 On Time Histograms for Four Cameras. West Lafayette Eastbound Through-Right Movement (Phase 4), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.19 Off Time Histograms for Four Cameras. West Lafayette Eastbound Through-Right Movement (Phase 4), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.20 On Time Histograms for Four Cameras. West Lafayette Westbound Through-Right Movement (Phase 8), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1
(Day)

c) Off Time Histogram Camera 2
(Day)

b) Off Time Histogram Camera 1
(Night)

d) Off Time Histogram Camera 2
(Night)

e) Off Time Histogram Camera 3
(Day)

g) Off Time Histogram Camera 4
(Day)

f) Off Time Histogram Camera 3
(Night)

h) Off Time Histogram Camera 4
(Night)

Figure E.21 Off Time Histograms for Four Cameras. West Lafayette Westbound Through-Right Movement (Phase 8), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.22 On Time Histograms for West Lafayette Northbound Camera 1 Through-Right Movement (Phase 2), (January 20th, 2005)

Figure E.23 Off Time Histograms for West Lafayette Northbound Camera 1 Through-Right Movement (Phase 2), (January 20th, 2005)

Table E.2 Difference between Loop Detector and Video Detector Turn On Times
During Red Through Phase (West Lafayette, Indiana, January 20, 2005, Day
Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	1.9	0.4	1.9	190	2.26	62.9	46.3	29.8	¹	✓	✓	✓	
EBC2	D	2.1	0.8	2.3	170	2.26	36.3	27.7	19.1	1.9	✓	✓	✓	
EBC3	D	1.8	1.0	2.0	174	2.26	22.6	16.2	9.7	¹	✓	✓	✓	
EBC4	D	1.5	0.5	1.4	220	2.26	44.9	29.5	14.0	¹	✓	✓	✓	
NBC1	D	1.4	0.4	1.4	150	2.26	40.4	26.3	12.2	¹	✓	✓	✓	
NBC2	D	1.3	0.6	1.4	149	2.26	26.9	16.9	6.9	¹	✓	✓	✓	
NBC3	D	1.3	0.5	1.3	145	2.27	34.8	21.8	8.8	¹	✓	✓	✓	
NBC4	D	1.8	0.3	1.7	152	2.26	81.6	58.7	35.8	¹	✓	✓	✓	
SBC1	D	Not included in test.												
SBC2	D	Not included in test.												
SBC3	D	Not included in test.												
SBC4	D	Not included in test.												
WBC1	D	1.2	0.7	1.2	150	2.26	21.7	12.3	2.8	¹	✓	✓	✓	
WBC2	D	1.9	1.5	1.8	159	2.26	16.1	11.8	7.6	¹	✓	✓	✓	
WBC3	D	0.8	0.9	1.0	163	2.26	11.5	4.7	¹	¹	✓	✓		
WBC4	D	0.3	2.0	0.0	155	2.26	1.9	¹	¹	¹				
EBC1	N	-0.4	2.1	0.0	157	2.26	2.5	¹	¹	¹	✓			
EBC2	N	-0.5	2.8	0.1	157	2.26	2.0	¹	¹	¹				
EBC3	N	-2.2	3.7	-1.4	142	2.27	7.0	5.4	3.8	0.5	✓	✓	✓	
EBC4	N	0.7	1.0	0.8	182	2.26	9.4	2.9	¹	¹	✓	✓		
NBC1	N	-2.8	7.0	-0.4	148	2.26	4.9	4.0	3.1	1.4	✓	✓	✓	
NBC2	N	-2.1	3.9	-1.0	144	2.27	6.6	5.0	3.5	0.4	✓	✓	✓	
NBC3	N	-3.5	6.5	-1.3	144	2.27	6.5	5.5	4.6	2.8	✓	✓	✓	✓
NBC4	N	1.0	3.8	1.5	169	2.26	3.2	1.5	¹	¹	✓			
SBC1	N	Not included in test.												
SBC2	N	Not included in test.												
SBC3	N	Not included in test.												
SBC4	N	Not included in test.												
WBC1	N	0.9	2.0	1.1	146	2.26	5.5	2.4	¹	¹	✓	✓		
WBC2	N	0.8	1.4	0.8	145	2.27	6.7	2.3	¹	¹	✓	✓		
WBC3	N	-1.3	1.4	-1.3	145	2.27	11.6	7.3	3.0	¹	✓	✓	✓	
WBC4	N	0.6	2.2	0.8	151	2.26	3.1	0.3	¹	¹	✓			

¹ T Statistic is out of range

Table E.3 Difference between Loop Detector and Video Detector Turn On Times During Green Through Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.4	0.2	0.4	319	2.25	30.0	¹	¹	¹	✓			
EBC2	D	0.8	0.3	0.8	272	2.25	44.5	15.1	¹	¹	✓	✓		
EBC3	D	0.5	0.6	0.6	256	2.25	15.5	1.0	¹	¹	✓			
EBC4	D	0.4	0.2	0.4	381	2.25	44.3	¹	¹	¹	✓			
NBC1	D	0.1	0.2	0.0	377	2.25	6.7	¹	¹	¹	✓			
NBC2	D	0.1	0.2	0.1	357	2.25	10.2	¹	¹	¹	✓			
NBC3	D	0.1	0.2	0.1	325	2.25	9.2	¹	¹	¹	✓			
NBC4	D	0.5	0.1	0.5	437	2.25	72.7	¹	¹	¹	✓			
SBC1	D	Not included in test.												
SBC2	D	Not included in test.												
SBC3	D	Not included in test.												
SBC4	D	Not included in test.												
WBC1	D	0.5	0.3	0.5	114	2.27	22.5	1.2	¹	¹	✓			
WBC2	D	1.2	1.1	1.2	18	2.46	4.6	2.7	0.7	¹	✓	✓		
WBC3	D	0.5	0.5	0.5	70	2.29	8.3	0.3	¹	¹	✓			
WBC4	D	0.7	0.4	0.6	133	2.27	18.5	4.6	¹	¹	✓	✓		
EBC1	N	-1.1	0.8	-1.2	272	2.25	23.4	13.0	2.5	¹	✓	✓	✓	
EBC2	N	-1.1	0.8	-1.0	264	2.25	22.1	12.5	2.8	¹	✓	✓	✓	
EBC3	N	-2.2	1.3	-2.3	221	2.26	25.2	19.4	13.6	2.1	✓	✓	✓	
EBC4	N	-0.1	0.6	-0.1	345	2.25	4.2	¹	¹	¹	✓			
NBC1	N	-1.0	0.7	-0.9	184	2.26	19.9	9.9	¹	¹	✓	✓		
NBC2	N	-1.5	1.0	-1.3	158	2.26	18.6	12.4	6.1	¹	✓	✓	✓	
NBC3	N	-1.4	0.9	-1.3	143	2.27	19.1	12.1	5.1	¹	✓	✓	✓	
NBC4	N	0.3	0.3	0.4	297	2.25	16.9	¹	¹	¹	✓			
SBC1	N	Not included in test.												
SBC2	N	Not included in test.												
SBC3	N	Not included in test.												
SBC4	N	Not included in test.												
WBC1	N	-0.8	0.9	-0.8	105	2.27	9.2	3.4	¹	¹	✓	✓		
WBC2	N	0.8	0.9	0.9	80	2.28	7.9	3.0	¹	¹	✓	✓		
WBC3	N	-0.9	1.4	-0.6	81	2.28	5.8	2.6	¹	¹	✓	✓		
WBC4	N	-0.1	0.8	-0.1	120	2.27	1.2	¹	¹	¹				

¹ T Statistic is out of range

Table E.4 Difference between Loop Detector and Video Detector Turn Off Times
During Red Through Phase (West Lafayette, Indiana, January 20, 2005, Day
Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	1.1	0.9	1.2	86	2.28	11.8	6.5	1.2	¹	✓	✓		
EBC2	D	1.9	1.0	1.8	65	2.30	15.1	11.1	7.1	¹	✓	✓	✓	
EBC3	D	1.5	0.9	1.5	71	2.29	13.2	8.8	4.3	¹	✓	✓	✓	
EBC4	D	0.5	0.7	0.4	113	2.27	7.6	0.4	¹	¹	✓			
NBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	D	Not included in test.												
SBC2	D	Not included in test.												
SBC3	D	Not included in test.												
SBC4	D	Not included in test.												
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	2.1	2.8	1.5	56	2.30	5.5	4.2	2.8	0.2	✓	✓	✓	
EBC2	N	2.3	1.2	1.9	56	2.30	14.0	11.0	7.9	1.8	✓	✓	✓	
EBC3	N	2.2	1.4	1.8	51	2.31	11.1	8.6	6.1	1.1	✓	✓	✓	
EBC4	N	1.6	1.5	1.3	66	2.29	8.7	5.9	3.1	¹	✓	✓	✓	
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	N	Not included in test.												
SBC2	N	Not included in test.												
SBC3	N	Not included in test.												
SBC4	N	Not included in test.												
WBC1	N	1.3	1.1	1.2	31	2.36	6.7	4.2	1.7	¹	✓	✓		
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	1.3	1.0	1.2	31	2.36	7.1	4.3	1.5	¹	✓	✓		
WBC4	N	0.8	0.9	0.6	36	2.34	5.1	1.9	¹	¹	✓			

¹ T Statistic is out of range

* Indicates Insufficient Data

Table E.5 Difference between Loop Detector and Video Detector Turn Off Times During Green Through Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.6	0.5	0.5	425	2.25	26.8	4.7	¹	¹	✓	✓		
EBC2	D	1.1	0.5	1.0	374	2.25	38.5	20.8	3.2	¹	✓	✓	✓	
EBC3	D	1.2	0.5	1.2	355	2.25	42.6	25.1	7.6	¹	✓	✓	✓	
EBC4	D	0.0	0.5	0.0	493	2.25	0.1	¹	¹	¹				
NBC1	D	0.3	0.4	0.3	511	2.25	19.7	¹	¹	¹	✓			
NBC2	D	0.3	0.4	0.3	511	2.25	19.7	¹	¹	¹	✓			
NBC3	D	0.5	0.4	0.5	488	2.25	26.0	0.4	¹	¹	✓			
NBC4	D	0.8	0.5	0.8	451	2.25	36.9	13.4	¹	¹	✓	✓		
SBC1	D	Not included in test.												
SBC2	D	Not included in test.												
SBC3	D	Not included in test.												
SBC4	D	Not included in test.												
WBC1	D	0.4	0.5	0.4	237	2.26	13.6	¹	¹	¹	✓			
WBC2	D	0.6	0.7	0.6	159	2.26	12.2	2.7	¹	¹	✓	✓		
WBC3	D	0.8	0.6	0.8	204	2.26	18.7	7.5	¹	¹	✓	✓		
WBC4	D	0.1	0.4	0.0	258	2.25	2.8	¹	¹	¹	✓			
EBC1	N	0.6	0.9	0.6	389	2.25	13.0	1.4	¹	¹	✓			
EBC2	N	0.9	1.0	0.9	379	2.25	18.6	8.7	¹	¹	✓	✓		
EBC3	N	1.1	0.9	1.0	335	2.25	20.8	11.1	1.3	¹	✓	✓		
EBC4	N	0.2	0.8	0.1	464	2.25	5.0	¹	¹	¹	✓			
NBC1	N	0.6	0.7	0.5	336	2.25	15.0	1.5	¹	¹	✓			
NBC2	N	0.6	0.7	0.5	336	2.25	15.0	1.5	¹	¹	✓			
NBC3	N	0.7	0.6	0.6	311	2.25	21.1	6.4	¹	¹	✓	✓		
NBC4	N	1.0	0.7	1.0	297	2.25	26.2	13.0	¹	¹	✓	✓		
SBC1	N	Not included in test.												
SBC2	N	Not included in test.												
SBC3	N	Not included in test.												
SBC4	N	Not included in test.												
WBC1	N	0.4	0.7	0.5	224	2.26	8.3	¹	¹	¹	✓			
WBC2	N	0.5	0.7	0.5	200	2.26	9.1	¹	¹	¹	✓			
WBC3	N	0.8	1.0	0.8	196	2.26	11.9	4.7	¹	¹	✓	✓		
WBC4	N	0.1	0.6	0.1	240	2.26	3.7	¹	¹	¹	✓			

¹ T Statistic is out of range

Figure E.24 On Time Histograms for Four Cameras. West Lafayette Northbound Left-Turn Movement (Phase 5), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.25 Off Time Histograms for Four Cameras. West Lafayette Northbound Left-Turn Movement (Phase 5), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.26 On Time Histograms for Four Cameras. West Lafayette Southbound Left-Turn Movement (Phase 1), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.27 Off Time Histograms for Four Cameras. West Lafayette Southbound Left-Turn Movement (Phase 1), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) On Time Histogram Camera 1
(Day)

c) On Time Histogram Camera 2
(Day)

b) On Time Histogram Camera 1
(Night)

d) On Time Histogram Camera 2
(Night)

e) On Time Histogram Camera 3
(Day)

g) On Time Histogram Camera 4
(Day)

f) On Time Histogram Camera 3
(Night)

h) On Time Histogram Camera 4
(Night)

Figure E.28 On Time Histograms for Four Cameras. West Lafayette Eastbound Left-Turn Movement (Phase 7), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.29 Off Time Histograms for Four Cameras. West Lafayette Eastbound Left-Turn Movement (Phase 7), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.30 On Time Histograms for Four Cameras. West Lafayette Westbound Left-Turn Movement (Phase 3), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

a) Off Time Histogram Camera 1
(Day)

c) Off Time Histogram Camera 2
(Day)

b) Off Time Histogram Camera 1
(Night)

d) Off Time Histogram Camera 2
(Night)

e) Off Time Histogram Camera 3
(Day)

g) Off Time Histogram Camera 4
(Day)

f) Off Time Histogram Camera 3
(Night)

h) Off Time Histogram Camera 4
(Night)

Figure E.31 Off Time Histograms for Four Cameras. West Lafayette Westbound Left-Turn Movement (Phase 3), (January 20th, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Figure E.32 On Time Histograms for West Lafayette Northbound Camera 1 Left-Turn Movement (Phase 5), (January 20th, 2005)

Figure E.33 Off Time Histograms for West Lafayette Northbound Camera 1 Left-Turn Movement (Phase 5), (January 20th, 2005)

Table E.6 Difference between Loop Detector and Video Detector Turn On Times During Red Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	1.9	1.4	1.9	124	2.27	14.4	10.5	6.7	¹	✓	✓	✓	
EBC2	D	2.4	1.1	2.4	122	2.27	25.6	20.4	15.1	4.6	✓	✓	✓	✓
EBC3	D	1.6	0.5	1.5	123	2.27	33.4	22.9	12.3	¹	✓	✓	✓	
EBC4	D	1.3	1.0	1.3	124	2.27	14.7	9.0	3.2	¹	✓	✓	✓	
NBC1	D	1.5	2.9	1.8	103	2.27	5.2	3.4	1.7	¹	✓	✓		
NBC2	D	2.0	0.3	2.0	103	2.27	78.5	59.2	39.9	1.3	✓	✓	✓	
NBC3	D	1.8	1.6	1.9	103	2.27	11.1	8.0	4.8	¹	✓	✓	✓	
NBC4	D	2.0	1.3	1.8	101	2.28	14.6	10.9	7.2	¹	✓	✓	✓	
SBC1	D	1.9	0.4	1.8	97	2.28	51.6	37.7	23.8	¹	✓	✓	✓	
SBC2	D	2.6	0.4	2.6	96	2.28	56.8	45.8	34.8	12.7	✓	✓	✓	✓
SBC3	D	2.1	0.8	2.2	100	2.28	26.1	19.9	13.7	1.3	✓	✓	✓	
SBC4	D	1.1	5.1	1.9	96	2.28	2.2	1.2	0.2	¹				
WBC1	D	1.4	11.2	3.3	80	2.28	1.1	0.7	0.3	¹				
WBC2	D	3.6	0.6	3.7	81	2.28	50.7	43.6	36.6	22.5	✓	✓	✓	✓
WBC3	D	2.6	1.2	2.8	83	2.28	19.9	16.0	12.2	4.4	✓	✓	✓	✓
WBC4	D	1.6	5.9	2.3	83	2.28	2.5	1.7	1.0	¹	✓			
EBC1	N	-0.3	4.5	0.5	109	2.27	0.7	¹	¹	¹				
EBC2	N	1.4	4.4	1.8	108	2.27	3.2	2.0	0.9	¹	✓			
EBC3	N	0.3	3.9	-0.1	100	2.28	0.8	¹	¹	¹				
EBC4	N	0.1	3.8	0.8	110	2.27	0.2	¹	¹	¹				
NBC1	N	-0.4	2.7	0.4	124	2.27	1.7	¹	¹	¹				
NBC2	N	0.5	1.9	0.8	126	2.27	2.8	¹	¹	¹	✓			
NBC3	N	-1.4	3.4	-0.3	118	2.27	4.4	2.8	1.2	¹	✓	✓		
NBC4	N	1.2	1.0	1.3	129	2.27	13.4	7.9	2.5	¹	✓	✓	✓	
SBC1	N	-1.9	6.0	0.1	77	2.29	2.7	2.0	1.3	¹	✓			
SBC2	N	1.9	1.7	2.0	61	2.30	8.7	6.4	4.1	¹	✓	✓	✓	
SBC3	N	-1.3	5.1	-0.1	70	2.29	2.2	1.3	0.5	¹				
SBC4	N	1.3	3.3	2.0	72	2.29	3.3	2.0	0.7	¹	✓			
WBC1	N	-1.2	6.8	1.1	42	2.33	1.1	0.6	0.2	¹				
WBC2	N	2.9	3.4	2.2	39	2.33	5.3	4.4	3.5	1.7	✓	✓	✓	
WBC3	N	-1.8	6.3	0.0	45	2.32	1.9	1.4	0.8	¹				
WBC4	N	-3.0	10.8	1.0	43	2.32	1.8	1.5	1.2	0.6				

¹ T Statistic is out of range

Table E.7 Difference between Loop Detector and Video Detector Turn On Times During Protected Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.3	0.2	0.4	41	2.33	11.9	¹	¹	¹	✓			
EBC2	D	0.9	0.2	0.9	32	2.36	31.8	13.8	¹	¹	✓	✓		
EBC3	D	0.3	0.3	0.3	36	2.34	5.4	¹	¹	¹	✓			
EBC4	D	0.3	0.2	0.3	50	2.31	12.0	¹	¹	¹	✓			
NBC1	D	0.3	0.2	0.3	30	2.36	8.3	¹	¹	¹	✓			
NBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	D	0.7	0.1	0.6	38	2.34	28.3	6.7	¹	¹	✓	✓		
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	-0.6	1.0	-0.5	39	2.33	3.9	0.8	¹	¹	✓			
EBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	N	-0.8	1.0	-0.8	37	2.34	4.7	1.7	¹	¹	✓			
EBC4	N	-0.1	0.8	-0.1	43	2.32	1.0	¹	¹	¹				
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*

* Indicates Insufficient Data

¹ T Statistic is out of range

Table E.8 Difference between Loop Detector and Video Detector Turn On Times During Permitted Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.4	0.2	0.4	131	2.27	20.9	¹	¹	¹	✓			
EBC2	D	1.0	0.3	0.9	124	2.27	32.7	16.1	¹	¹	✓	✓		
EBC3	D	0.4	0.5	0.4	123	2.27	8.3	¹	¹	¹	✓			
EBC4	D	0.3	0.3	0.3	142	2.27	15.6	¹	¹	¹	✓			
NBC1	D	0.3	0.2	0.1	145	2.27	12.8	¹	¹	¹	✓			
NBC2	D	0.5	0.3	0.5	143	2.27	23.6	1.8	¹	¹	✓			
NBC3	D	0.4	0.3	0.4	128	2.27	14.7	¹	¹	¹	✓			
NBC4	D	0.7	0.3	0.6	150	2.26	30.9	8.6	¹	¹	✓	✓		
SBC1	D	0.4	0.2	0.4	70	2.29	15.2	¹	¹	¹	✓			
SBC2	D	2.4	0.4	2.3	40	2.33	35.0	27.6	20.3	5.5	✓	✓	✓	✓
SBC3	D	0.7	0.7	0.6	67	2.29	7.7	1.8	¹	¹	✓			
SBC4	D	0.7	1.0	0.8	72	2.29	5.8	1.7	¹	¹	✓			
WBC1	D	0.8	0.3	0.6	41	2.33	15.1	5.5	¹	¹	✓	✓		
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	2.4	0.8	2.5	36	2.34	18.6	14.7	10.8	2.9	✓	✓	✓	✓
WBC4	D	1.1	0.5	1.0	40	2.33	15.1	8.5	1.9	¹	✓	✓		
EBC1	N	-0.9	1.2	-1.0	82	2.28	6.7	3.0	¹	¹	✓	✓		
EBC2	N	0.7	1.5	0.5	56	2.30	3.6	1.1	¹	¹	✓			
EBC3	N	-1.5	1.4	-1.4	97	2.28	10.5	7.0	3.5	¹	✓	✓	✓	
EBC4	N	-0.2	1.3	-0.3	81	2.28	1.1	¹	¹	¹				
NBC1	N	-0.9	0.7	-0.8	87	2.28	12.0	5.2	¹	¹	✓	✓		
NBC2	N	-0.5	0.5	-0.5	97	2.28	9.8	¹	¹	¹	✓			
NBC3	N	-1.5	1.1	-1.3	76	2.29	11.7	7.7	3.7	¹	✓	✓	✓	
NBC4	N	0.3	0.5	0.3	108	2.27	6.0	¹	¹	¹	✓			
SBC1	N	-0.8	0.6	-0.8	41	2.33	8.6	3.5	¹	¹	✓	✓		
SBC2	N	1.7	1.3	1.9	39	2.33	7.7	5.4	3.1	¹	✓	✓	✓	
SBC3	N	-0.9	1.3	-0.8	41	2.33	4.3	1.9	¹	¹	✓			
SBC4	N	0.8	0.5	0.8	40	2.33	10.8	3.8	¹	¹	✓	✓		
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*

¹ T Statistic is out of range

Table E.9 Difference between Loop Detector and Video Detector Turn Off Times
During Red Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day
Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	D	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	D	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
EBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
NBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
SBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*

* Indicates Insufficient Data

¹ T Statistic is out of range

Table E.10 Difference between Loop Detector and Video Detector Turn Off Times During Protected Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	0.6	0.5	0.5	166	2.26	15.4	1.4	¹	¹	✓			
EBC2	D	1.2	0.4	1.2	153	2.26	36.2	21.0	5.8	¹	✓	✓	✓	
EBC3	D	1.2	0.4	1.2	153	2.26	34.0	19.6	5.3	¹	✓	✓	✓	
EBC4	D	0.1	0.6	0.1	173	2.26	2.6	¹	¹	¹	✓			
NBC1	D	0.8	0.5	0.8	132	2.27	17.0	6.6	¹	¹	✓	✓		
NBC2	D	1.2	0.6	1.2	128	2.27	24.3	14.4	4.4	¹	✓	✓	✓	
NBC3	D	1.6	0.6	1.5	123	2.27	31.0	21.1	11.1	¹	✓	✓	✓	
NBC4	D	0.4	0.8	0.4	146	2.26	6.0	¹	¹	¹	✓			
SBC1	D	1.0	0.5	1.2	86	2.28	18.3	9.3	0.4	¹	✓	✓		
SBC2	D	1.0	0.5	1.0	80	2.28	18.0	9.0	¹	¹	✓	✓		
SBC3	D	1.5	0.4	1.5	82	2.28	39.5	26.7	14.0	¹	✓	✓	✓	
SBC4	D	0.7	0.4	0.8	89	2.28	17.1	4.5	¹	¹	✓	✓		
WBC1	D	0.5	0.3	0.4	67	2.29	11.6	¹	¹	¹	✓			
WBC2	D	1.0	0.7	0.9	66	2.29	12.2	6.3	0.5	¹	✓	✓		
WBC3	D	1.2	0.8	1.0	63	2.30	12.9	7.7	2.5	¹	✓	✓	✓	
WBC4	D	0.6	0.3	0.5	67	2.29	15.0	2.1	¹	¹	✓			
EBC1	N	0.5	1.1	0.6	133	2.27	5.4	¹	¹	¹	✓			
EBC2	N	0.8	1.3	1.0	122	2.27	6.7	2.4	¹	¹	✓	✓		
EBC3	N	1.1	0.6	1.2	131	2.27	20.3	11.3	2.4	¹	✓	✓	✓	
EBC4	N	0.5	0.7	0.5	140	2.27	8.6	0.1	¹	¹	✓			
NBC1	N	0.7	0.9	0.8	126	2.27	9.2	3.0	¹	¹	✓	✓		
NBC2	N	1.1	0.6	1.2	129	2.27	20.2	11.3	2.3	¹	✓	✓	✓	
NBC3	N	1.2	1.3	1.4	124	2.27	10.0	5.8	1.5	¹	✓	✓		
NBC4	N	0.6	0.6	0.6	130	2.27	11.6	2.0	¹	¹	✓			
SBC1	N	0.8	1.0	1.2	57	2.30	6.4	2.6	¹	¹	✓	✓		
SBC2	N	1.1	1.2	0.8	44	2.32	6.3	3.6	0.8	¹	✓	✓		
SBC3	N	1.0	1.0	1.2	58	2.30	8.0	4.1	0.1	¹	✓	✓		
SBC4	N	0.6	0.7	0.8	56	2.30	6.5	1.4	¹	¹	✓			
WBC1	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC2	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC3	N	*	*	*	*	*	*	*	*	*	*	*	*	*
WBC4	N	*	*	*	*	*	*	*	*	*	*	*	*	*

¹ T Statistic is out of range

Table E.11 Difference between Loop Detector and Video Detector Turn Off Times During Permitted Left-Turn Phase (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

	Day/Night	Average Residual	Standard Deviation	Median	Sample Size	Critical T	Test T (0.0 s)	Test T (0.5 s)	Test T (1.0 s)	Test T (2.0 s)	Sig. Different (0.0 s)	Sig. Different (0.5 s)	Sig. Different (1.0 s)	Sig. Different (2.0 s)
EBC1	D	1.5	1.1	1.2	120	2.27	14.9	9.8	4.7	¹	✓	✓	✓	
EBC2	D	1.9	1.1	1.5	113	2.27	18.9	13.9	8.8	¹	✓	✓	✓	
EBC3	D	3.1	3.1	2.0	101	2.28	9.8	8.2	6.6	3.4	✓	✓	✓	✓
EBC4	D	0.1	0.8	0.1	133	2.27	1.0	¹	¹	¹				
NBC1	D	1.3	1.3	1.0	147	2.26	12.3	7.6	3.0	¹	✓	✓	✓	
NBC2	D	1.4	1.1	1.2	149	2.26	16.0	10.3	4.5	¹	✓	✓	✓	
NBC3	D	3.1	2.5	2.3	123	2.27	13.4	11.2	9.0	4.6	✓	✓	✓	✓
NBC4	D	0.2	1.6	0.3	160	2.26	1.7	¹	¹	¹				
SBC1	D	1.2	1.2	0.8	83	2.28	8.8	5.0	1.2	¹	✓	✓		
SBC2	D	1.2	1.1	1.2	58	2.30	8.3	4.9	1.5	¹	✓	✓		
SBC3	D	2.8	2.2	2.2	78	2.29	11.6	9.6	7.5	3.4	✓	✓	✓	✓
SBC4	D	0.8	0.8	0.5	88	2.28	9.2	3.6	¹	¹	✓	✓		
WBC1	D	1.4	1.6	0.8	62	2.30	6.8	4.4	1.9	¹	✓	✓		
WBC2	D	1.6	1.3	1.3	46	2.32	8.4	5.8	3.2	¹	✓	✓	✓	
WBC3	D	2.5	2.4	1.5	55	2.31	7.8	6.3	4.7	1.6	✓	✓	✓	
WBC4	D	1.2	1.3	0.6	59	2.30	7.2	4.2	1.2	¹	✓	✓		
EBC1	N	0.5	1.8	0.6	95	2.28	2.8	0.1	¹	¹	✓			
EBC2	N	1.3	1.2	1.2	63	2.30	9.0	5.7	2.3	¹	✓	✓		
EBC3	N	2.2	2.2	1.7	103	2.27	10.3	8.0	5.7	1.1	✓	✓	✓	
EBC4	N	0.4	1.0	0.1	93	2.28	3.6	¹	¹	¹	✓			
NBC1	N	1.0	1.4	0.8	105	2.27	7.4	3.7	0.0	¹	✓	✓		
NBC2	N	1.2	0.8	1.0	110	2.27	15.0	8.7	2.4	¹	✓	✓	✓	
NBC3	N	2.4	1.5	2.0	92	2.28	15.7	12.4	9.1	2.6	✓	✓	✓	✓
NBC4	N	0.6	1.8	0.4	127	2.27	3.8	0.7	¹	¹	✓			
SBC1	N	1.1	1.0	0.9	51	2.31	7.9	4.5	1.0	¹	✓	✓		
SBC2	N	0.9	0.8	0.8	48	2.32	7.3	3.0	¹	¹	✓	✓		
SBC3	N	2.3	1.9	1.8	53	2.31	8.7	6.9	5.0	1.2	✓	✓	✓	
SBC4	N	0.7	0.7	0.4	49	2.31	6.8	1.8	¹	¹	✓			
WBC1	N	1.0	3.6	1.0	35	2.35	1.7	0.8	0.0	¹				
WBC2	N	0.1	3.4	0.5	33	2.35	0.3	¹	¹	¹				
WBC3	N	3.7	4.1	2.4	35	2.35	5.3	4.6	3.8	2.4	✓	✓	✓	✓
WBC4	N	1.1	4.0	0.9	31	2.36	1.5	0.8	0.1	¹				

¹ T Statistic is out of range

Table E.12 Difference between Loop Detector and Video Detector Turn On Times (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓	✓		✓				✓	✓	✓		✓				✓			
EBC2	D	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓			✓	✓		
EBC3	D	✓	✓	✓		✓				✓	✓	✓		✓				✓			
EBC4	D	✓	✓	✓		✓				✓	✓	✓		✓				✓			
NBC1	D	✓	✓	✓		✓				✓	✓			✓				✓			
NBC2	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	✓			
NBC3	D	✓	✓	✓		✓				✓	✓	✓		*	*	*	*	✓			
NBC4	D	✓	✓	✓		✓				✓	✓	✓		✓	✓			✓	✓		
SBC1	D	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓		*	*	*	*	✓			
SBC2	D	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓	✓	*	*	*	*	✓	✓	✓	✓
SBC3	D	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓		*	*	*	*	✓			
SBC4	D	NA	NA	NA	NA	NA	NA	NA	NA					*	*	*	*	✓			
WBC1	D	✓	✓	✓		✓								*	*	*	*	✓	✓		
WBC2	D	✓	✓	✓		✓	✓			✓	✓	✓	✓	*	*	*	*	*	*	*	*
WBC3	D	✓	✓			✓				✓	✓	✓	✓	*	*	*	*	✓	✓	✓	✓
WBC4	D					✓	✓			✓				*	*	*	*	✓	✓		
EBC1	N	✓				✓	✓	✓						✓				✓	✓		
EBC2	N					✓	✓	✓		✓				*	*	*	*	✓			
EBC3	N	✓	✓	✓		✓	✓	✓						✓				✓	✓	✓	
EBC4	N	✓	✓			✓															
NBC1	N	✓	✓	✓		✓	✓							*	*	*	*	✓	✓		
NBC2	N	✓	✓	✓		✓	✓	✓		✓				*	*	*	*	✓			
NBC3	N	✓	✓	✓	✓	✓	✓	✓		✓	✓			*	*	*	*	✓	✓	✓	
NBC4	N	✓				✓				✓	✓	✓		*	*	*	*	✓			
SBC1	N	NA	NA	NA	NA	NA	NA	NA	NA	✓				*	*	*	*	✓	✓		
SBC2	N	NA	NA	NA	NA	NA	NA	NA	NA	✓	✓	✓		*	*	*	*	✓	✓	✓	
SBC3	N	NA	NA	NA	NA	NA	NA	NA	NA					*	*	*	*	✓			
SBC4	N	NA	NA	NA	NA	NA	NA	NA	NA	✓				*	*	*	*	✓	✓		
WBC1	N	✓	✓			✓	✓							*	*	*	*	*	*	*	*
WBC2	N	✓	✓			✓	✓			✓	✓	✓		*	*	*	*	*	*	*	*
WBC3	N	✓	✓	✓		✓	✓							*	*	*	*	*	*	*	*
WBC4	N	✓												*	*	*	*	*	*	*	*

* Indicates Insufficient Data

Table E.13 Difference between Loop Detector and Video Detector Turn Off Times (West Lafayette, Indiana, January 20, 2005, Day Period: 12:00 PM to 4:00 PM, Night Period: 8:00 PM to 12:00 AM)

Camera	Time of Day	Through Red				Through Green				Left Turn Red				Left Turn Protected				Left Turn Permitted			
		0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s	0.0 s	0.5 s	1.0 s	2.0 s
EBC1	D	✓	✓			✓	✓			*	*	*	*	✓				✓	✓	✓	
EBC2	D	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC3	D	✓	✓	✓		✓	✓	✓		*	*	*	*	✓	✓	✓		✓	✓	✓	✓
EBC4	D	✓								*	*	*	*	✓							
NBC1	D	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓	✓	
NBC2	D	*	*	*	*	✓				*	*	*	*	✓	✓	✓		✓	✓	✓	
NBC3	D	*	*	*	*	✓				*	*	*	*	✓	✓	✓		✓	✓	✓	✓
NBC4	D	*	*	*	*	✓	✓			*	*	*	*	✓							
SBC1	D	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
SBC2	D	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
SBC3	D	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓	✓		✓	✓	✓	✓
SBC4	D	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
WBC1	D	*	*	*	*	✓				*	*	*	*	✓				✓	✓		
WBC2	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓	✓	
WBC3	D	*	*	*	*	✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
WBC4	D	*	*	*	*	✓				*	*	*	*	✓				✓	✓		
EBC1	N	✓	✓	✓		✓				*	*	*	*	✓				✓			
EBC2	N	✓	✓	✓		✓	✓			*	*	*	*	✓	✓			✓	✓		
EBC3	N	✓	✓	✓		✓	✓			*	*	*	*	✓	✓	✓		✓	✓	✓	
EBC4	N	✓	✓	✓		✓				*	*	*	*	✓				✓			
NBC1	N	*	*	*	*	✓				*	*	*	*	✓	✓			✓	✓		
NBC2	N	*	*	*	*	✓				*	*	*	*	✓	✓	✓		✓	✓	✓	
NBC3	N	*	*	*	*	✓	✓			*	*	*	*	✓	✓			✓	✓	✓	✓
NBC4	N	*	*	*	*	✓	✓			*	*	*	*	✓				✓			
SBC1	N	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
SBC2	N	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓		
SBC3	N	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓	✓			✓	✓	✓	
SBC4	N	NA	NA	NA	NA	NA	NA	NA	NA	*	*	*	*	✓				✓			
WBC1	N	✓	✓			✓				*	*	*	*	*	*	*	*				
WBC2	N	*	*	*	*	✓				*	*	*	*	*	*	*	*				
WBC3	N	✓	✓			✓	✓			*	*	*	*	*	*	*	*	✓	✓	✓	✓
WBC4	N	✓				✓				*	*	*	*	*	*	*	*				

* Indicates Insufficient Data