National Center for Intermodal Transportation for Economic Competitiveness

Final Report 566

Traffic Counting Using Existing Video Detection Cameras

by

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TECHNICAL REPORT STANDARD PAGE

1. Report No. **FHWA/LA.15/566**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Traffic Counting Using Existing Video Detection Cameras**	5. Report Date September 2016 6. Performing Organization Code LTRC Project Number: 12-1SS SIO Number:30000760	
7. Author(s) Sherif Ishak, Julius Codjoe, Saleh Mousa, Syndney Jenkins, Jennifer Bonnette	8. Performing Organization Report No.	
9. Performing Organization Name and Address Department of Civil and Environmental Engineering Louisiana State University Baton Rouge, LA 70803	10. Work Unit No. 11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Louisiana Department of Transportation and Development Baton Rouge, LA 70804-9245 National Center for Intermodal Transportation for Economic Competitiveness Mississippi State University Starkville, MS ,39762	13. Type of Report and Period Covered **Final Report** **November 2015** 14. Sponsoring Agency Code Final Report, 07/01/12 – 12/31/15	
15. Supplementary Notes **Conducted in Cooperation with the U.S. Department of Transportation, Federal Highway Administration**		

16. Abstract

The purpose of this study is to evaluate the video detection technologies currently adopted by the city of Baton Rouge and DOTD. The main objective is to review the performance of Econolite Autoscope cameras in terms of their ability to detect data, ease of use, accessibility to data, security issues and cost. The final goal of this project is to investigate the effectiveness of this video detection technology in traffic data collection at signalized intersections in Baton Rouge and to judge the reliability of integrating the traffic count data from the Autoscopes into a database that could be used to supplement traffic count information at any time. In order to accomplish these tasks, a sample of intersections was selected for analysis from an inventory detailing each site's traffic volume, lighting conditions, turning movements, camera mounting type, technology used, and geometric characteristics. Volume counts from the video detection technology (camera counts) were statistically compared against ground truth data (manual counts) by means of Multiple Logistic Regression and t-tests. Using this data, the capabilities of the existing video detection system was assessed to determine the quality of the data collected under various settings. The results of this research indicate that the performance of the Solo Terra Autoscopes was not consistent across the sample. Of the 20 intersections sampled, eight locations (40%) proved to show significant statistical differences between the camera and manual counts. The results of the regression analysis showed only lane configuration, time of day, and actual traffic volumes were statistically affecting the performance of the Autoscopes. According to supplemental t-test analysis on the time of day, the least accurate counts were recorded during the morning and afternoon peak hours and late at night. When testing based on traffic volume, the camera performance worsened as the traffic volume increased; when considering lane configuration, there were statistical differences for the through lanes, right lanes, and shared right/through lanes. Due to the fact that 60% of the sampled intersections (the remaining 12 out of the 20) provided reliable performance under high traffic volumes and during the same study period and weather conditions, the research team attributed the poor performance of some of the cameras to poor calibration and maintenance of the system. It was concluded that the recalibration of the Econolite Autoscopes can significantly enhance the performance of the video detection system, and can therefore be considered a reliable means for traffic counting.

17. Key Words Video detection system, Naztec, Solo Terra Autoscopes, Advanced Traffic Management Center, Centracs		18. Distribution Statement **Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.**	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 125	22. Price

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LTRC Project No. 12-1SS
SIO No. 300-00-760

conducted for

Louisiana Department of Transportation and Development
Louisiana Transportation Research Center
and
National Center for Intermodal Transportation for Economic Competitiveness
Mississippi State University

September 2016

ABSTRACT

The purpose of this study was to evaluate the video detection technologies currently adopted by the city of Baton Rouge and the Louisiana Department of Transportation and Development (DOTD). The main objective was to review the performance of Econolite Autoscope cameras in terms of their ability to detect data, ease of use, accessibility to data, security issues, and cost. The final goal of this project was to investigate the effectiveness of this video detection technology in traffic data collection at signalized intersections in Baton Rouge and to judge the reliability of integrating the traffic count data from the Autoscopes into a database that could be used to supplement traffic count information at any time. In order to accomplish these tasks, a sample of intersections was selected for analysis from an inventory detailing each site's traffic volumes, lighting conditions, turning movements, camera mounting type, technology used and geometric characteristics. Volume counts from the video detection technology (camera counts) were statistically compared against ground truth data (manual counts) by means of Multiple Logistic Regression and t-tests. Based on the analysis results, the capabilities of the existing video detection system were assessed to determine the quality of the data collected under various settings.

The results of this research indicate that the performance of the Solo Terra Autoscopes was not consistent across the sample. Of the 20 intersections sampled, eight locations (40%) proved to show significant statistical differences between the camera and manual counts. The results of the regression analysis showed only lane configuration, time of day, and actual traffic volumes were statistically affecting the performance of the Autoscopes. According to supplemental t-test analysis on the time of day, the least accurate counts were recorded during the morning and afternoon peak hours and late at night. When testing based on traffic volume, the camera performance worsened as the traffic volume increased; when considering lane configuration, there were statistical differences for the through lanes, right lanes, and shared right/through lanes.

Due to the fact that 60% of the sampled intersections (the remaining 12 out of the 20) provided reliable performance under high traffic volumes and during the same study period and weather conditions, the research team attributed the poor performance of some of the cameras to poor calibration and maintenance of the system. It was concluded that the recalibration of the Econolite Autoscopes can significantly enhance the performance of the video detection system, and can therefore be considered a reliable means for traffic counting.

ACKNOWLEDGMENTS

This project was completed with support from DOTD and the Louisiana Transportation Research Center (LTRC) as well as the University Transportation Center (UTC). The research team also gratefully acknowledges the assistance received from the Project Review Committee (PRC) members for their valuable feedback and all other DOTD personnel involved during the course of this project. The research team extends their sincere gratitude to Econolite for providing the research team with the assistance needed.

IMPLEMENTATION STATEMENT

The traffic volumes collected by DOTD over a 24 hour period once every three years at specific locations are deemed insufficient to respond to the current needs to measure AADT and the adjustment factors addressing daily, monthly, and seasonal variations. With the increasing use of video detection technology by state and local agencies, there are better opportunities to collect traffic counts on a continuous basis. The video detection cameras are capable of collecting and storing large amounts of traffic data which can be downloaded remotely or on site. This study investigates the effectiveness of video detection technology in traffic data collection at signalized intersections in Baton Rouge and attempts to integrate the traffic count data from video cameras into a database that can be accessed to extract the required information at any time. This report presents findings of the evaluation of the existing video detection systems for traffic counts.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Traffic data collection at intersections is a very demanding task due to the number of different movements occurring simultaneously. Currently, the most commonly used tools are inductive loops, which are copper wires installed in a circular loop shape into the pavement. When properly installed, these provide accurate data. However, inductive loops are intrusive forms of detectors that involve lane closure during installation and maintenance, not to mention the damage they cause to pavement due to fixing them directly into the pavement. Moreover, inductive loops are more prone to damage as they are installed into the asphalt layer. In some situations, immediate maintenance can be unfeasible due to their intrusive nature, specifically during peak hours for high demand traffic roads. Furthermore, retrieving traffic counts per lane needs separate devices to be installed at each lane.

Surveillance cameras are currently widely used at intersections for encouraging drivers to drive safely. They are utilized for law enforcement purposes via recording movement violations and determining driver's liability for accidents occurring at the intersection. Their imperative need for surveillance purposes at intersections enhanced the usage of these cameras to detect vehicles and measure traffic parameters; e.g., flow and speed. Video detection is non-intrusive system that combines real-time image processing and computerized pattern recognition in a flexible platform. In video detection systems, the camera, which is the image sensor, captures and transmits videos to vision microprocessor that is either located in the camera (e.g., Autoscope Solo Terra) or as an attached module to the controller cabinet. The video signal is analyzed and results are recorded. An illustration of how video detection systems operate is shown in Figure 1.

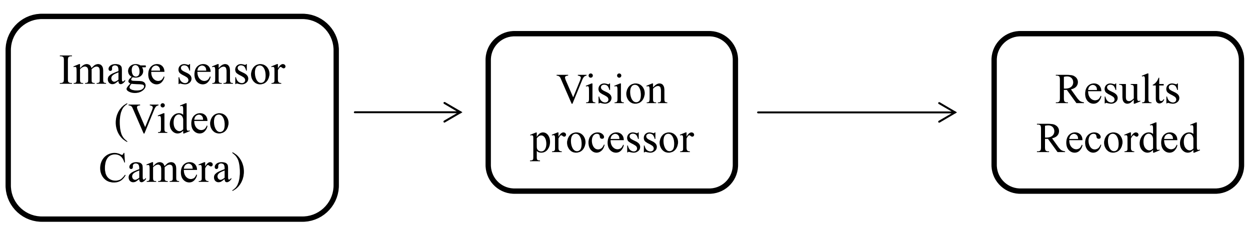

Figure 1
Key components of any video detection system

Recent technological advancements along with reduced computer and image processing hardware costs have made video detection systems the primary alternative to traditional loop detectors at multilane intersections and interchanges. Video detection cameras also have the advantage of cheaper installation and maintenance costs compared to inductive loop detectors. This is in addition to their capability to provide real time surveillance of intersection. Traffic performance measures such as speed, volume, queue lengths, and headways are provided to traffic engineers through video detection systems. Moreover, traffic stream characteristics such as Level of Service (LOS), space mean speed, acceleration, and density can be reported by these systems. Another benefit of the video image detection is its adaptability for changing conditions at intersections (e.g., lane reassignment and temporary lane closure for work zone activities), which can provide traffic managers with the means to reduce congestion and improve traffic flow planning. Additionally, it can be used to automatically detect incidents in tunnels and on freeways, therefore providing information to improve emergency response times of local authorities. Finally, it can provide documented videos for any incident occurring in their field of view to determine driver's liability in any incident dispute.

The vision processor in the detection system analyzes the video image input from a video camera. Algorithms are applied to detect traffic with most algorithms being either the trip line or the tracking algorithm. The trip line technique analyses the video image of a target area on the pavement, and the change in this target area through sequential photos is an indication for a vehicle passing across the target area. The following are examples of commercial trip line systems: AUTOSCOPE, CCATS, TAS, IMPACTS, and TraffiCam *[1], [2], [3], [4], [5]*. The video tracking technique; on the other hand, employs algorithms to identify and track vehicles as they pass through the camera's field of view. The following are common commercial tracking systems: CMS Mobilizer, Eliop EVA, PEEK VideoTrak, Nestor TracVision, and Sumitomo IDET *[6], [7]*. Trip line and tracking can both be employed in the existing video detection technologies. Video detectors can be used to collect most traffic parameters including volume, speed, presence, occupancy, density, queue length, dwell time, headway, turning movements, acceleration, lane changes, and classification.

Despite all of the advantages and benefits video detection systems offer, several reports have documented missed and false calls by these systems during night at low light intensity and during shades. Severe weather conditions such as rain, snow, and wind also compromise the performance of these systems. There are other factors that can negatively impact the quality of data retained from these cameras, such as occlusion, camera motion, seasonal changes in the sun's position, glare and spray from vehicles, and particularly salt, which can accumulate on the camera's lens.

In view of the above shortcomings, it is imperative to perform evaluation study for the accuracy of the video detection systems. Evaluation must be performed under different light, weather, and site conditions that are expected to occur in reality at the intersection.

OBJECTIVE

This study will evaluate the video detection technologies currently adopted by the city of Baton Rouge and DOTD. Initially, the objective was to establish design guidelines based on the detection needs, functionality, and cost. The study will also develop a mechanism for integrating traffic count data from video cameras at intersections in the Baton Rouge Metropolitan Area into a database that can be used to supplement traffic count information. The main initial objectives of this research were:

1. Conduct a review of similar studies by other researchers with emphasis on the type of video detection technology used and the ability of the system to retrieve, edit, and analyze data as well as how the information is used.

2. Create an inventory of the intersections in the Baton Rouge Metropolitan Area where video cameras are installed. Information on the mounting type, technology used, geometric characteristics of the intersection, lighting condition, and turning movements/lanes will be collected to include in the evaluation process.

3. Select sample of intersections from the inventory. The sample size will be determined based on the factors outlined in objective 2.

4. Collect traffic data from the selected signalized intersections using the video detection system installed on site and another reliable method (inductive loops, video recording, or manual observations) to provide ground truth data.

5. Assess the capabilities of the existing video detection systems used to analyze the data and the quality of the data collected under different settings (nighttime, mounting angle, turning movements, etc.).

6. Determine the accuracy of the video detection system through a comparison with the ground truth data.

7. Develop design guidelines for the selection of the appropriate video detection system based on detection need, functionality, ease of use, and cost, and make final recommendations.

However, upon commencing the study, it was realized that only one video detection system (Econolite's Autoscope) was available to be analyzed. This prompted the review of the seventh objective, and it was agreed that the design guidelines be omitted from this study.

The final report will, instead, include a review of the Autoscopes's performance in terms of its ability to detect, ease of use, accessibility to data, security issues, and cost.

SCOPE

The scope of this study is limited to the Baton Rouge Metropolitan Area and the video detection systems installed at intersections. If a new system is recommended by the study, testing will be required prior to implementation. The test system could be evaluated for a year and compared to the data produced by conventional methods.

METHODOLOGY

The research team achieved the aforementioned objectives of the study by performing several tasks. The first task of the research included conducting a review of similar studies using different types of video detection technology. The reviewed studies discussed the ability of the different video detection systems to retrieve, edit, and analyze data, in addition to the way the extracted information is processed and used. Second, an inventory was designed for intersections where video cameras are installed in the Baton Rouge Metropolitan Area. The inventory included information on the technology used, mounting type, geometric characteristics of the intersection, lighting condition, and turning movements/lanes. Third, once the inventory of intersections was complete, a sample of intersections was selected from the inventory. Fourth, traffic counts were collected using the installed video detection system at each intersection of the selected sample. In addition, manual counts were collected from each intersection to represent the ground truth data. Finally, the accuracy of the existing video detection systems was evaluated statistically according on different factors. The tasks are discussed in details in the following sections.

Literature Review

This section includes a review of similar studies performed by other researchers with emphasis on the type of video detection technology (VDT) used and also on the image processing algorithm (IPA). It also reviews and evaluates the most common video detection systems currently available in market according to their ability to retrieve, edit, and analyze data.

Review of Similar Studies (Based on VDT)

MacCarley et al. conducted a study where eight different video detection systems were evaluated under the same traffic, lighting, and weather conditions *[8]*. The video detection systems were evaluated using two different algorithms. The Type 1 algorithm establishes two virtual gates at a known distance apart within the image. It then measures the amount of time difference for a vehicle to change the pixel intensity from gate to gate. The Type 2 algorithm is much more complex, and actually tracks the vehicle, determining the velocity. The two detection systems were evaluated based on speed and volume measurements from each of the system. A series of tests of 28 different parameters were identified, including variations of camera angle, camera mounting position, departing or arriving traffic, lighting, weather, vibration, electromagnetic noise, and traffic. The evaluation results showed that neither the Type 1 nor Type 2 algorithm proved to be highly superior to the other. This was one of the early studies in mentioning the deficits of implementing video detection, and addressing problems with the technology that were mentioned later in more recent studies, namely, inaccurate detection during transitional lighting periods and poor weather conditions such as rain.

In 1994, a video image processing systems evaluation study was performed in cooperation between the Virginia Department of Transportation (VDOT) along with the Maryland State Highway Administration (MSHA) *[9]*. According to this study, evaluating the Autoscope video detection system for its capability to monitor traffic parameters revealed that speed and volume measurements were inconsistent. The volumes detected by the Autoscope system were significantly greater than the volumes measured by loop detectors, indicating high false calls by such systems. The study confirmed that locating the sensor above the travel lanes yields better results compared to at the side of the road.

Another research project conducted in the mid-1990s in a joint effort between the Minnesota Department of Transportation (MnDOT) and the Federal Highway Administration (FHWA) compared two video detection systems, the Econolite Autoscope 2004 and Peek Video Trak-900 video detection systems. The tests were performed on a freeway and a signalized intersection highway sections. Results revealed that the performance of detectors at intersections were inconsistent compared to those at freeway. The researchers documented the decline in performance under non-ideal conditions including the transitional periods at sunrise and sunset where stationary and moving shadows resulted in false detections, and direct sunlight compromised the accurate performance of the detectors.

Another joint effort study was conducted in 1998 by MnDOT and the SRF Consulting Group, Inc. *[10]*. The study investigated four image sensors under different environmental and traffic conditions at intersections and freeways: Trafficam S (Rockwell International), Autoscope 2004 (Image Sensing Systems), EVA 2000 S (Eliop Trafico S.A.), and VideoTrak 900 (Peek Transyt). Results showed that performance was negatively affected by the congested traffic. Lighting conditions, wind, and snow were found to have the strongest impact on the performance of all the detection systems

Grenard et al. conducted research to investigate the effectiveness of selected video detection systems *[11]*. A substantial effort went into assembling a test-bed for video detection in order for it to occur. Unlike most studies, where volume and speed data are used to compare inductive loop detectors with video detections, the video detectors and inductive loop detectors were compared to one another in real-time at the time of data collection. The first evaluation procedure used involved comparing the occupancy times of inductive loop detectors and video detectors to find the amount of discrepancy between the two. The second evaluation procedure involved calibrating a statistical model in order to determine which weather and traffic characteristics had the greatest effects on the operation of the video detectors. It was recommended that due to the imprecision of night detection, video detection should not be used to provide dilemma zone protection. Also, when used for stop bar detection, special care of the video should be exercised to ensure proper operation.

In 2002, Middleton et al. completed an evaluation of two types of vehicle detectors in a freeway setting *[12]*. The detectors tested were the Econolite Autoscope Solo Pro and Iteris Vantage. The Autoscope camera was mounted 7 feet higher than the Iteris Vantage to allow for a direct comparison of the performance of the two systems in real time. The report indicated that both the Autoscope and Iteris systems demonstrated good and consistent occupancy values.

In another study, conducted by Martin et al. in 2004 for evaluating the Utah Department of Transportation's (UDOT) video detection systems in Utah, the Econolite Autoscope, Traficon NV, Iteris, and Peek systems were evaluated under different environmental conditions *[13]*. Results indicated that the Traficon performed the best in all test conditions with 96.4% correct detection, followed by the Autoscope (92.0%), then the Iteris (85.2%). The Peek system produced the lowest percentage of correct detection at 75.8% accuracy.

Rhodes et al. conducted a comprehensive evaluation study for the Autoscope (version8.10), Peek UniTrak (version 2), and Iteris Vantage (Camera CAM-RZ3) video detection systems at signalized intersections *[14]*. The study did not recommend deploying any of the three systems at signalized intersections based on the following: All the detection systems experienced a moderate to high number of missed and false calls unlike the inductive loops which experienced only 1 missed call and 1 false call over the same study period. None of the three video detection systems outperformed the other two, and due to the degradation in performance with time the study recommended the recalibration for the video systems every 4 months.

Review of Similar Studies (Based on IPA)

While the previous section dwelt on the accuracy of detection of the video systems, this section dwells on studies that were concerned with enhancing and evaluating the algorithms used for processing the images for vehicle detection. One of the remarkable studies was developing a wavelet-based algorithm to distinguish vehicles from shadows was conducted in 1996 by Chao et al. *[15]*. The algorithm was developed by integrating two types of mother wavelet: one for shape and size discrimination of vehicles from their background; and the other for locating where vehicles join their shadows, thus enabling segmentation of the vehicles from their shadows.

In another study, Kamijo et al. focused more on the dangerous aspects of the road. They explained that ITS (Intelligent Transportation Systems) play an important role in reducing and sometimes preventing car accidents *[16]*. Their goal was to track vehicles against the obstruction and confusion effects which usually happen at the intersections. Several vehicles traveling from and to all directions may obstruct other vehicles or be obstructed. A solution to those issues is the development of a tracking algorithm using the spatio-temporal Markov random field (MRF) model. This algorithm models a tracking problem by determining the state of each pixel in an image, and how the states transit along both the x-y image axes and the time axis. The paper noted that one of the most important advantages of using such vision sensors for event recognition is their ability to collect useful information such as traffic jams, illegally parked vehicles, traffic violations, and accidents.

Laparmonpinyo and Chitsobhuk presented a new algorithm for video-based traffic monitoring systems which deals with two main processes *[17]*. In the first process, vehicles are extracted to be used as an input to the next process during which traffic information is evaluated. The new technique uses the gradient-based adaptive threshold values (GATE) that are flexible to be adapted automatically to the different times during the day; moreover, this technique uses the horizontal moving edge detection (HMED) that gives the ability to extract different traffic parameters and gets rid of the over detection problem resulting from vehicles with uneven edge density. These algorithms minimize the time required for computations and have very high accuracy.

Mo and Zhang tried to make the video imaging process more effective by adopting a multiple video object segmentation algorithm in the vehicle detection process *[18]*. The algorithm consists of two main sections: the training section and the segmentation section. As a video image is taken, the training section starts working at which the image goes through three consecutive stages. During the first stage the Scale-invariant feature transform method is used to extract and recognize the features of vehicle image samples, then the image is segmented into small patches, and finally the number of video image samples is reduced by activating the codebook. Afterwards, the image goes through the segmentation section at which an Implicit Shape Model is used to combine the recognition knowledge and the segmentation knowledge together. This approach is applied to each vehicle to get its voting center during the detection process. Then, based on coordinates of each voting center and using the Traffic Flow Analysis System, the shortest frames distances are searched. Then, using color features information, vehicles are tracked. Experiments of this approach proved that it is very reliable and efficient and achieved the desired results.

Huang proposed a real-time multi-vehicle detection and tracking system *[19]*. This system allows counting traffic on each lane and assists in removing the foreground noise and shadow. In addition, a vehicle sub-feature filter is used to track vehicles instead of tracking vehicle blob. This detection approach makes the data collection system more robust especially to partial closure that occurs frequently during congestion periods. Results showed that this system is more robust and proved to be of better performance than the vehicle blob tracking systems.

Bramhe and Kulkarni presented an efficient moving object detection algorithm composed of segmenting moving objects, blob analysis, and tracking *[20]*. The blob analysis process by this algorithm allows the extraction of the significant features of vehicles; furthermore, the microscopic speed values are determined in addition to the vehicle flow through a predefined area. The new algorithm uses the video sequence to construct a reference background image that is compared to every image to identify moving objects. Then, noise regions are removed to produce smooth shape boundaries. Finally, images are segmented using many methods such as binarization algorithm, conversion from RGB to grays image and thresholding and watershed algorithms. Results proved that the developed algorithm gives accurate results and can be used in different applications such as vehicle counter and traffic controller.

JunFang et al. introduced a new approach for vehicle identification and counting *[21]*. It is a staged approach in which a segmentation process is conducted for regions of moving object. These segments are processed to identify whether it is a complete vehicle, then vehicles are counted using a simple formula according to the difference between two adjacent images. Experiment results showed that this approach is robust and counts vehicles very accurately so that it can be used in different traffic applications.

Shuguang et al. developed a new technique for video-based traffic data collection that allows detecting and classifying vehicles under mixed traffic conditions *[22]*. This technique is a color image processing-based system that can detect the speed and type of vehicles. In addition, it is able to take cross lanes vehicles and decrease vehicle classification caused by vehicle blocking errors using the blob and a vote algorithm. This system gives comprehensive traffic data for different vehicle types with high accuracy. This traffic data is highly reliable and effective so that it can be used in different traffic areas such as traffic management systems and traffic safety.

Review of Common Detection Systems

Autoscope 2004. The Autoscope 2004 by ImageSensing Systems (ISS) has the capability to receive and monitor input from up to four video cameras and each camera can monitor multiple lanes of traffic with multiple detection zones. Many traffic variables including volume, presence, occupancy, density, speed, and classification can be made available. Figure 2 shows a photo for the Autoscope 2004 detector. The extensive usage of the device revealed it to be reliable but susceptible to undercounting during lighting changes such as the transition from day to evening. Also, a combination of the lighting impact and other factors such as wind has been found to create periods of miscounting. To achieve optimum results, extra time should be spent in setting up the camera position and orientation.

Figure 2
The Autoscope 2004

TraffiCam. The TraffiCam by RockWell International is a fully combined unit in a single housing which contains the camera and all of the processing hardware. A serial communication to a PC and an interface card enables settings for setup, calibration, data download, and relay loop emulation outputs. Volume, speed and occupancy data are available through the serial data. Volume and presence data are available in the loop emulation outputs. The video device can monitor multiple lanes of traffic with multiple detection zones.

Video Trak-900. The Video Trak-900 by Peek Transyt is able to monitor the input from up to four video cameras and each camera can monitor multiple lanes of traffic with multiple detection zones. Many traffic variables including volume, presence, occupancy, density, speed, and classification are provided by this system. Figure 3 shows a photo for the Video Trak-900 detector. However, as with most video detection systems, the Video Trak-900 requires extensive installation and calibration work in order to obtain optimum performance.

Figure 3
Peek Transyt Video Trak-900

EVA 2000. The EVA 2000 is a video system made by Eliop Trafico of Spain. It is capable of monitoring multiple lanes of traffic with multiple detection zones. Many traffic variables including volume, presence, occupancy, density, speed, and classification are available with this system. The calibration of this system is difficult because of the complicated user interface. The device can only store two or three days of data with a 15-minute time interval, requiring frequent downloading of data. The data are in a format that requires additional effort to integrate into a computer's database but generally data can be collected on a consistent basis.

FLIR TrafiBot. The FLIR TrafiBot series system provided by FLIR, amalgamates field-proven video detection algorithms with advanced camera optics and powerful processing technology in a single housing. TrafiBot (with D1 resolution) and TrafiBot HD (with 1920 x 1080 resolutions) are network box cameras that provide superior image quality, embedded AID analytics as well as multi-stream encoding. The TrafiBot's advanced processing unit collects traffic data per lane and per vehicle. Traffic data collected per lane includes traffic flow, speed, and zone occupancy; while individual vehicle traffic data includes speed, gap time, headway, and vehicle classification. A photo of the FLIR TrafiBot camera is shown in Figure 4. The FLIR TrafiBot advanced processing unit is capable of providing automatic incident detection for the following traffic events: stopped vehicle, speed drop, levels of service, over speed, wrong-way drivers, traffic congestion, and under speed. It can also provide detection for the following non-traffic events: smoke in tunnel, pedestrian, and fallen object.

Figure 4
FLIR TrafiBot Camera

VIP3D. The VIP3D system provided by TRAFICON, is a data acquisition tool that provides all needed traffic parameters as volume, speed, gap time, headway, occupancy, concentration, classification and queue length. The VIP3D cameras act as a flow monitoring tool capable of surveilling up to eight lanes. They are also capable of monitoring zone occupancy of the detection area and automatically distinguishing five types of traffic flow (level of service). They can detect both wrong-way drivers and sudden speed variations within a time frame of seconds. Alarm level can be defined during setup, for speed drop, occupancy or image quality. Figure 5 depicts a photo of the VIP3D.1 system.

Figure 5
VIP3D.1 detector

RZ-4 AWDR. The RZ-4 AWDR is a video detection camera with wide dynamic range technology provided by ITERIS. The camera uses an advanced imaging technology to handle extremes in light, dark, and severe glare conditions. The RZ-4 AWDR is an easy to install camera that allows technicians the option to set up the field of view (FOV) from the bucket truck or from the ground at the cabinet. The LAM (Lens Adjustment Module) is an easy to use device that enables adjustment of the camera settings in field without the need for a laptop. A picture of the RZ-4 AWDR camera is shown in Figure 6. According to ITERIS, the camera performs in the most challenging lighting conditions and can be used in a broad range of traffic management applications, including intersection control and highway management systems. The advanced video detection system can be used to detect vehicle presence, count, speed, occupancy, and other traffic data used in traffic management systems. This camera can integrate with traffic signal controllers and modify traffic signal timing based on real time data; it is capable of detecting incidents quickly.

Figure 6
RZ-4 AWDR Camera

Autoscope Solo Terra. The Autoscope Solo Terra, provided by Econolite, is an integrated color video detection, zoom lens, and machine vision processor in one compact surveillance unit. It is a MPEG-4 digital streaming device with a Dual-core processor for advanced image processing that is easily installed with only one 3-wired cable, ensuring high quality video for processing. The Autoscope can be easily integrated into an agency's IP-based communications network. The device provides safe and secure password protected access over the internet using a simple internet browser interface. The embedded web server capability is user friendly, enabling access to streaming video, and remote control via the internet for configuration editing, and remote video surveillance. A photo of the Autoscope Solo Terra is shown in Figure 7. The Solo Terra Autoscope can be set to collect traffic data at tunnels, highways, bridges, and intersections. The collected traffic data includes: volume, occupancy, speed, and classification. The Autoscope can function as a traffic incident management tool as well, providing detection for stopped vehicles, wrong way vehicles and slow moving vehicles.

The current video detection system implemented in the City of Baton Rouge is the Solo Terra Autoscope provided by Econolite. All of the intersections equipped with video detection systems for counting vehicles in the City of Baton Rouge have the Solo Terra Autoscope provided by Econolite manufacturer.

Figure 7
Autoscope Solo Terra

For the Autoscopes to communicate with traffic signals and optimize them based on the traffic counts, they require to be connected to an Autoscope Solo Terra Access Point (TAP). The TAP shown in Figure 8 is a robust Autoscope detector port master, easily installed within the traffic cabinet, for up to eight Autoscope Terra devices as the Solo Terra device. The Terra Access point is imperative when seeking controller adaption based on the traffic counts provided by Autoscopes. None of the Autoscopes installed at the intersections of the City of Baton Rouge are used for signal adaption.

Another primary component within the detection system is the Autoscope Solo Terra Interface Panel (TIP). It is a Bus Interface Unit (BIU) module that provides a robust Autoscope EasyLink connection point in the cabinet for communicating with Solo Terra video detection sensors. The TIP supports a "one cable three wires only" connection to the sensors, an interface to the Autoscope Terra Access Point (TAP) for outputs to traffic controllers, and a standard Ethernet connection for a laptop at the cabinet or back at the office. The interface panel also protects other cabinet components from branch cable transients and surges, while making zoom set up and sensor maintenance accessible from the cabinet. According to Econolite, EasyLink connection means simple installation within the traffic cabinet and user-friendly integration into an agency's Ethernet-based communications network. An illustration of the Solo Terra video detection system components is depicted in Figure 9.

Figure 8
Autoscope Solo Tera Access Point

The Autoscope RackVision Terra. The Autoscope RackVision Terra is a video detection system that features simple setup, robust color or black and white processing, and MPEG-4 video compression to a laptop at the cabinet or traffic control center (TCC). They offer high speed Ethernet interface, web browser maintenance and data over power line communications. The Autoscope Configuration Wizard provides Simple mouse and keyboard operations which enables custom positioning for up to 99 virtual detectors per field-of-view. The device provides for every detection zone the traffic count, presence, speed, and incident detection alarms. Incident types include freeway congestion, stopped vehicles, wrong direction vehicles, slow-moving vehicles, debris, pedestrians, or other customized alarms. Real-time polling or stored data include volume, occupancy, five vehicle classes by length, density, and other traffic data for selected periods or by phase. The RackVision Terra detector card interfaces detector outputs directly to NEMA TS1/TS2, Type 170/179, or 2070 ATC controllers. Figure 10 depicts a picture of the Autoscope Rackvision Terra.

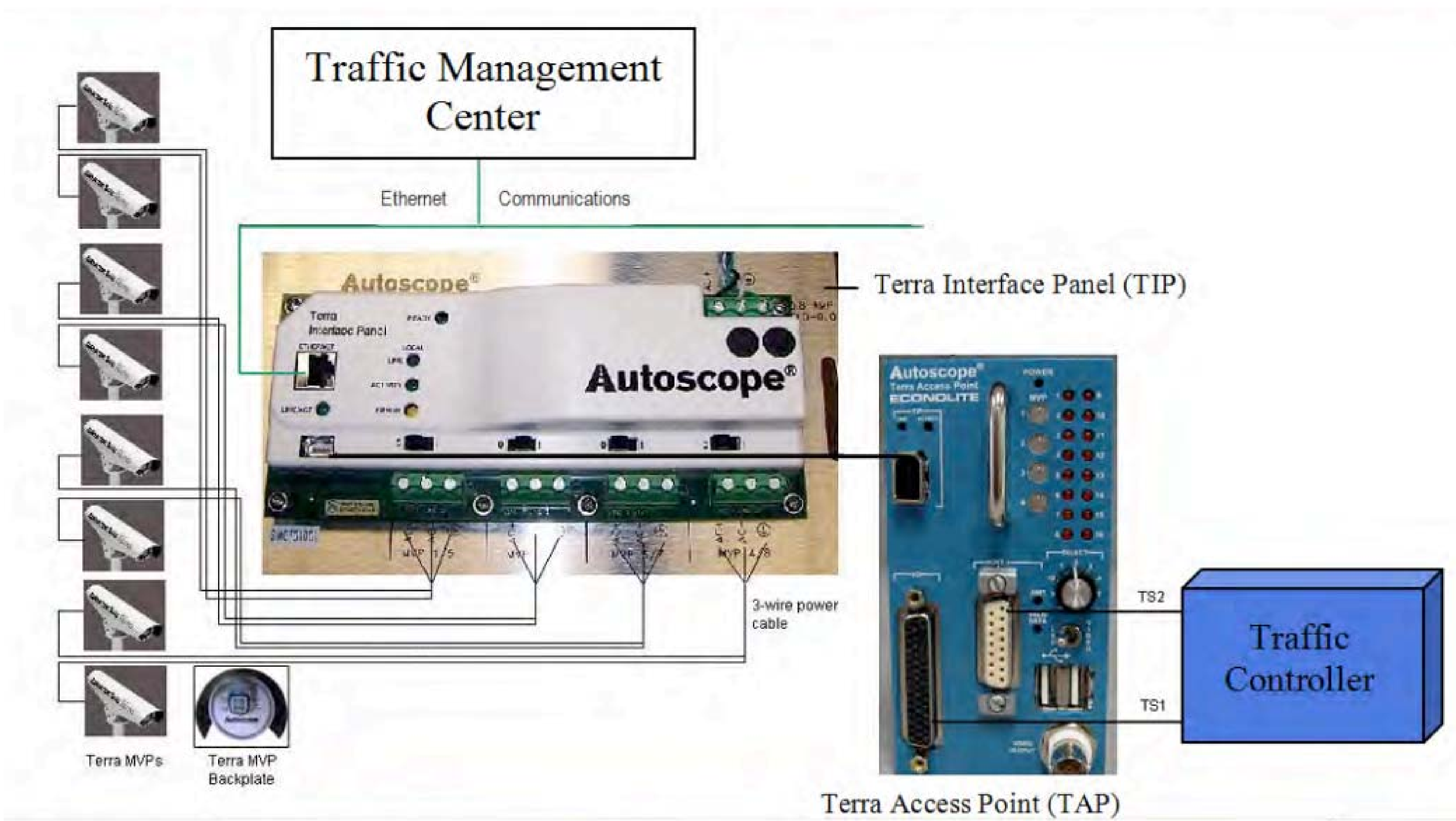

Figure 9
The Solo Terra Autoscope system components

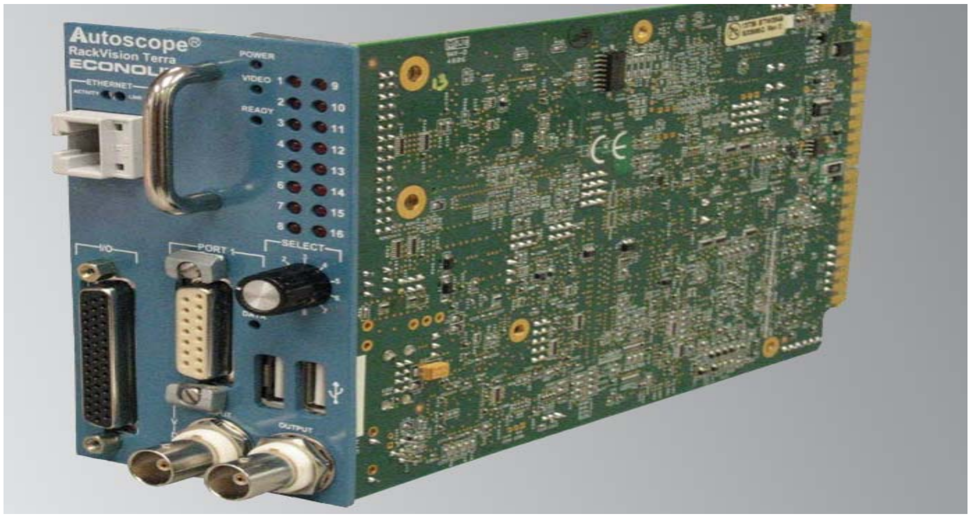

Figure 10
Autoscope RackVision Terra

Naztec VU system. The Naztec VU system provided by Trafficware consists of a VU CAM camera connected to VU detector. The VU CAM camera is an integrated color video camera with Adjustable focal length and focus and 550 TV Lines resolution. The VU detector processes the input videos from cameras and provides all relevant traffic data such as, volume, speed, gap time, headway, occupancy, concentration, and vehicle classification. It automatically reports the levels of service based on flow speed and zone occupancy. The detectors can provide for the intersection, the queue length, and the directional counts on the intersections. Four or eight detection zones per camera can be identified depending on the version of the detector. In addition to reporting the level of service, the Naztec VU detector can operate as a flow monitoring tool: it detects both wrong-way drivers and sudden speed variations within seconds. During set-up, alarm levels can be programmed for specific incidents such as speed drop. Figure 11 depicts a photo of both the Naztec VU CAM and VU detector.

The VU COM is responsible for the communication between the detector boards and PC, and transmitting traffic data and events from the detector boards to the PC via Ethernet communication. In addition, VU COM does the compression of images and records image sequences in case of an event. The VU COM board with communication via Ethernet is IP-addressable, allowing a web server with dynamic HTML pages to run, which can provide the following: streaming video, real-time data reports and the setup of the detector boards. The Video Bus Interface unit (BIU) for TS2 unit is a module that allows VU detectors to communicate with TS-2 controllers using standard SDLC protocols. Two photos of the Naztec VU COM and the BIU for TS2 are shown in Figure 12.

Figure 11
Naztec VU CAM and Detector

Figure 12
VU COM and the BIU for TS2

Evaluation of the Video Detection Technology

In summary, evaluations of commercial video detection systems indicates that the systems have problems with congestion, high flow, occlusion, camera vibration due to wind, lighting transitions between night/day and day/night, and long shadows linking vehicles together *[7]*. Commercial companies have been continually improving the ability of their video detection systems to account for missed and false calls produced during shadows, illumination changes, headlight reflections on the road, inclement weather, and camera motion from wind or vehicle-induced vibration. However, the fact that these systems detect vehicles from videos using artificial algorithms dominates, and the absences of human intelligence persists. Occlusion, variable lighting conditions, wind, and snow continually have a significant adverse impact on the performance of the video detection system. Occlusion occurs when multiple vehicles are considered by the detector as one vehicle due to the overlapping of objects from viewpoint of camera or due to lighting conditions, as shades or the reflections of the headlight in the road. Apart from these types of weather and lighting conditions, video detection systems have reasonably good detection capabilities.

Evaluation of Different Detection Systems

Econolite is a global leader, innovator, manufacturer, and supplier of transportation management solutions since the company's commencement in 1933. ISS which emerged in 1984, formed a joint relationship with Econolite in 1991 for the exclusive manufacturing and distribution of ISS Autoscopes video products in the United States, Mexico, Canada and the Caribbean. According to the annual report published by ISS, as of December 31, 2014, they had supplied, along with their partners Econolite, more than 160,000 units in more than 60 countries. Oakland County in Michigan, Sacramento, CA, and Bernalillo County, New Mexico are examples of the cities that have successfully deployed video detection systems offered by Econolite and achieved successful results.

The two companies provide mainly two types of video detection systems: the integrated cameras and the rack-based cameras. The integrated cameras are integrated units with color zoom camera and machine vision processing computer held in a compact housing. In other words, the sensor and the processor are combined into a compact single unit. There are many integrated cameras offered by Econolite, with the Autoscope Solo Terra being among the most common ones by the time of initiation of this project. The rack-based cameras, however, are card only machine vision processing computers that are located in the intersection signal controller, intersection cabinet, control hub, incident management center or traffic management center that receives the video from a separate camera.

The review of the literature indicates that Econolite proves to be one of the pioneer companies in video detection technology, if not the leading, having video detectors installed in cities all over the US states. Recently, the detection systems developed by FLIR and Iteris are reported to perform well and they provide a direct competition to Econolite. According to the FLIR brochure, they have more than 100,000 video detectors operating worldwide and according to Iteris they had by 2012, more than 100,000 video detection sensors worldwide deployed. According to the annual report of ImageSensing systems 2014, Econolite and ImageSensing Systems have the largest number of installations as compared to their direct competitors by more than 160,000 units in more than 60 countries, FLIR and Iteris were mentioned among their direct competitors in this report.

Autoscopes, provided by Econolite, are considered among the systems providing best performance. This statement comes in accordance with a study performed by Middleton D. and Parker R. in 2002 to evaluate different detection systems developed by Peek Traffic Corporation, Econolite, Iteris, EIS, and SmarTek *[23]*. Among all the evaluated systems, the Autoscope Solo Pro provided by Econolite exhibited overall the most consistent count, speed, and occupancy performance of all non-intrusive detectors tested in this research project. However, in another study performed by Martin et al., in 2004, the Traficon system outperformed the Autoscope Solo Pro, but the Autoscope performed better than Iteris and Peek systems *[13]*.

The inconsistency in performance for a given system among different studies indicates that evaluating the system under different field and weather conditions is imperative prior to a decision. This is due to the fact that the quality of the performance for a given detector relies primarily on light conditions, shading, weather conditions and the quality of the field calibration for the detector. The aforementioned artifacts for video enhanced the regular improvement and development of the detectors offered by companies. Most of the detection systems mentioned in recent studies are outdated by newer versions developed and still being developed, making the consensus for a specific detector a debatable issue. As a result, to judge the reliability in the traffic counts provided by any detection system, it is imperative to evaluate the system in field under different weather and light conditions.

The Calibration Process

Inventory of Intersections

This task involved making an inventory of the intersections in the Baton Rouge Metropolitan Area where video cameras are installed. This was achieved by compiling inventory of all intersections that have video detection systems installed, obtaining technical specifications for the different systems, and obtaining intersection details. The inventory of intersections in the Baton Rouge Metropolitan Area with video detection technology included 235 intersections. These intersections were coded in an excel file, and for each intersection, the number of cameras, the manufacturer of the cameras, and the availability of remote access for the camera were recorded. In order to generate a representative sample for the different field conditions, additional data per intersection was collected: traffic volumes, lighting conditions, intersection orientation, camera orientation and geometric layout. The geometric layout embraced the presences or absence of turn lanes and their number, if any. The excel file was expanded to include the collected data. Due to the large number of columns of the spreadsheet, it was split into several tables to be included in Appendix A. The data collected at each intersection is described in detail in the following subsections. These were all used to generate the representative sample of intersections to be analyzed for this study.

Traffic Volumes. The purpose of collecting the traffic volumes is to provide a total Average Daily Traffic (ADT) on each approach. This, in turn, provides an indication of the total daily traffic volume detected by each camera. All traffic volumes were obtained from DOTD's website. Figure 13 shows the typical layout of the volume collection points of an intersection. Each of the points represents the location where volume data was collected. Two points for each approach (one for each direction) is available in this layout. The ideal case is to have the data for four points for each intersection, however, in some cases this was not applicable. For instance, 21 intersections out of the 235 intersections (8.9% of the inventory) had no available data**.**

Whenever data is available for different years, the most recent is used. In most of the cases, data is available up to year 2011. There are a few instances where only the 2008 or 2009 data are used. Table 1 shows the volume data collected for a sample of the inventory intersections and how they are displayed in the excel file. For each intersection, data is collected on each of the four approaches. These approaches were named as "Major" and "Major Supplemental" to represent either side of the intersection on the major road and "Minor" and "Minor Supplemental" to represent either side of the intersection on the minor road. Because the orientation of the intersections varied, a column for "D" to indicate "Direction" was included to indicate for each approach which side of the intersection the volume data was provided. For instance, for the first intersection shown Table 1, ACADIAN @ BAWELL, Acadian is the major road and Bawell is the minor intersecting road. On Acadian, there is only one data point located on the south side of the intersection, with a recorded ADT of 26,945 in the year 2011. Likewise, there is only one data point located on the east side of the intersection on Bawell, the minor street. It has an ADT of 7,688 that was recorded in the year 2005.

Figure 13
Volume collection locations

Lighting Conditions. Poor lighting conditions can significantly compromise the performance of video detection cameras. Glare or low lighting conditions, caused either by the absence of light or the abundance of shade, are the main causes of the missed or false calls by the detections cameras. The light and shade conditions at each intersection were compiled for each intersection and included in the inventory of intersections excel file.

For lighting conditions, two types of lighting were identified: intersection lighting (lights mounded on traffic signal poles) and/or street lighting (lighting running along either the major or minor road or both). Similarly, for shading conditions, two causes of shading were set as: either by nearby tall buildings or the abundance of trees. For an intersection to be considered as having a "Shade" condition at least 50% of the intersection needed to be in full shade from either of the two causes. There were few intersections that met this criteria. Table 2 represents the lighting and shade data collected for a sample of the inventory intersections and depicts how they are presented in the excel file.

Intersection Orientation. The intersection orientation was identified by notating for both the major and the minor streets the direction of orientation. Four categories were set: North-South, East-West, Northeast-Southwest, or Northwest-Southeast. The orientation for the major and minor streets was picked from the defined categories. Table 3 presents the orientation data for a sample of the inventory intersections and depicts how they are presented in the inventory excel file.

Camera Orientation. The camera orientation was notated similar to the intersection orientation, except that the orientation was notated for every camera at each intersection. This was a time consuming task and the Street-View feature of Google was used. Table 4 shows the camera orientation data for a sample of the inventory intersection extracted from the inventory excel data file.

Lane Configuration. In order to be able to investigate the impact of different turning movements on the performance of the detection cameras, it was crucial to identify the lane configuration for each intersection. The lane configuration of each intersection was observed, and the configuration and number of the lanes was recorded in the inventory of intersection data spreadsheet. Table 5 shows the lane configuration data for a sample of the intersections and presents how the data fits in the inventory data spreadsheet.

Determination of Sample Groups

Once the data was collected, sample groups were determined. A criteria was set for selecting the sample groups from the inventory of intersections to ensure providing a representative sample. This required the inventory of intersections to be stratified into different strata based on multiple factors, and a sample was drawn later on from each stratum.

Inventory Stratification. The main objective of selecting the sample groups is to ensure there is a good mix of the different types of intersections and the sample is a good representative of the inventory. Out of the 235 intersections in the inventory list, 232 intersections have cameras provided by Econolite and only 3 (1.3% of the inventory) have cameras provided by Naztec manufacturer. It was initially decided to include all three Naztec cameras but this was not possible as those cameras had not been set up to collect traffic count data. The City of Baton Rouge noted that Naztec cameras provided no counting data for intersections. They stated that the Naztec cameras were used only as surveillance tool providing video records for intersections with no vehicle detection. As a result, all the counting reports provided by the City of Baton Rouge were only for the Econolite video detection Autoscopes. Throughout the entire inventory only 39 (16.6% of the inventory) intersections had remote access. The count data to be used for the analysis were available for only cameras with remote access. Therefore, all cameras without remote access were to be omitted from the final sample size.

Table 1
Volume data collected for a sample of the inventory intersections

		MAJOR			MAJOR supplemental			MINOR			MINOR supplemental		
Main	Minor	Volume (ADT)	Year	D	Volume (ADT)	Year	D	Volume (ADT)	Year	D	Volume (ADT)	Year	D
ACADIAN	BAWELL	26,945	2011	S	-	-	-	7,688	2005	E	-	-	-
ACADIAN	BROUSSARD	23,188	2005	S	15,777	2005	N	5,766	2005	W	3,253	2005	E
ACADIAN	CLAYCUT	15,777	2005	S	15,608	2005	N	7,307	2005	E	-	-	-
ACADIAN	GOVERNMENT	15,777	2005	S	15,608	2005	N	20,249	2011	W	21,298	2011	E
ACADIAN	HUNDRED OAKS	23,188	2005	S	-	-	-	-	-	-	-	-	-
ACADIAN	I-10	25,678	2011	S	26,945	2011	N	129,942	2011	W	142,715	2011	E
ACADIAN	NORTH BLVD	15,608	2005	S	9,350	2005	N	9,029	2005	E	-	-	-

Table 2
Lighting and shade data collected for a sample of the inventory intersections

		Lighting		Significant Shade	
Main	Minor	Street	Intersection	Trees	Structure
ACADIAN	BAWELL	Yes	Yes	No	Yes
ACADIAN	BROUSSARD	Yes	No	No	No
ACADIAN	CLAYCUT	Yes	Yes	No	No
ACADIAN	GOVERNMENT	Yes	No	No	No
ACADIAN	HUNDRED OAKS	Yes	Yes	Yes	No
ACADIAN	I-10	Yes	No	No	No
ACADIAN	NORTH BLVD	Yes	No	No	No

Table 3
Orientation for a sample of the inventory intersections

Main	Minor	Major St. Orientation	Minor St. Orientation
ACADIAN	BAWELL	NW-SE	NE-SW
ACADIAN	BROUSSARD	NS	EW
ACADIAN	CLAYCUT	NE-SW	EW
ACADIAN	GOVERNMENT	NW-SE	EW
ACADIAN	HUNDRED OAKS	NS	EW
ACADIAN	I-10	NE-SW	NW-SE
ACADIAN	NORTH BLVD	NE-SW	EW

Table 4
Camera orientation for a sample of the inventory intersections

		Camera Orientation							
Main	Minor	N	S	E	W	NE	SE	NW	SW
ACADIAN	BAWELL		1			1		1	
ACADIAN	BROUSSARD	1	1	1	1				
ACADIAN	CLAYCUT	1	1	1	1				
ACADIAN	GOVERNMENT	1	1	1	1				
ACADIAN	HUNDRED OAKS	1	1	1	1				
ACADIAN	I-10		1						
ACADIAN	NORTH BLVD					1	1	1	1

In order to provide the capability of evaluating the impact of different factors, such as lighting and shade, and ensure all of them are included in the sample, a hierarchy was designed that broke down the data into five levels. The resulting hierarchical structure for grouping the inventory is illustrated in **Figure 14**. The sample was then selected from these elements, the factors are as follow:

1. All Data
2. Traffic volume
3. Turning Lanes
4. Lighting
5. Shade

Level 1 – All Data. The first level consisted of all the data collected and/or not collected. There were few intersections, such as along the Central Throughway, that had no data because these intersections were too new. Other intersections had some but not all data available. These intersections needed to be identified to make sure that the sample to be selected later on is free of any intersection without any data. The All Data group consisted of the entire 235 intersections, and included these without remote access as well as the Naztec cameras.

Table 5
Lane configuration for a sample of the inventory intersections

		Lane #s - Major																Lane #s - Major															
		Through				Left Turn				Through/ Left Combo				Right Turn				Through				Left Turn				Through/ Left Combo				Right Turn			
Main	Minor	NB	SB	EB	WB	NB	SB	EB	WB	NB	SB	EB	WB	NB	SB	EB	WB	NEB	SWB	NWB	SEB	NEB	SWB	NWB	SEB	NEB	SWB	NWB	SEB	NEB	SWB	NWB	SEB
ACADIAN	BAWELL																			2	2												
ACADIAN	BROUSSARD	2	2			1	1																										
ACADIAN	CLAYCUT																	2	2			1	1										
ACADIAN	GOVERNMENT																			2	2			1	1							1	1
ACADIAN	HUNDRED OAKS	2	2			1	1																										
ACADIAN	I-10																	2	2			1	1							1	1		
ACADIAN	NORTH BLVD																	2	2			1	1										

Level 2 –Volume. The second level is grouping the intersections based on the volume. As the ADT was collected per direction and not for the entire road, the intersections were filtered based on the Major Road ADT. Mean, median, mode, minimum, and maximum values for the volumes were calculated for the data in order to determine a good dividing threshold. These calculations are summarized in Table 6.

Table 6
Parametric calculations for the ADT

ADT	Major	Major Supplemental
Mean	24,433	26,574
Median	23,051	24,009
Mode	5,495	35,511
Greatest	66,419	66,419
Lowest	73	1,199

Based on these calculations, a threshold of ADT = 24,000 was adopted, which resulted in three subgroups:

1. ADT > 24,000
2. ADT ≤ 24,000
3. Intersections with no volume data on the Major Road

The intersections with no volume data for the major road were identified and removed from the inventory to make sure the sample to be selected later is free of these intersections. The first two groups containing volume data were then further subdivided based on the next factor.
Level 3 – Turn Lanes, both of the two volumes groups were further subdivided based on whether or not that intersection contained a turning lane. Referring back to Table 5, the number and type of turning lanes was recorded for each approach. With that format, a formula was used to look at those counts and return either a "yes" or a "no." If at least one turn lane (of any type) is present at that intersection, then a "yes" is returned. If a "yes" was returned, then that intersection was included in the subgroup "Turn Lanes." Otherwise it was placed in the "No Turn Lanes" subgroup.

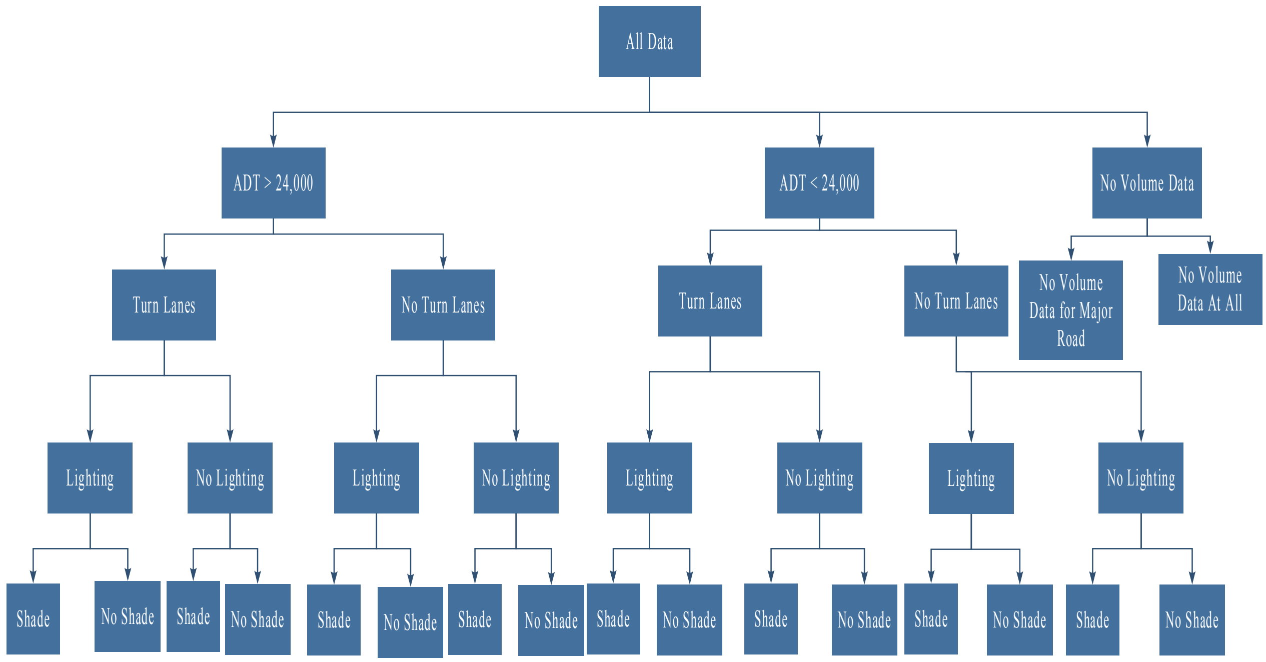

Figure 14
Hierarchy of Sample groups

The Level 4. Lighting data was divided in a way similar to Level 3. Once Level 3 was broken down into subgroups, a formula was written that looked at the lighting data collected and returned either a "yes" or a "no" depending on whether that intersection had any lighting or not (refer back to Table 2). Even though data was collected at each intersection initially for two types of lighting (lighting by street lights and lighting at the intersection), both were coded as "Lighting." If at least one type of lighting was present then that intersection was placed in the subgroup "Lighting." Otherwise, the intersection was placed in the subgroup "No Lighting."

The Level 5. Shade was the final grouping factor. At this level, the Level 4 subgroups were segregated into two groups, namely, with shade and with no shade. The criteria for segregation at this level is very similar to Level 4 – Lighting. The intersection data included two types of shading, specifically, shade provided by trees and shade provided by structures. The formula written returned a "yes" for shade if at least one type of shade was present at intersection.

Sample Selection

After the break down of data, there was a total of 16 subgroups at Level 5. In order to have good spread of intersections, a representative number of intersections from each of these 16 subgroups is to be taken. To allow for geographical diversity, while selecting the sampled intersections from each subgroup, visual inspection was made for each one on the map for its relative location to the other selected intersections. This assured that all of the sample elements selected were not bunched together in one location, but rather spread across the city and the sample is providing geographical coverage.

To determine the sample size, level of confidence of 90% was assumed, and the calculations were as follows:

a) Assuming Confidence level (P) = 90%
b) Z value for 90% confidence level = 1.645
c) Assumed margin of error (D) = 10%
d) Finite Population of Size (N) = 235
e) Sample Size for infinite population (n_0) =

$$Z^2 \left[\frac{P(1-P)}{D^2}\right] = (1.645^2)\left[\frac{.90(1-.90)}{.10^2}\right] = 24.35 \quad (1)$$

f) Sample size for finite Population of Size 235: (2)

$$\frac{\boldsymbol{n_0}}{\boldsymbol{1+\frac{n_0}{N}}} = \frac{\mathbf{24.35}}{\mathbf{1+\frac{24.35}{235}}} = 22$$

g) Sample Size from each Stratum:

$$\frac{Size\ of\ Group}{235} * 22 \tag{3}$$

For the Level 5 group stratification, the sample size to be drawn from each stratum was calculated using equation (3). A default value of 1 was taken whenever the group sample was less than 1. The following criteria were followed as a guideline while picking up the sample intersections from each group:

1. Select intersections with remote access.
2. Select intersections in a manner providing the maximum possible geographic coverage.
3. Omit all Naztec cameras.

Table 7 shows the final sampled intersections from the inventory. It also includes the number of intersections in each group/stratum, number of intersections having remote access to the cameras, and the number of intersections included into the sample from each stratum. The final sample size, however, reduced to only 20 intersections due to unavailability of the camera data for some stratums.

Table 7
Inventory subgroups and final sample groups

	ALL DATA																	
	Cleaned Data																No Volume Data	
	Volume > 24,000								Volume < 24,000								At all	At Major Street
Intersections	100								101								21	13
Naztec Cameras	0								3								0	0
Remote Access	10								18								7	4
Number Sampled	11								11									
	Turn Lanes				No Turn Lanes				Turn Lanes				No Turn Lanes					
Intersections	93				7				70				31				21	13
Naztec Cameras	0				0				3				0				0	0
Remote Access	10				0				4				14				7	4
Number Sampled	9				2				7				4					
	Lighting		No Lighting		Lighting		No Lighting		Lighting		No Lighting		Lighting		No Lighting			
Intersections	79		14		3		4		60		10		27		4		21	13
Naztec Cameras	0		0		0		0		2		1		0		0		0	0
Remote Access	10		0		0		0		7		0		11		0		7	4
Number Sampled	8		1		1		1		6		1		3		1			
	Shade	No Shade	Shade	No Shade	Shade	No Shade	Shade	No Shade	Shade	No Shade	Shade	No Shade	Shade	No Shade	Shade	No Shade		
Intersections	4	75	0	14	0	3	0	4	5	55	0	10	0	27	0	4	21	13
Naztec Cameras	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0
Remote Access	0	10	0	0	0	0	0	0	1	6	0	0	0	11	0	0	7	4
Number Sampled	0	10	0	0	0	0	0	0	1	6	0	1	0	2	0	0		

Video Detection System Data (Camera Counts)

Data were collected from the City of Baton Rouge for the 20 intersections in the sample. The city provided the traffic counts generated from the cameras installed at these intersections. Each intersection had a counting report summarizing all the traffic counts per each lane, turning movement, direction and signal phase. The traffic counts were for the whole day grouped at 15 minutes interval. A sample of the Total volume report generated by the Econolite cameras at the Florida Blvd @ O'Neal/Central Throughway intersection is shown in Figure 15.

Choice of Ground Truth Data (Manual Counts)

For the purpose of evaluating the current implemented video detection systems at the sampled intersection, ground truth traffic counts are to be provided. These counts are then compared statistically to the traffic counts obtained from the video detection systems implemented at these intersections to test for any significant difference. This was achieved by collecting recorded video data from the selected signalized intersections, using the video detection system installed on site. Manual observation counts were used to provide the ground truth traffic counts from the videos provided. Figure 16 shows a snapshot from the videos recorded by Econolite Autoscopes. The snapshot depicts how the signal phase status, and the time of the camera are displayed within the video. The total volume reports produced by the camera can be manually calculated for each phase, lane, and turning movement for the identical 15 minutes; i.e., there is no time shift between the camera and the videos. However, this task was very demanding and time consuming, requiring a lot of man hours to reduce possible errors due to human factors. Several graduate research assistants were recruited to count the traffic from the recorded data. Each student was not allowed to count for more than six hours daily. As a data check procedure, each video was analyzed for counts by two different students. Once the ground truth data was available several statistical comparative analysis were performed to compare the ground truth data to the video detection data according to different factors. The statistical analysis performed is discussed in detail in the next chapter.

Total Volume Report

Group/Device: Florida Blvd @ Central Thrwy/O'Neal

Resolution: 15 Minutes

Run Date: 4/4/2014 5:19:04 PM

Date Range: 4/3/2014-4/3/2014

Time	Florida Blvd @ Central Thrwy/O'Neal - EB Phases 2 & 5 det 150 (EB Phase 2 Right Turn Lane)	Florida Blvd @ Central Thrwy/O'Neal - EB Phases 2 & 5 det 151 (EB Phase 2 Thru Lane 2)	Florida Blvd @ Central Thrwy/O'Neal - EB Phases 2 & 5 det 153 (EB Phase 2 Thru Lane 1)	Florida Blvd @ Central Thrwy/O'Neal - EB Phases 2 & 5 det 154 (EB Phase 5 Left Turn Lane 2)	Florida Blvd @ Central Thrwy/O'Neal - EB Phases 2 & 5 det 156 (EB Left Turn Lane 1)	Florida Blvd @ Central Thrwy/O'Neal - NB Phases 3 & 8 det 150 (NB Phase 8 Right Turn Lane)	Florida Blvd @ Central Thrwy/O'Neal - NB Phases 3 & 8 det 151 (NB Phase 8 Thru Lane 2)
00:00 - 00:15	4	3	8	1	0	1	4
00:15 - 00:30	4	9	7	1	2	1	8
00:30 - 00:45	4	3	1	0	0	3	8
00:45 - 01:00	4	4	4	1	1	1	2
01:00 - 01:15	3	5	4	1	0	0	9
01:15 - 01:30	3	8	1	0	0	0	4
01:30 - 01:45	2	4	0	1	0	1	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 15
A Sample from total volume report produced by the Econolite cameras at the Florida Blvd @ O'Neal/Central Throughway intersection

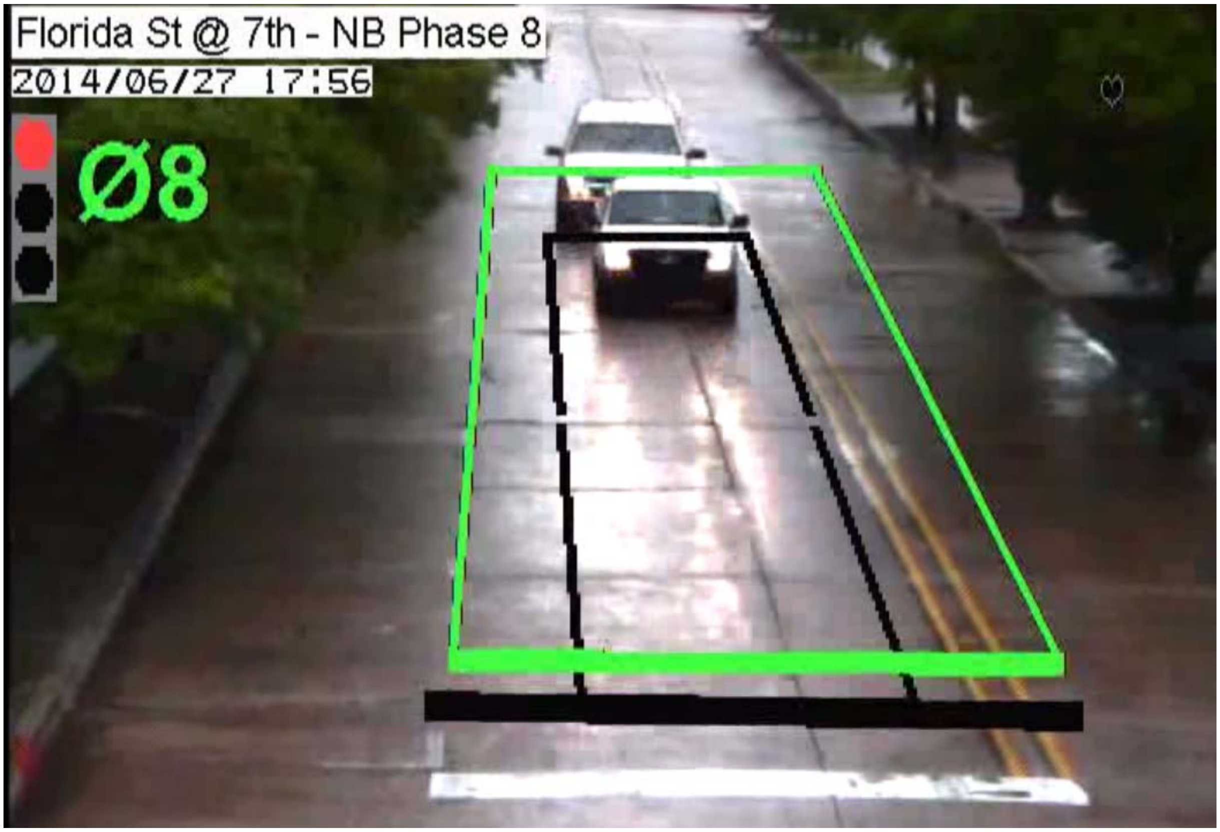

Figure 16
A snapshot from the video records generated by the Econolite Autoscopes

DISCUSSION OF RESULTS

Transportation management centers (TMC) act as the hub for monitoring and operating the road network within the area they are responsible for. These centers employ engineers, technicians, radio operators, and other staff to ensure the efficient monitoring of traffic detectors, and ITS devices deployed within the network. TMCs usually operate 24 hours a day, seven days a week to maintain safe and smooth traffic. They are responsible for optimizing the performance of the network by initiating convenient control strategies, routing decision and prompt responses to incidents. In order to perform the aforementioned tasks smoothly, TMCs need to access large amounts of traffic count data on real time basis, which makes the data management system implemented the heart of the center on which all decisions and possibility of integration with other resources is dependent. As the scope of this study is limited to video detection systems installed within the Baton Rouge Metropolitan Area, the coming sections will discuss the current adopted data management system by Baton Rouge Advanced Traffic Management Center (ATMC).

This section was intended to include an evaluation for both the Econolite video detection system and the Naztec system along with the traffic data management systems they are integrating with. However, the Naztec detections systems were not discussed in view of the fact that they were not functioning as counting cameras, and therefore did not integrate with any data management system. Accordingly, only the Econolite detection system is evaluated in this section along with the traffic data management system used by the City of Baton Rouge for collecting data from the video detectors. The existing video detection system is evaluated for ability to produce the required information, ease of use, accessibility to data, security issues, and cost.

Data Management System for the City of Baton Rouge

The Baton Rouge ATMC currently uses Centracs software to collect data throughout all installed Solo Terra Autoscopes. Currently, the Solo Terra Autoscopes, as mentioned earlier, are the dominating detectors, covering most of the intersections in Baton Rouge. This section will review the Centracs system used for collecting data from these Autoscopes, and the types of data retrieved. The section also discusses the accessibility options and the security measures implemented by the city in handling the data.

Centracs Software

The Solo Terra Autoscopes manufactured by Econolite operate along with their pertinent softwares as a module in the Centracs application. Centracs is an Intelligent Transportation System (ITS) application that provides a centralized integrated platform for Closed-Circuit TV (CCTV) monitoring and control, information management, and graphical data display. The Centracs is characterized by its friendly, modern Graphical User Interface (GUI) design allowing new users the immediate capability of using it. The “Container” technology implemented in this system assists the user in managing the various maps, status, and control screens by enabling the user to drag-and-drop open windows into containers.

The Centracs system uses distributed processing where data processing can be distributed among multiple servers and applications to achieve a flexible and scalable design, which ensures system functioning effectively in terms of cost, communications, security, backups and network interface capabilities. The system can integrate information from any detection technology such as Autoscopes, or loop detectors.

Furthermore, Centracs is extremely modular and contains a vast number of modules that are optional to implement and can integrate together easily. For instance, there is a CCTV module for video surveillance, an adaptive module for adaptive controllers, a travel time module for calculating vehicle travel time, etc. These different modules can work together and the outputs from a specific module can be used as inputs for another one. An illustration of the Centracs system along with offered modules is shown in Figure 17. Detailed information and technical specifications can be accessed for each module through Econolite's website.

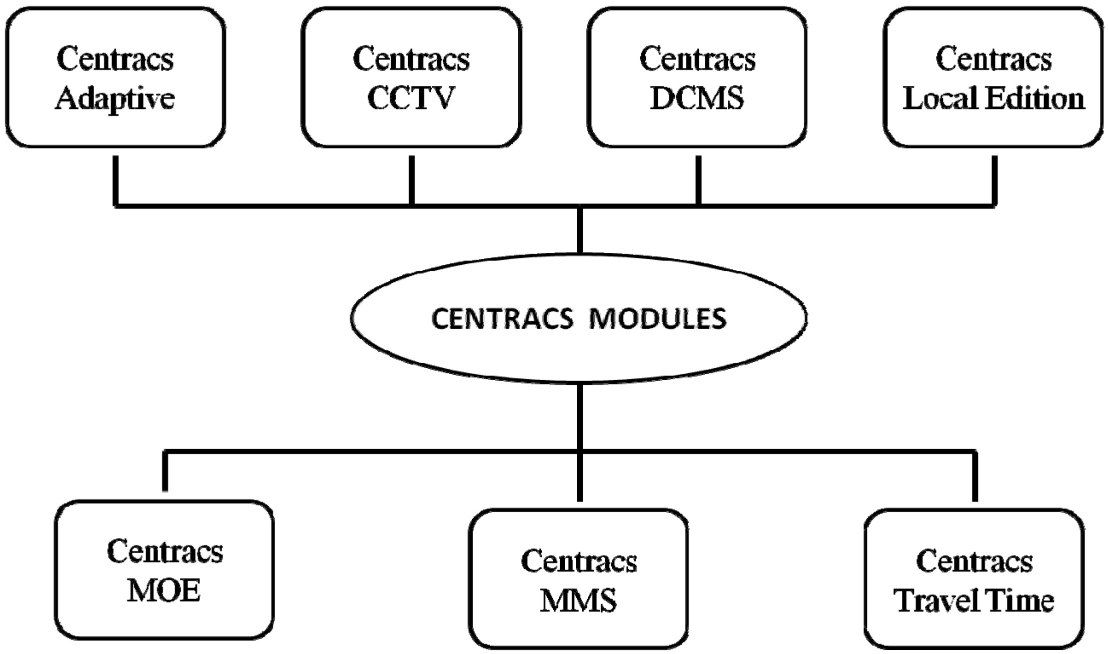

Figure 17
Centracs modules offered by Econolite

Data Retrieved by the Centracs Application

The Solo Terra Autoscopes are used primarily by the City of Baton Rouge for vehicle detection during the whole year. These Autoscopes can be incorporated in other applications as adaptive signals, and incident detection. However, for now they are used as 24/7 detection stations for 365 days of the year. They also provide real time surveillance tool for the intersection, providing the capability of monitoring the intersection at any time, which is essential whenever a problem occurs and visual inspection is needed.

A secondary use of these devices is traffic counting all year round. The counting reports generated by the Autoscopes via the Centracs provide the traffic counts per lane for each phase of the signal cycle for different types of movements (through, left, or right). These counts can be aggregated for every 15 minute period or any other period according to the user interest. The data generated by Centracs from these Autoscopes are automatically stored to a standard, ODBC-compliant SQL database system, which is used to store, retrieve, and maintain all system data and parameter files. Client (system user) workstations access network servers that perform traffic management, database management, and real-time traffic control and communications functions.

Data Accessibility and Security Measures

Centracs interfaces to many different field devices and operates easily using any type of communications media, including twisted pair and leased line cable, wireless, and single or multi-mode fiber optic cable. However, for security reasons, the SQL Server of the City of Baton Rouge is not connected to the internet. To sustain the physical safety of the data, it is located in a secure server room that is only accessible to a selected number of people. Only these people in the Advanced Traffic Management Center (ATMC) have access to the raw videos and the data provided by the Centracs. In the meantime, the City of Baton Rouge does not have any backups of the Centracs system data, in case of any system failure.

The data generated by the Centracs system is available for free to anyone who wants to use it, either for industrial or research purpose. The data is found on the City of Baton Rouge's website brgov.com. As mentioned before, due to the fact that the SQL Server is not connected to the internet, for security reasons, the data need to be manually pulled from Centracs and placed on the website on regular basis. Figure 18 depicts the sequence for the process of synthesizing data using Solo Terra Autoscopes.

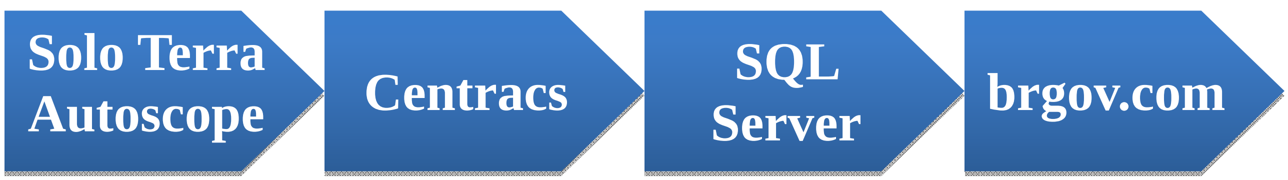

Figure 18
Process of synthesizing data using Solo Terra Autoscopes

The Econolite Autoscopes Cost Estimates

The project team contacted Econolite to obtain the cost for equipping a four-leg intersection with Autoscope cameras. Econolite mentioned that the Solo Terra Autoscope is no more offered, and has been replaced by the Encore Autoscope. The Encore Autoscope operates in similar way to the Solo Terra and fits within same system components. It can be considered as an up-to-date version of the Solo Terra Autoscopes.

Table 8 provides the total expected cost estimates for equipping a four-leg intersection with Encore Autoscopes. The table includes cost breakdown per item such that a cost estimate can be derived for any other intersection. The values in the table are the contract pricing as of October 2015, and they are expected to decrease slightly based on the purchased quantity.

Table 8
Video detection cost estimates breakdown for a four leg intersection

QTY	Autoscope Items	Each	Total
4	Encore Camera (replaced the Solo Terra camera)	$ 4,200	$ 16,800
4	Camera bracket	$ 55	$ 220
1000	Camera cable for foot	$ 0.69	$ 690
1	Terra Interface Panel	$ 750	$ 750
1	Terra Access Point	$ 2,100	$2,100
1	SDLC & TIP to TAP cable	$ 61	$61
Total Cost			$ 20,621

Data Analysis

The objective of this exercise was to determine the detection accuracy of the cameras, which was done by comparing the camera counts to the manual counts. The latter was referred to as the ground truth data and assumed to be free of any errors. Basic summary statistics were accumulated in order to assess the overall distribution of the camera accuracy. The percent error was used as the primary estimate for data analysis. This figure evaluated the difference between the actual volume counted manually and the volumes calculated using Econolite Autoscopes, as shown in the following equation:

$$\% \boldsymbol{Error} = \frac{\boldsymbol{Manual\ Count} - \boldsymbol{Camera\ Count}}{\boldsymbol{Manual\ Count}} * \mathbf{100} \qquad (4)$$

Multiple Logistic Regression (MLR) was then utilized to statistically assess whether the lighting, time of day, weather, lane configuration, or traffic volume variables could be used to predict how well the cameras recorded the amount of vehicles in the intersections. Following this test, the variables that were statistically significant and remained in the model were further analyzed using t-tests. This section describes the initial MLR test setup and the t-tests that followed.

Multiple Logistic Regression (MLR)

Logistic regression is frequently used in research to predict the probability that a particular outcome will occur. The outcome can either be a continuous-level variable or a dichotomous (binary) variable *[24]*. However, the outcomes are usually classified in a binary nature in

Logistic regression. In this case, the dependent variable is dichotomous and is coded as "1" if the event did occur and "0" if the event did not occur. During the analysis, the logistic function estimates the probability that specified event will occur as a function of unit change in the independent variable(s) *[25]*. The logistic function used to calculate the expected probability that Y=1 for a given value is shown in equation (5). In literature, logistic regression has been described as "conceptually analogous" to linear regression. This similarity is because a single dependent variable is predicted from either a single predictor has in simple logistic regression or multiple predictors (multiple logistic regression) *[24]*. In the logistic function displayed in equation (5), the $B_0 + B_1 X$ element is directly pulled from the equation for the regression line *[26]*.

$$\hat{p} = \frac{\exp(B_0 + B_1 X)}{1 + \exp(B_0 + B_1 x)} = \frac{e^{B_0 + B_1 x}}{1 + e^{B_0 + B_1 x}} \tag{5}$$

The intent of the analysis was to use five independent variables (lighting, time of day, weather, lane type, and traffic volume calculated from the manual count) to predict the camera accuracy. Since five independent variables were considered, multiple logistic regression (MLR) was used instead of simple logistic regression. SAS Enterprise Guide 5.1 was used to run the MLR utilizing the Backward Elimination Method. This means all five variables began in the model and they were removed one by one until all of the variables that remained produced F statistics significant at the significance level of 0.05.

The percent error was estimated for each intersection and this information was partitioned into two groups: percent error between 0-5% and percent error greater than 5%. It was assumed that 5% error in the Econolite Autoscopes was acceptable in practice, therefore up to 5% error was categorized in the same group as when no error was detected. These two groups were used to binary code the data where a "0" value represented all intersections that have percent error greater than 5% and a "1" designation coded all intersections that between 0-5% error between the manual counts and the cameras.

T-tests

The t-test can be used to test the statistical significance of mean differences between independent samples or correlated samples. Since the objective for this research was to compare the volume data obtained from cameras and counted manually, a paired t-test was used as the two data sets were correlated. The null hypothesis for each t-test assumed the means of the manual count and camera counts were equal. The level of significance for each case was set to 5% or 0.05. The t-statistic was calculated based on the equation shown in equation (6).

$$t = \frac{\bar{d}}{\sqrt{s^2/n}} \quad (6)$$

where,
$\bar{d}$ = mean difference between samples,
s^2 = sample variance, and
n = sample size.

Overall Distribution

Out of the 3,084 total records, 526 resulted in no camera error, or there was 0% difference between the ground truth manually counted volume and the camera counts. When there was a recorded difference between the ground truth and cameras, 43% showed the cameras overestimated the volume and 40% underestimated. A summary of the overall characteristics of the data examined are displayed in Table 9.

Table 9
Overall distribution summary

Distribution Summary	Number	Percentage
Total Records	3084	100%
Camera overestimated	1328	43%
Camera underestimated	1230	40%
No Difference	526	17%

When considering the percent error, almost a 25% of the total records had between 0-5% error, while more than 50% of the total records had over 10% error. Figure 20 depicts the overall distribution of the percent error.

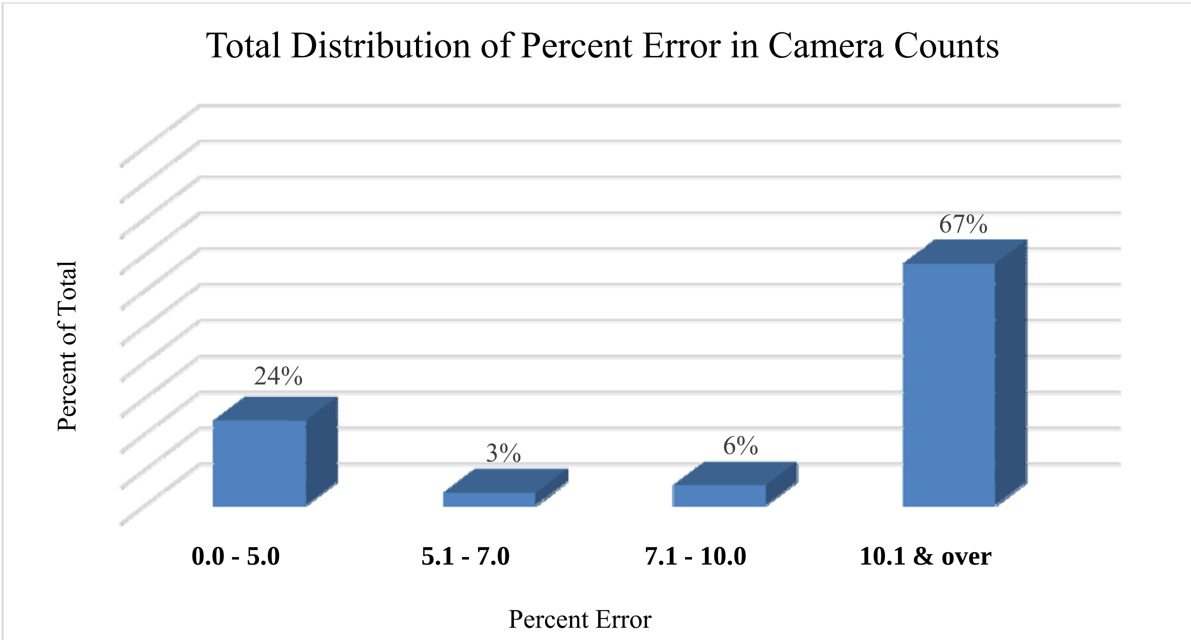

Figure 19
Total distribution of percent error in camera counts

In order to gain some insight into which locations showed statistical differences between the ground truth volume and the camera counts, a t-test was conducted for each intersection. Since the null hypothesis for each test was no difference between the datasets, a significant p-value (at alpha = 0.05) would determine which intersections showed statistical differences in the volume counts. Table 10 displays the results of the t-tests by intersection and Figure 21 summarizes these results as well. The red line on the figure represents the alpha value that separates intersections with significant differences from the ground truth from intersections without significant differences. Eight of the 20 intersections proved to have statistically different volume counts from the ground truth data. As 12 intersections from the sample (60%) indicated no statistical difference, it can be concluded that the Autoscopes are performing with reliable accuracy and the site calibration of the Autoscopes is the main cause of the difference across the rest of the sample.

Table 10
Results of t-test by intersection

Intersection	t-value	p-value	Conclusion
Florida at Sherwood	-0.01	0.9947	No Difference
Perkins at Acadian/Stanford	0.3	0.7677	No Difference
Florida at Stevendale	-0.3	0.7643	No Difference
Florida at Sharp	0.67	0.5034	No Difference
Florida at Flannery	0.91	0.3616	No Difference
Florida at 7th	-1.1	0.2721	No Difference
Goodwood at Chevelle	-1.3	0.1966	No Difference
Florida at 4th	1.44	0.1557	No Difference
Florida at Centerway	1.55	0.1246	No Difference
Florida at Monterrey	-1.56	0.1208	No Difference
Laurel at 4th	1.76	0.0855	No Difference
Laurel at 7th	-1.97	0.051	No Difference
Acadian at Hundred Oaks	1.98	0.0486	Different
Goodwood at Tara	2.27	0.0242	Different
Florida at Little John	-2.46	0.0157	Different
Millerville at S. Harrells Ferry	2.55	0.0117	Different
Central Throughway at O'Neal	-2.96	0.0034	Different
Florida at McGehee/Greenoaks	3.06	0.0025	Different
Florida at Oak Villa	3.51	0.0006	Different
Florida at Marilyn	3.89	0.0001	Different

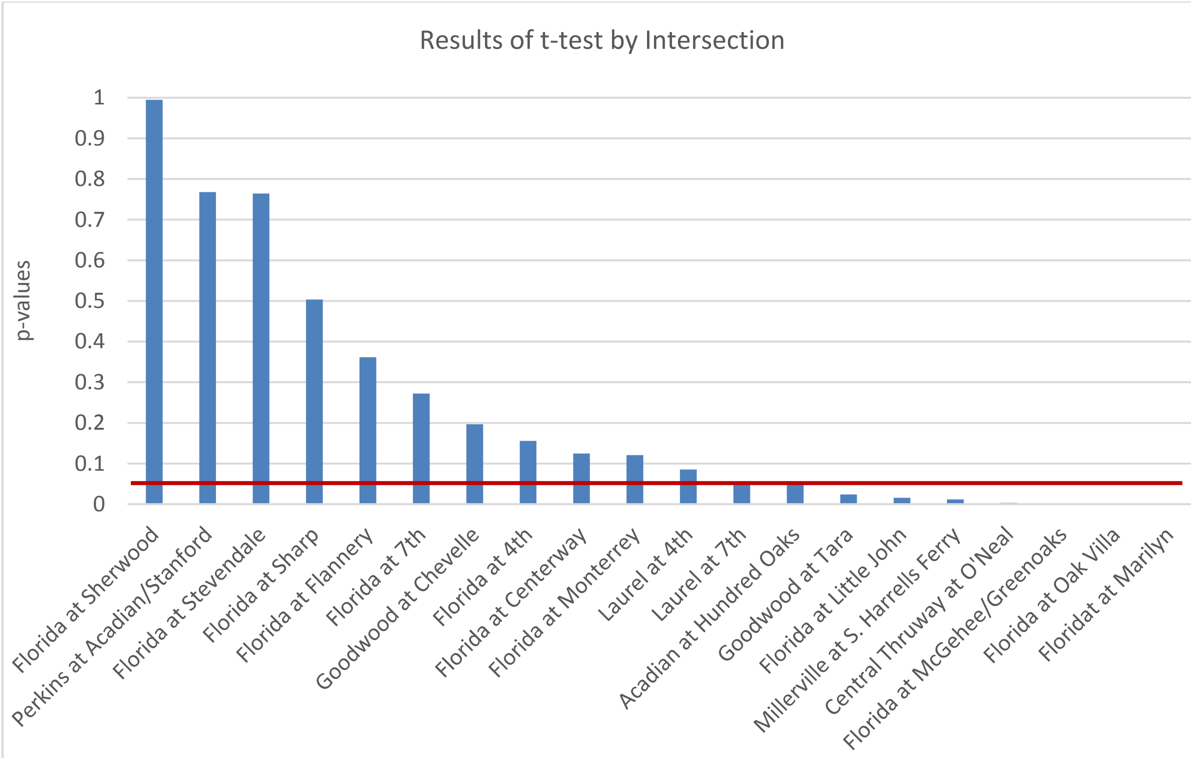

Figure 20
Results of t-test by intersection

The previous figure and table display there were statistical differences in the volume counts at some intersections. Although the t-test exploited these differences, the researchers were still unsure if associated factors such as the weather or lane configuration for example contributed to these inaccuracies. The MLR analysis was tasked to further explore the datasets and to determine if any associated factors contributed to the camera errors.

MLR Results

As stated in the previous section, the Backward Elimination Method was used to run the MLR. This method begins with all five variables input into the model and each removed until only variables that produced significant F-statistics at 0.05 significance level. Table 11 summarizes the results of the MLR. The effect types displayed in the table correspond to how each variable is represented in the model: main effects analyze the variable independently, interaction effects analyze the cross relationship between the two variables. For example the Manual Count Volume*Weather interaction variable examined both of these variables interacting at the same time. As shown in the table, time of day, lane type, and manual count variables remained in the model at the completion of the MLR. Due to this conclusion, those three variables were targeted in the next phase of the analysis.

Table 11
Summary of MLR results

Dependent Variables	Effect Type in Model	Time of Removal from Model	p-value at Removal Point
Manual Count Volume*Lane	Interaction	Removed 1st	0.2463
Lighting (shade or no shade at intersection)	Main	Removed 2nd	0.1530
Manual Count Volume*Weather	Interaction	Removed 3rd	0.1419
Weather	Main	Removed 4th	0.0748
Time of Day (hour)	Main	-	-
Lane Type	Main	-	-
Manual Count Volume	Main	-	-

T-test Results – Time of Day

Figure 22 depicts the results of the t-tests for the time variable. There was a statistical difference in the accuracy of the counts during six one-hour timeslots throughout the day. The statistical differences occurred during 6:00-7:00AM, 3:00-4:00PM, 4:00-5:00PM, 8:00-9:00PM, 9:00-10:00PM and 11:00PM-12:00AM.

The inaccuracies in the camera counts that occurred from 6:00-7:00AM (underestimated) and 3:00-5:00PM (underestimated) could be due to high traffic volumes the morning and afternoon peak periods. According to the distribution of the percent error during these times, the cameras underestimated the volume during both of these intervals. This supports the notion that the increase in traffic could result in the cameras missing some vehicles and therefore increasing the amount of error. The evening times where there were statistical differences (8:00-10:00PM and 11:00-12:00AM) could be explained by the darkness of the night. During the 9:00-10:00PM hour the cameras also underestimated the volume, this could be accounted for by the dark shadows that may appear if the cameras are pointed at a particular angle.

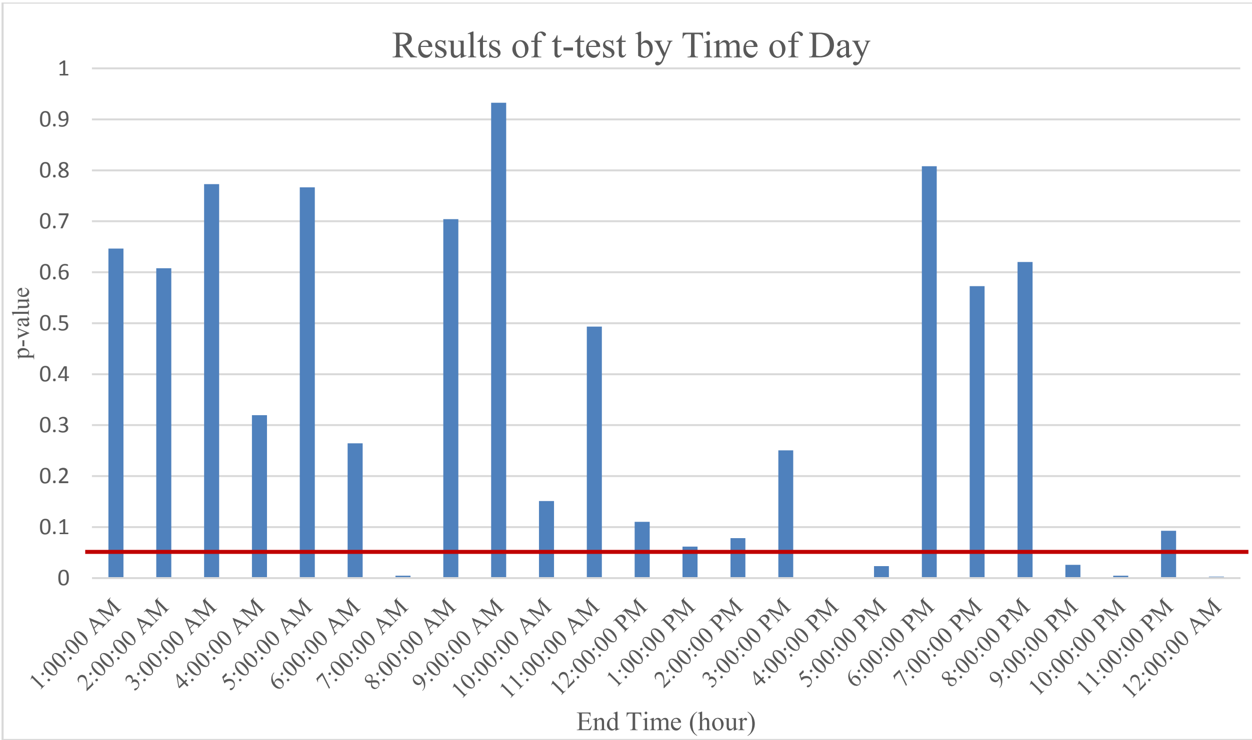

Figure 21
Summary of t-test Results by Time of Day

T-test Results – Lane Configuration

The t-test results analyzing lane configuration showed that there were statistical differences for the through lanes, right lanes, and shared right/through lanes. This finding was not expected, as the researchers hypothesized that the left lanes would have more camera errors due to the increased distance from the camera itself. Possible reasoning for this finding could be the opposite of what the researchers initially thought. Are the cameras better positioned to view the left lanes intentionally to ensure those lanes are not excluded from view? Or, maybe vehicles spend more time in the camera detection zone when they are turning left, waiting for a free space in traffic. If this were the case it would be logical that the left lane area would count the traffic more accurately. This finding can be attributed to the Autoscopes physical location as they were positioned on the traffic signals as nearest as possible to the left lanes. This positioning caused occlusion due to the angle of view for the detection at the lanes away from the left lanes. The further away the lanes are from the left lanes, the more occlusion is expected. This can be justified by the lower p-values seen for the right lanes compared to the through. Table 7 displays the results for the t-test of all lane types.

Table 12
Summary of t-test by lane configuration results

Lane Type	t-value	P-value	Conclusion
Through	2.95	0.0032	Different
Left	-0.34	0.7338	No Difference
Right	4.2	<0.0001	Different
Left/Through	-1.12	0.265	No Difference
Right/Through	4.72	<0.0001	Different
Left/Through/Right	-0.83	0.4092	No Difference

T-test Results – Volume

The manually counted data was used in order to assess the camera accuracy based on the volume. The manually counted volume was grouped into five categories: 0-50, 51-100, 101-150, 151-200, and 201-300 vehicles respectively. There proved to be statistical differences in the camera counts as the volume increased. Once the number of vehicles exceeded 100, the data revealed the statistical differences. However the p-value for the last group containing 201-300 vehicles was 0.0564, which means at an alpha level of 0.05 the null hypothesis cannot be rejected. Therefore for this amount of traffic there was not technically a statistical difference. Although not technically significant, 0.0564 is extremely close to the alpha level so the trend maintains despite this technicality. Table 8 displays the t- and p-values associated with this t-test.

Table 13
Summary of t-test by volume results

Volume	t-value	P-value	Conclusion
0-50	0.61	0.5414	No Difference
51-100	-1.7	0.091	No Difference
101-150	-3.85	0.0002	Different
151-200	-3.7	0.0005	Different
201-300	-2.11	0.0564	No Difference

CONCLUSIONS

The results of this research indicate that the performance of the Solo Terra Autoscopes was not consistent across the sample. Of the 20 intersections sampled, eight locations (40%) proved to show significant statistical differences between the manual counts and the camera counts. As 12 intersection (60% of the sample) indicated no significant statistical differences, the research team considered the drop in the performance of the Autoscopes at some intersections to be primarily due to poor calibration and maintenance of the video detection system. Further analyses showed that the performance of the Autoscopes varied with weather conditions, lane configuration, time of day, traffic volume, and lighting conditions. These factors were input into a Multiple Logistic Regression model using the Backwards Elimination Method to determine which factors significantly varied the cameras' performance. The results of the regression analysis showed only lane configuration, time of day, and traffic volumes were accounting for statistically significant variations in the performance of the Autoscopes.

According to supplemental t-test analysis on the time of day, the least accurate counts were recorded during 6:00-7:00 AM, 3:00-5:00 PM, 8:00-10:00 PM, and 11:00-12:00 AM. The missed counts occurring by the Autoscopes during 6:00-7:00 AM and 3:00-5:00 PM is expected as result of the morning and afternoon peak periods, where the Autoscopes experience the highest traffic volumes during the day. The difference in the counts from 8:00 to 10:00 PM and from 11:00 to 12:00 AM is explained by the darkness leading to missing a vehicle by the Autoscopes due to low light intensity. During low light intensity, the glare of the cars headlights become more visible and interrupts the images recorded by the Autoscopes. This compromises the detections significantly.

The t-test analysis on the volume results indicated worsened performance of the detection system as the traffic volumes increase. This comes in accordance with the drop in performance results during 6:00-7:00 AM, 3:00-5:00 PM, both periods within the morning and evening peak periods, respectively.

The t-test results analyzing lane configuration showed there were statistical differences for the through lanes, right lanes, and shared right/through lanes. The left movement provided the highest accuracy for detections, this can be due to vehicles spending more time in the camera detection zone when they are turning left, waiting for a gap in traffic. This finding can also be attributed to the Autoscopes physical location as they were positioned on the traffic signals as nearest as possible to the left lanes. This positioning causes occlusion due to the angle of view for the detection at the lanes away from the left lanes. The further away the lanes are from the left lanes, the more occlusion is expected. This can be justified by the lower p-values seen for the right lanes compared to the through.

The goal of this project was to investigate the effectiveness of Econolite's Autoscope video detection system in traffic data collection at signalized intersections in Baton Rouge. Due to the fact that 60% of the sampled intersections provided reliable performance under high traffic volumes and during the same study period and weather conditions as the remaining 40% that performed badly, the technology (or system) itself cannot be the source of the poor results. The primary function of the video system now is to detect, and not to count data. These two functions are two separate processes within Autoscope's functionality and while the cameras can perform both functions simultaneously, there is bound to be superior performance in one functionality over the other. Econolite had requested, prior to the beginning of this project, to fine-tune (recalibrate) the cameras for optimal traffic count accuracies. However, the research team declined this offer as it was believed it would defeat the purpose of the study. Considering the current performance of the system, the research team can conclude that recalibration of the Econolite Autoscopes can significantly enhance the performance of the video detection system, and the system can therefore be considered a reliable means for traffic counting.

RECOMMENDATIONS

The research team recommends that any traffic count data from the video detection systems should first be verified for accuracy. Since the results of this research displayed 40% of the cameras proved inaccurate in volume detection, it is best to verify all of the camera counted data to ensure the data is correct. Another recommendation would be to adopt a preventive maintenance schedule to improve the calibration of the cameras specifically for the identified variables proven to be the most critical. According to Econolite, many agencies perform annual or semi-annual preventive maintenance visits to the intersections where they are in use. During these visits, the electrical and mechanical aspects should be inspected to ensure proper installation, and operation of the cameras. Cleaning the Autoscope camera faceplate is also a recommended step during the maintenance visits. Specifically, inspection of the faceplate for fingerprints or dirt and cleaning using only water and a lint-free lens tissue or cloth. A full checklist of potential inspections procedures can be found in the document "How do I Correctly Maintain my Video Detection System," cited in the references section.

According to the findings of this study, the research team recommends the improvement of the lighting conditions at the intersections, as the low light intensity during night enhanced the occurrence of missed and false calls. A possible solution for compromising the adverts of occlusion is fixing the detection cameras at higher elevations at the intersections. This will provide better angle of view for the camera, especially for the outer lanes away from the location of the fixed cameras. However, more research will be needed to detect the optimal height providing the most acceptable accuracy with reasonable practical implementation.

Based on the results of the study, a final suggestion would be to evaluate the performance of the new Econolite Encore Autoscope as well as the existing Naztec cameras in order to perform a comparative study. The research team recommends this comparative study to include a detection system from Iteris and another one from Trafficon as well to detect the performance of these systems under same traffic conditions. The team recommends performing this study for different fixation heights to detect the impact of increasing the height on the accuracy of the systems. Finally, the team would recommend to perform the comparative analysis for these systems twice, first after installing and calibrating different systems, and another time after a period of several months, to detect any possible degradation in the performance of any of the systems.

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ADT	Average Daily Traffic
ATMC	Advanced Traffic Management Center
BIU	Bus Interface Unit
CCTV	Closed-Circuit TV
DOTD	Department of Transportation and Development
FHWA	Federal Highway Administration
FOV	Field of View
GUI	Graphical User Interface
HMED	Horizontal Moving Edge Detection
ITS	Intelligent Transportation System
IPA	Image Processing Algorithm
LAM	Lens Adjustment Module
LOS	Level of Service
LTRC	Louisiana Transportation Research Center
MnDOT	Minnesota Department of Transportation
MRF	Markov random field
MSHA	Maryland State Highway Administration
PRC	Project Review Committee
TAP	Terra Access Point
TIP	Terra Interface Panel
TMC	Transportation management centers
VDOT	Virginia Department of Transportation
VDT	Video Detection Technology

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APPENDIX A

Inventory of Intersections

Table A-1
ID of inventory intersection and type of installed cameras

ID	Main	Minor	No. of Autoscopes	Autoscope Counting	Manufacturer	Remote Access
1	ACADIAN	BAWELL	3	NO	Econolite	
2	ACADIAN	BROUSSARD	4	YES	Econolite	
3	ACADIAN	CLAYCUT	4	YES	Econolite	
4	ACADIAN	GOVERNMENT	4	YES	Econolite	
5	ACADIAN	HUNDRED OAKS	4	YES	Econolite	
6	ACADIAN	I-10	1	YES	Econolite	
7	ACADIAN	NORTH BLVD	4	NP	Econolite	
8	ACADIAN	RICHLAND PLANTATION/ ACADIAN CENTRE	1	YES	Econolite	
9	ACADIAN	WINBOURNE	4	NP	Econolite	
10	AIRLINE	BEECHWOOD	3	NO	Econolite	
11	AIRLINE	CEDARCREST	5	YES	Econolite	
12	AIRLINE	COURSEY / BLUEBONNET BLVD	4	NO	Econolite	
13	AIRLINE	DAWNADELE	4	NO	Econolite	
14	AIRLINE	EVANGELINE	1	NO	Econolite	
15	AIRLINE	FOSTER	1	NO	Econolite	
16	AIRLINE	GOODWOOD	4	NO	Econolite	
17	AIRLINE	GREENWELL ST	4	NO	Econolite	
18	AIRLINE	HAMMOND AIRE	4	NO	Econolite	
19	AIRLINE	INDUSTRIAL E / SAM'S	1	NO	Econolite	
20	AIRLINE	INDUSTRIPLEX / PECUE	4	YES	Econolite	
21	AIRLINE	INTERLINE	4	NO	Econolite	
22	AIRLINE	MERRYDALE	1	NO	Econolite	
23	AIRLINE	OLD HAMMOND	4	NO	Econolite	
24	AIRLINE	PRESCOTT	4	NO	Econolite	
25	AIRLINE	SHERWOOD	4	YES	Econolite	

		COMMONS				
26	AIRLINE	STUMBERG / PECUE	4	YES	Econolite	
27	AIRLINE	TOM	1	NO	Econolite	
28	AIRLINE	VINE / CONNELL'S VILLAGE	4	NO	Econolite	
29	ARDENWOOD	RENOIR	4	NP	Econolite	
30	ARDENWOOD	WINBOURNE	1	NO	Econolite	
31	BLOUNT	VETERAN'S MEMORIAL	4	YES	Econolite	
32	BLUEBONNET BLVD	BLUE CROSS	1	YES	Econolite	
33	BLUEBONNET BLVD	BURBANK	4	YES	Econolite	
34	BLUEBONNET BLVD	CELTIC	3	YES	Econolite	
35	BLUEBONNET BLVD	HIGHLAND	4	PARTIAL	Econolite	
36	BLUEBONNET BLVD	I-10	1	YES	Econolite	
37	BLUEBONNET BLVD	MALL DRIVE 1	7	YES	Econolite	
38	BLUEBONNET BLVD	MALL DRIVE 2 / PICARDY	7	YES	Econolite	
39	BLUEBONNET BLVD	MALL DRIVE 3	5	YES	Econolite	
40	BLUEBONNET BLVD	PARK ROWE	4	YES	Econolite	
41	BRIGHTSIDE	ALVIN DARK	3	YES	Econolite	
42	BURBANK	GARDERE	4	YES	Econolite	
43	BURBANK	LEE	4	YES	Econolite	
44	BURBANK	PARKER	4		Naztec	
45	BURBANK	STARING	3	YES	Econolite	
46	CAPITOL ACCESS	WEST HWY DR	3	YES	Econolite	
47	CENTRAL THROUGHWAY	FRENCHTOWN	4	YES	Econolite	
48	CHIPPEWA	I-110	6	NO	Naztec	
49	CHIPPEWA	SORREL	1	NP	Econolite	
50	CHOCTAW	CENTRAL THROUGHWAY	3	YES	Econolite	
51	CHOCTAW	FLANNERY	4	YES	Econolite	
52	CHOCTAW	MONTERREY	2	NP	Econolite	

53	COLLEGE	BANKERS / BAWELL	4	YES	Econolite	
54	COLLEGE	BENNINGTON / RABEY	4	YES	Econolite	
55	COLLEGE	CONCORD	4	YES	Econolite	
56	COLLEGE	CORPORATE	4	YES	Econolite	
57	COLLEGE	FOSTER	3	YES	Econolite	
58	COLLEGE	I-10 EB / CONSTITUTION	6	PARTIAL	Econolite	
59	COLLEGE	WOODSIDE	2	YES	Econolite	
60	CONVENTION	03RD ST	2	YES	Econolite	YES
61	CONVENTION	04TH ST	3	YES	Econolite	YES
62	CONVENTION	05TH ST	2	YES	Econolite	YES
63	CONVENTION	06TH ST	2	YES	Econolite	YES
64	CONVENTION	09TH ST	2	YES	Econolite	
65	CONVENTION	10TH ST	2	YES	Econolite	
66	CONVENTION	LAFAYETTE	2	YES	Econolite	YES
67	CORPORATE	TOWNE CENTER	4	YES	Econolite	
68	CORTANA PLACE	AIRWAY	4	YES	Econolite	
69	COURSEY	HICKORY RIDGE	1	NP	Econolite	
70	COURSEY	JONES CREEK	4	YES	Econolite	
71	COURSEY	LAKE SHERWOOD	4	YES	Econolite	
72	COURSEY	MARKET ST / WALMART	4	YES	Econolite	
73	COURSEY	ROYAL ASCOT / SOUTHPARK	4	YES	Econolite	
74	ESSEN	HENNESSY / SUMMA	2	NP	Econolite	
75	ESSEN	MARGARET ANN	1	YES	Econolite	
76	ESSEN	PICARDY	2	NP	Econolite	
77	ESSEN / STARING	PERKINS	4	YES	Econolite	
78	FLORIDA STREET	03RD ST	3	YES	Econolite	YES
79	FLORIDA STREET	04TH ST	4	YES	Econolite	YES
80	FLORIDA STREET	05TH ST	3	YES	Econolite	YES
81	FLORIDA STREET	06TH ST	3	YES	Econolite	YES
82	FLORIDA	07TH ST	4	YES	Econolite	YES

	STREET					
83	FLORIDA STREET	09TH ST	3	NP	Econolite	
84	FLORIDA STREET	10TH ST	4	YES	Econolite	
85	FLORIDA BLVD	BON CARRE	2	PARTIAL	Econolite	
86	FLORIDA BLVD	CENTERWAY	3	YES	Econolite	YES
87	FLORIDA BLVD	CHOCTAW / O'NEAL	4	YES	Econolite	YES
88	FLORIDA BLVD	FLANNERY	4	YES	Econolite	YES
89	FLORIDA BLVD	LAFAYETTE	3	YES	Econolite	
90	FLORIDA BLVD	LITTLE JOHN	4	YES	Econolite	YES
91	FLORIDA BLVD	LOBDELL	4	NP	Econolite	
92	FLORIDA BLVD	MARILYN	4	YES	Econolite	YES
93	FLORIDA BLVD	MCGEHEE / GREENOAKS	4	YES	Econolite	YES
94	FLORIDA BLVD	MONTERREY	4	YES	Econolite	YES
95	FLORIDA BLVD	OAK VILLA	4	YES	Econolite	YES
96	FLORIDA BLVD	RIVER RD	3	YES	Econolite	
97	FLORIDA BLVD	SHARP	4	YES	Econolite	YES
98	FLORIDA BLVD	SHERWOOD FOREST	4	YES	Econolite	YES
99	FLORIDA BLVD	STEVENDALE	4	YES	Econolite	YES
100	FLORLINE	CORTANA PLACE	4	YES	Econolite	
101	FOSTER	CLAYCUT	4	PARTIAL	Econolite	
102	GARDERE	GSRI	4		Econolite	
103	GOODWOOD	CHEVELLE	4	YES	Econolite	
104	GOODWOOD	EAST AIRPORT	4	YES	Econolite	
105	GOODWOOD	LOBDELL	4	YES	Econolite	
106	GOODWOOD	TARA	4	YES	Econolite	
107	GOVERNMENT	EAST BLVD	2	YES	Econolite	
108	GOVERNMENT	EDISON	2	NP	Econolite	
109	GOVERNMENT	FOSTER	4	YES	Econolite	
110	GOVERNMENT	I-110	2	YES	Econolite	
111	GOVERNMENT	ST CHARLES	1	YES	Econolite	
112	GOVERNMENT	ST FERDINAND	2	YES	Econolite	
113	GOVERNMENT	ST LOUIS	1	YES	Econolite	
114	GOVERNMENT	ST PHILLIP	3	NO	Econolite	
115	GREENWELL SPRINGS	CAPITOL MIDDLE	3	YES	Econolite	
116	GREENWELL SPRINGS	CENTRAL THROUGHWAY	4		Econolite	
117	GREENWELL	JOOR / OAK	4	NP	Econolite	

	SPRINGS	VILLA				
118	GREENWELL SPRINGS	JOYCE	2	NP	Econolite	
119	GREENWELL SPRINGS	LANIER	4	NP	Econolite	
120	GREENWELL SPRINGS	MONTERREY	3	PARTIAL	Econolite	
121	GREENWELL SPRINGS	PAULSON	4	YES	Econolite	
122	GREENWELL SPRINGS	PLATT	2	YES	Econolite	
123	GREENWELL SPRINGS	RIDGEMONT	2	PARTIAL	Econolite	
124	GREENWELL SPRINGS	SHERWOOD FOREST	2	PARTIAL	Econolite	
125	GREENWELL SPRINGS	WOODDALE	3	PARTIAL	Econolite	
126	GREENWELL ST	SILVERLEAF	4	NO	Econolite	
127	HARDING	ATMC	4	YES	Econolite	
128	HARDING	HOWELL BLVD	3	NO	Econolite	
129	HARRELL'S FERRY	JONES CREEK	4	YES	Econolite	
130	HARRELL'S FERRY	MILLERVILLE	3	YES	Econolite	
131	HIGHLAND	FIRE STATION / ASTER	3	YES	Econolite	
132	HIGHLAND	GARDERE	1	YES	Econolite	
133	HIGHLAND	KENILWORTH	4	YES	Econolite	
134	HIGHLAND	LEE	4	NP	Econolite	
135	HIGHLAND	SIEGEN / BURBANK	4	YES	Econolite	
136	HIGHLAND	SOUTH BLVD / ST FERDINAND	4	YES	Econolite	
137	HIGHLAND	STARING	4	YES	Econolite	
138	JEFFERSON	CORPORATE / OLD HAMMOND	4	YES	Econolite	
139	JEFFERSON	ESSEN	1	NO	Econolite	
140	JEFFERSON	LOBDELL	3	NP	Econolite	
141	JEFFERSON	TOWNE CENTER	4	YES	Econolite	
142	JEFFERSON	WRENWOOD / OFFICE PARK	1	NO	Econolite	
143	JONES CREEK	SHENANDOAH	4	YES	Econolite	
144	JOOR	CORE LN	4	YES	Econolite	
145	LAUREL	03RD ST	2	YES	Econolite	YES

146	LAUREL	04TH ST	3	YES	Econolite	YES
147	LAUREL	05TH ST	2	YES	Econolite	YES
148	LAUREL	06TH ST	2	YES	Econolite	YES
149	LAUREL	07TH ST	3	YES	Econolite	YES
150	LAUREL	09TH ST	2	YES	Econolite	
151	LAUREL	10TH ST	2	YES	Econolite	
152	LAUREL	LAFAYETTE	2	YES	Econolite	YES
153	MAIN	03RD ST	2	YES	Econolite	YES
154	MAIN	04TH ST	3	YES	Econolite	YES
155	MAIN	05TH ST	2	YES	Econolite	YES
156	MAIN	06TH ST	2	YES	Econolite	YES
157	MAIN	07TH ST	3	YES	Econolite	YES
158	MAIN	09TH ST	2	YES	Econolite	
159	MAIN	10TH ST	2	YES	Econolite	
160	MAIN	LAFAYETTE	2	YES	Econolite	YES
161	MALL OF LOUISIANA	I-10	2	YES	Econolite	
162	MALL OF LOUISIANA	MALL DRIVE 1	4	YES	Econolite	
163	MALL OF LOUISIANA	RAVE THEATER	3	YES	Econolite	
164	MILLERVILLE	AVALON	4	YES	Econolite	
165	MILLERVILLE	TARGET / SPRINGRIDGE	4	NP	Econolite	
166	MILLERVILLE	WELDWOOD	4	YES	Econolite	
167	NICHOLSON	GARDERE	4		Naztec	
168	NICHOLSON	JENNIFER JEAN / BOB PETTIT	2	YES	Econolite	
169	NICHOLSON	ROOSEVELT	4	NO	Econolite	
170	NICHOLSON / ST LOUIS	SOUTH BLVD	7	YES	Econolite	
171	NORTH BLVD	05TH ST / ST CHARLES	4	YES	Econolite	
172	NORTH BLVD	09TH / 10TH	7	PARTIAL	Econolite	
173	NORTH BLVD	19TH ST	4	YES	Econolite	
174	NORTH BLVD	22ND ST	4	NP	Econolite	
175	NORTH ST	03RD ST	2	YES	Econolite	YES
176	NORTH ST	04TH ST	3	YES	Econolite	YES
177	NORTH ST	05TH ST	2	YES	Econolite	YES
178	NORTH ST	06TH ST	2	YES	Econolite	YES
179	NORTH ST	09TH ST	2	YES	Econolite	
180	NORTH ST	10TH ST	2	YES	Econolite	
181	NORTH ST	LAFAYETTE	2	YES	Econolite	YES

182	NORTH ST	RIVER RD	4	YES	Econolite	
183	OAK VILLA	CROSSWAY	3	YES	Econolite	
184	OLD HAMMOND	CEDARCREST / SHARP	4	YES	Econolite	
185	OLD HAMMOND	CHEVELLE	1	YES	Econolite	
186	OLD HAMMOND	DRUSILLA	4	NP	Econolite	
187	OLD HAMMOND	HARRELL'S FERRY	2	YES	Econolite	
188	OLD HAMMOND	MILLERVILLE	3	YES	Econolite	
189	OLD HAMMOND	SHERWOOD FOREST	4	YES	Econolite	
190	O'NEAL	BRISTOE	1	NO	Econolite	
191	O'NEAL	FIREWOOD	1	NO	Econolite	
192	O'NEAL	GEORGE O'NEAL	4	YES	Econolite	
193	O'NEAL	HOBBY LOBBY / OLD LONDON TOWNE	4	YES	Econolite	
194	O'NEAL	I-12	4	YES	Econolite	
195	O'NEAL	MEDICAL CENTER	2	NO	Econolite	
196	O'NEAL	WALMART	3	NO	Econolite	
197	PERKINS	ACADIAN / STANFORD	4	YES	Econolite	YES
198	PERKINS	BALIS / STUART	3	PARTIAL	Econolite	
199	PERKINS	BLUEBONNET BLVD	4	YES	Econolite	
200	PERKINS	COLLEGE / LEE	4	YES	Econolite	
201	PERKINS	GRAND	4	YES	Econolite	
202	PERKINS	GREAT OAKS / WIMBLEDON	4	YES	Econolite	
203	PERKINS	OAKDALE	4	YES	Econolite	
204	PERKINS	PECUE	4	YES	Econolite	
205	PERKINS	WINDERMERE / YMCA	4	YES	Econolite	
206	PICARDY	MEDICAL CENTER	4	YES	Econolite	
207	PLANK	72ND AV / MONARCH	4	NO	Econolite	
208	PLANK	COKE PLANT	2	PARTIAL	Econolite	
209	PLANK	HARDING	4	NP	Econolite	
210	PLANK	MOHICAN	2	NO	Econolite	
211	PLANK	ST GERARD / TONY'S	3	NO	Econolite	

212	RIVER RD	CASINO	1	YES	Econolite	
213	RIVER RD	CENTROPLEX CRSWLK	2	YES	Econolite	
214	RIVER RD	LAUREL	3	YES	Econolite	
215	RIVER RD	NORTH BLVD	3	YES	Econolite	
216	RIVER RD	RIVER PARK	3	YES	Econolite	
217	SCENIC	72ND AV / MENGEL	1	NO	Econolite	
218	SCENIC	LA 19 / SCOTLAND	3	NO	Econolite	
219	SHERWOOD FOREST	COURSEY	4	YES	Econolite	
220	SHERWOOD FOREST	HARRELL'S FERRY S / MEAD	4	YES	Econolite	
221	SHERWOOD FOREST	I-12	6	YES	Econolite	
222	SHERWOOD FOREST	LAKE SHERWOOD	4	YES	Econolite	
223	SHERWOOD FOREST	NEWCASTLE	2	YES	Econolite	
224	SIEGEN	CLOVERLAND	4	YES	Econolite	
225	SIEGEN	MALL DRIVE/KINGLET	4	YES	Econolite	
226	SIEGEN	OAK HILLS N	4	YES	Econolite	
227	SIEGEN	RIEGER	4	PARTIAL	Econolite	
228	SOUTH BLVD	ST PHILLIP	3	YES	Econolite	
229	SPANISH TOWN	09TH ST	3	YES	Econolite	
230	STANFORD	HYACINTH / LAKESHORE E	4	NO	Econolite	
231	STANFORD	LAKESHORE W / LSU AVE	3	NO	Econolite	
232	STANFORD	MORNING GLORY	4	NO	Econolite	
233	STARING	HYACINTH	4	NO	Econolite	
234	SULLIVAN	LOVETT	4	YES	Econolite	
235	SULLIVAN	WAX	4	YES	Econolite	

Table A-2
Volume data for the inventory of intersections

	MAJOR			MAJOR supplemental			MINOR			MINOR supplemental		
ID	ADT	Year	Dir.	ADT	Year	Dir.	ADT	Year	Dir.	ADT	Year	Dir.
1	26,945	2011	S	-	-	-	7,688	2005	E	-	-	-
2	23,188	2005	S	15,777	2005	N	5,766	2005	W	3,253	2005	E
3	15,777	2005	S	15,608	2005	N	7,307	2005	E	-	-	-
4	15,777	2005	S	15,608	2005	N	20,249	2011	W	21,298	2011	E
5	23,188	2005	S	-	-	-	-	-	-	-	-	-
6	25,678	2011	S	26,945	2011	N	129,942	2011	W	142,715	2011	E
7	15,608	2005	S	9,350	2005	N	9,029	2005	E	-	-	-
8												
9	8,863	2005	S	8,125	2005	N	7,965	2005	W	11,620	2005	E
10	43,060	2011	E	34,083	2011	W	-	-	-	-	-	-
11	63,999	2011	NW	43,951	2011	SE	8,523	2005	N	-	-	-
12	63,999	2011	NW	43,951	2011	SE	47,452	2005	E	-	-	-
13	63,999	2011	NW	43,951	2011	SE	-	-	-	-	-	-
14	46,899	2011	S	-	-	-	3,184	2005	W	-	-	-
15	43,060	2011	W	-	-	-	6,802	2005	S	-	-	-
16	66,417	2011	NW	54,851	2011	SE	22,513	2005	W	16,266	2005	E
17	43,060	2011	NW	46,899	2011	SE	10,425	2005	W	18,403	2005	E
18	63,999	2011	SE	66,419	2011	NW	-	-	-	-	-	-
19	48,825	2011	NW	54,145	2011	SE	-	-	-	-	-	-
20	37,575	2011	NW	31,538	2011	SE	-	-	-	-	-	-
21	63,999	2011	NW	43,951	2011	SE	-	-	-	-	-	-
22	43,060	2011	NW	46,899	2011	SE	1,883	2007	E	-	-	-
23	54,851	2011	NW	63,999	2011	SE	22,551	2011	W	23,086	2011	E
24	46,899	2011	NW	51,091	2011	SE	9,683	2005	W	5,460	2005	E
25	53,863	2011	NW	37,575	2011	SE	-	-	-	-	-	-
26	37,575	2011	NW	31,538	2011	SE	-	-	-	-	-	-
27	54,145	2011	SE	48,825	2011	NW	9,275	2005	NE	9,075	2005	SW
28	66,419	2011	NW	54,851	2011	SE	-	-	-	-	-	-
29	13,380	2005	N	12,345	2005	S	3,585	2005	E	-	-	-
30	8,712	2005	S	-	-	-	8,929	2005	E	14,889	2005	W
31	4,625	2007	W	-	-	-	-	-	-	-	-	-
32	44,132	2007	SW	-	-	-	-	-	-	-	-	-
33	34,250	2011	NE	-	-	-	21,620	2011	NW	-	-	-
34	44,132	2007	SW	-	-	-	-	-	-	-	-	-
35	34,250	2011	NE	-	-	-	11,740	2011	NW	16,139	2011	SE
36	44,132	2007	SW	-	-	-	99,400	2011	NW	73,329	2011	SE
37	44,132	2007	SW	-	-	-	-	-	-	-	-	-

38	44,132	2007	SW	-	-	-	-	-	-	-	-	-
39	44,132	2007	SW	-	-	-	-	-	-	-	-	-
40	47,235	2011	NE	34,250	2011	SW	-	-	-	-	-	-
41	23,051	2005	E	7,144	2005	W	-	-	-	-	-	-
42	23,166	2011	NW	21,620	2011	SE	11,550	2011	NE	9,258	2005	SW
43	22,406	2011	NW	23,166	2011	SE	22,425	2005	SW	31,572	2005	NE
44	17,357	2011	NW	22,406	2011	SE	7,255	2005	NE	-	-	-
45	23,166	2011	SE	-	-	-	-	-	-	-	-	-
46	3,703	2011	W	1,199	2007	E	-	-	-	-	-	-
47	-	-	-	-	-	-	-	-	-	-	-	-
48	10,362	2011	W	-	-	-	71,046	2011	N	66,231	2011	S
49	7,645	2005	W	12,753	2011	E	3,165	2005	S	-	-	-
50	-	-	-	-	-	-	-	-	-	-	-	-
51	15,936	2005	W	15,750	2005	SE	13,817	2007	N	12,253	2005	S
52	20,241	2005	W	22,829	2005	E	17,592	2007	N	10,214	2005	S
53	29,402	2005	SW	-	-	-	-	-	-	-	-	-
54	26,659	2007	SW	29,402	2005	NE	24,561	2007	NW	-	-	-
55	26,659	2007	NE	28,177	2007	SW	-	-	-	-	-	-
56	29,402	2005	NE	26,659	2007	SW	33,675	2005	E	-	-	-
57	9,122	2005	NE	-	-	-	15,435	2005	NW	-	-	-
58	26,659	2007	SW	29,402	2005	NE	-	-	-	-	-	-
59	29,402	2005	SW	-	-	-	-	-	-	-	-	-
60	5,451	2007	E	-	-	-	5,155	2007	N	-	-	-
61	5,451	2007	W	-	-	-	6,114	2005	N	-	-	-
62	5,451	2007	W	-	-	-	-	-	-	-	-	-
63	5,451	2007	W	-	-	-	-	-	-	-	-	-
64	5,451	2007	W	-	-	-	4,060	2005	S	-	-	-
65	5,451	2007	W	-	-	-	4,872	2005	S	-	-	-
66	5,451	2007	E	-	-	-	-	-	-	-	-	-
67	33,675	2005	W	-	-	-	-	-	-	-	-	-
68	5,344	2005	NW	-	-	-	-	-	-	-	-	-
69	23,703	2007	E	34,119	2005	W	-	-	-	-	-	-
70	34,119	2005	W	23,703	2007	E	20,755	2005	N	-	-	-
71	34,119	2005	W	-	-	-	-	-	-	-	-	-
72	34,119	2005	W	23,703	2007	E	-	-	-	-	-	-
73	24,052	2005	E	47,452	2005	W	-	-	-	-	-	-
74	-	-	-	-	-	-	544	2005	E	-	-	-
75	-	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	-	-	5,018	2005	W	-	-	-
77	23,468	2005	SW	-	-	-	29,523	2011	SE	38,610	2005	NW
78	5,495	2011	W	-	-	-	5,155	2007	N	-	-	-
79	5,495	2011	W	-	-	-	6,114	2005	N	-	-	-
80	5,495	2011	W	-	-	-	-	-	-	-	-	-

81	5,495	2011	W	-	-	-	-	-	-	-	-	-
82	5,495	2011	W	-	-	-	-	-	-	-	-	-
83	5,495	2011	W	-	-	-	4,060	2005	S	-	-	-
84	5,495	2011	W	-	-	-	4,872	2005	S	-	-	-
85												
86	47,743	2011	W	35,511	2011	E	-	-	-	-	-	-
87	21,925	2011	W	23,650	2011	E	22,123	2005	S	-	-	-
88	27,678	2011	W	21,925	2011	E	12,253	2005	N	11,874	2005	S
89	5,495	2011	E	-	-	-	-	-	-	-	-	-
90	35,511	2011	W	27,678	2011	E	3,241	2005	S	-	-	-
91	47,949	2011	E	38,605	2011	W	15,949	2005	N	13,620	2005	S
92	47,743	2011	W	35,511	2011	E	-	-	-	-	-	-
93	47,743	2011	W	35,511	2011	E	-	-	-	-	-	-
94	47,743	2011	W	35,511	2011	E	10,214	2005	N	-	-	-
95	47,743	2011	W	35,511	2011	E	-	-	-	-	-	-
96	5,495	2011	E	-	-	-	10,784	2011	N	10,632	2011	S
97	47,743	2011	W	35,511	2011	E	13,546	2005	S	-	-	-
98	35,511	2011	W	27,678	2011	E	23,943	2005	S	24,893	2005	N
99	21,925	2011	W	23,650	2011	E	2,457	2005	S	4,232	2005	N
100	-	-	-	-	-	-	-	-	-	-	-	-
101	14,886	2005	N	15,435	2005	S	8,436	2005	E	-	-	-
102	9,258	2005	SW	-	-	-	5,696	2005	NE	-	-	-
103	20,041	2005	W	22,513	2005	E	-	-	-	-	-	-
104	20,041	2005	W	22,513	2005	E	-	-	-	-	-	-
105	73	2005	W	20,041	2005	E	-	-	-	-	-	-
106	20,041	2005	W	22,513	2005	E	16,946	2005	S	-	-	-
107	26,434	2011	E	-	-	-	3,720	2007	S	-	-	-
108	21,298	2011	E	20,249	2011	W	-	-	-	-	-	-
109	24,192	2011	E	21,298	2011	W	14,886	2005	S	-	-	-
110	14,967	2011	W	26,434	2011	E	78,381	2011	S	71,710	2011	N
111	26,434	2011	E	-	-	-	-	-	-	-	-	-
112	26,434	2011	E	-	-	-	-	-	-	-	-	-
113	26,434	2011	E	-	-	-	13,119	2005	S	-	-	-
114	26,434	2011	E	-	-	-	16,018	2011	S	-	-	-
115	24,856	2011	NE	-	-	-	20,690	2005	N	-	-	-
116	-	-	-	-	-	-	-	-	-	-	-	-
117	32,684	2011	NE	12,510	2011	SW	27,372	2011	N	-	-	-
118	12,510	2011	NE	18,544	2011	SW	-	-	-	-	-	-
119	18,544	2011	NE	20,492	2011	SW	5,090	2005	N	-	-	-
120	32,684	2011	SW	24,932	2011	NE	17,592	2007	S	-	-	-
121	24,856	2011	NE	-	-	-	-	-	-	-	-	-
122	32,684	2011	SW	24,932	2011	NE	-	-	-	-	-	-
123	32,684	2011	SW	24,932	2011	NE	-	-	-	-	-	-

124	32,684	2011	SW	24,932	2011	NE	12,453	2005	S	-	-	-
125	24,856	2011	NE	-	-	-	10,921	2005	S	-	-	-
126	18,403	2005	W	7,176	2005	E	15,670	2005	N	-	-	-
127												
128	18,439	2011	W	33,443	2011	E	-	-	-	-	-	-
129	19,929	2008	W	13,728	2005	E	24,487	2005	S	-	-	-
130	19,929	2008	E	-	-	-	19,450	2005	N	-	-	-
131	17,298	2005	S	13,366	2005	N	-	-	-	-	-	-
132	11,740	2011	SE	19,813	2011	NW	11,550	2011	SW	-	-	-
133	19,813	2011	SE	-	-	-	13,750	2005	NE	-	-	-
134	20,550	2005	SE	19,180	2005	NW	28,928	2005	NE	31,572	2005	SW
135	16,139	2011	SE	11,740	2011	NW	19,421	2011	NE	-	-	-
136	12,426	2005	S	-	-	-	5,856	2005	W	-	-	-
137	19,813	2011	SE	-	-	-	15,047	2005	NE	-	-	-
138	33,922	2011	NW	37,059	2011	SE	17,105	2011	E	-	-	-
139	37,059	2011	NW	36,941	2011	SE	42,108	2008	SW	-	-	-
140	33,922	2011	SE	19,188	2011	NW	-	-	-	-	-	-
141	33,922	2011	SE	19,188	2011	NW	-	-	-	-	-	-
142	37,059	2011	NW	36,941	2011	SE	-	-	-	-	-	-
143	20,755	2005	N	-	-	-	-	-	-	-	-	-
144	5,325	2011	N	5,566	2005	S	-	-	-	-	-	-
145	1,393	2005	E	-	-	-	5,155	2007	S	-	-	-
146	1,393	2005	E	-	-	-	6,114	2005	S	-	-	-
147	1,393	2005	E	-	-	-	-	-	-	-	-	-
148	1,393	2005	E	-	-	-	-	-	-	-	-	-
149	1,393	2005	E	-	-	-	-	-	-	-	-	-
150	1,393	2005	E	-	-	-	4,060	2005	S	-	-	-
151	1,393	2005	E	-	-	-	4,872	2005	S	-	-	-
152	1,393	2005	E	-	-	-	-	-	-	-	-	-
153	-	-	-	-	-	-	5,155	2007	S	-	-	-
154	-	-	-	-	-	-	6,114	2005	S	-	-	-
155	-	-	-	-	-	-	-	-	-	-	-	-
156	-	-	-	-	-	-	-	-	-	-	-	-
157	-	-	-	-	-	-	-	-	-	-	-	-
158	-	-	-	-	-	-	4,060	2005	S	-	-	-
159	-	-	-	-	-	-	4,872	2005	S	-	-	-
160	-	-	-	-	-	-	-	-	-	-	-	-
161	-	-	-	-	-	-	73,329	2011	NW	82,979	2001	SE
162	-	-	-	-	-	-	-	-	-	-	-	-
163	-	-	-	-	-	-	-	-	-	-	-	-
164	13,730	2005	N	19,450	2005	S	-	-	-	-	-	-
165	13,730	2005	N	19,450	2005	S	-	-	-	-	-	-
166	13,730	2005	N	19,450	2005	S	-	-	-	-	-	-

167	12,199	2011	NW	14,384	2008	SE	2,764	2011	SW	9,258	2005	NE
168	29,570	2011	NW	23,051	2005	SE	14,277	2005	SW	-	-	-
169	20,891	2011	N	29,570	2011	S	1,966	2005	W	4,168	2005	E
170	20,891	2011	S	13,119	2005	N	5,856	2005	W	-	-	-
171	7,378	2007	E	3,653	1994	W	-	-	-	-	-	-
172	7,378	2007	E	3,653	1994	W	4,060	2005	NW	6,280	2005	SE
173	7,057	1994	W	-	-	-	-	-	-	-	-	-
174	7,057	1994	W	-	-	-	7,913	2005	S	-	-	-
175	-	-	-	-	-	-	5,155	2007	S	-	-	-
176	-	-	-	-	-	-	6,114	2005	S	-	-	-
177	-	-	-	-	-	-	-	-	-	-	-	-
178	-	-	-	-	-	-	-	-	-	-	-	-
179	-	-	-	-	-	-	4,060	2005	S	-	-	-
180	-	-	-	-	-	-	4,872	2005	S	-	-	-
181	-	-	-	-	-	-	-	-	-	-	-	-
182	-	-	-	-	-	-	10,784	2011	S	-	-	-
183	-	-	-	-	-	-	-	-	-	-	-	-
184	23,086	2011	E	-	-	-	18,101	2005	N	-	-	-
185	22,551	2011	E	17,105	2011	W	-	-	-	-	-	-
186	22,551	2011	E	17,105	2011	W	15,782	2005	S	-	-	-
187	23,086	2011	E	-	-	-	9,893	2005	SE	-	-	-
188	-	-	-	-	-	-	13,730	2005	S	-	-	-
189	23,086	2011	SW	-	-	-	36,153	2005	S	-	-	-
190	20,250	2011	N	26,795	2011	S	-	-	-	-	-	-
191	26,795	2011	N	16,725	2005	S	-	-	-	-	-	-
192	16,725	2005	N	-	-	-	23,703	2008	W	-	-	-
193	20,250	2011	N	26,795	2011	S	-	-	-	-	-	-
194	20,250	2011	N	26,795	2011	S	88,599	2011	SW	85,322	2008	NE
195	20,250	2011	N	26,795	2011	S	-	-	-	-	-	-
196	20,250	2011	N	26,795	2011	S	-	-	-	-	-	-
197	23,956	2011	NW	25,678	2011	SE	27,136	2005	SW	23,188	2005	NW
198	25,678	2011	NW	31,365	2011	SE	9,706	2005	NE	-	-	-
199	29,523	2011	NW	-	-	-	47,235	2011	NE	34,250	2011	SW
200	25,678	2011	NW	31,365	2011	SE	24,992	2005	SW	28,177	2007	NE
201	29,523	2011	NW	-	-	-	-	-	-	-	-	-
202	-	-	-	-	-	-	-	-	-	-	-	-
203	-	-	-	-	-	-	-	-	-	-	-	-
204	14,760	2011	NW	-	-	-	3,090	2005	SW	6,167	2005	NE
205	14,760	2011	NW	-	-	-	-	-	-	-	-	-
206	5,018	2005	NW	-	-	-	-	-	-	-	-	-
207	19,034	2011	SW	24,315	2011	NE	2,473	2005	E	-	-	-
208	30,012	2011	SW	-	-	-	-	-	-	-	-	-
209	24,315	2011	SW	30,012	2011	NE	33,443	2011	W	27,726	2011	E

210	13,772	2011	SW	18,420	2011	NE	5,933	2005	W	10,417	2005	E
211	18,420	2011	SW	20,466	2011	NE	-	-	-	-	-	-
212	7,577	2011	N	10,784	2011	S	-	-	-	-	-	-
213	10,632	2011	N	-	-	-	-	-	-	-	-	-
214	7,577	2011	N	10,784	2011	S	-	-	-	-	-	-
215	10,784	2011	N	10,632	2011	S	7,378	2007	E	-	-	-
216												
217	20,310	2011	SE	16,832	2011	NW	1,280	2005	W	1,993	2005	E
218	16,832	2011	SE	7,244	2011	NW	7,174	2011	NE	-	-	-
219	33,945	2005	S	43,356	2005	N	24,052	2005	W	34,119	2005	E
220	47,590	2005	S	36,153	2005	N	9,893	2005	W	9,404	2005	E
221	53,337	2005	SE	47,590	2005	NW	101,028	2011	SW	92,257	2011	NE
222	43,356	2005	S	53,337	2005	N	-	-	-	-	-	-
223	43,356	2005	S	53,337	2005	N	3,512	2005	E	-	-	-
224	45,468	2007	NE	34,961	2011	SW	-	-	-	-	-	-
225	34,961	2011	NE	19,421	2011	SW	-	-	-	-	-	-
226	14,455	2005	SW	19,421	2011	NE	370	2005	NW	-	-	-
227	34,961	2011	NE	19,421	2011	SW	-	-	-	-	-	-
228	5,856	2005	W	-	-	-	16,018	2011	N	-	-	-
229	10,553	2007	E	-	-	-	9,651	2005	N	-	-	-
230	27,136	2005	NE	31,675	2005	SW	-	-	-	-	-	-
231	31,675	2005	NE	-	-	-	16,457	2005	NW	-	-	-
232	27,136	2005	NE	31,675	2005	SW	-	-	-	-	-	-
233	23,468	2005	NE	15,047	2005	SW	-	-	-	-	-	-
234	14,862	2011	S	21,644	2011	N	-	-	-	-	-	-
235	14,862	2011	S	21,644	2011	N	17,303	2011	E	-	-	-

Table A-3
Camera orientation, lighting and shade data for the inventory of intersections

	Camera Orientation								Lighting		Significant Shade	
ID	N	S	E	W	NE	SE	NW	SW	Street	Intersection	Trees	Structure
1		1			1		1		Yes	Yes	No	Yes
2	1	1	1	1					Yes	No	No	No
3	1	1	1	1					Yes	Yes	No	No
4	1	1	1	1					Yes	No	No	No
5	1	1	1	1					Yes	Yes	Yes	No
6		1							Yes	No	No	No
7					1	1	1	1	Yes	No	No	No
8												
9	1	1	1	1					Yes	No	No	No
10	1	1		1					Yes	No	No	No
11				1	1	1	1	1	Yes	Yes	No	No
12	1	1	1	1					Yes	Yes	No	No
13	1	1	1	1					Yes	Yes	No	No
14				1					Yes	No	No	No
15				1					Yes	No	No	No
16	2		1	2					Yes	Yes	No	No
17					1	1	1	1	Yes	No	No	No
18									Yes	Yes	No	No
19								1	Yes	Yes	No	No
20					1	1	1	1	Yes	No	No	No
21			1		1	1	1		Yes	Yes	No	No
22							1		Yes	No	No	No
23				1	1	1	1		Yes	No	No	No
24			1	1		1	1		Yes	No	No	No
25					1	1	1	1	Yes	No	No	No
26									Yes	Yes	No	No
27									Yes	Yes	No	No
28					1	1	1	1	Yes	Yes	No	No
29					1	1	1	1	Yes	Yes	No	No
30								1	Yes	Yes	Yes	No
31	1	1	1	1					Yes	Yes	No	No

32						1			Yes	Yes	No	No
33			1	1	1			1	No	Yes	No	No
34				1	1		1		Yes	No	No	No
35			1			1	1	1	Yes	No	No	No
36				1					No	Yes	No	No
37												
38												
39												
40	1		1	1				1				
41	1		1	1					Yes	Yes	No	No
42	1	1	1	1					Yes	Yes	No	No
43					1	1	1	1	Yes	Yes	No	No
44					1	1	1	1	Yes	Yes	No	No
45						1	1	1	Yes	Yes	No	No
46		1	1	1					Yes	No	No	No
47					1	1	1	1	Yes	No	No	No
48					2	1	1	2	Yes	No	No	No
49		1							Yes	Yes	No	No
50	1	1	1						Yes	No	No	No
51					1	1	1	1	Yes	No	No	No
52	1	1							Yes	No	No	No
53				1	1	1		1	Yes	Yes	No	No
54	1	1	1	1					Yes	Yes	No	No
55					1	1	1	1	Yes	Yes	No	No
56			1	1	1			1	Yes	No	No	No
57	1				1			1	Yes	No	Yes	No
58	1		1		1	1	1	1	Yes	Yes	No	No
59	1	1							Yes	No	Yes	No
60		1	1						No	Yes	No	No
61	1	1	1						Yes	Yes	No	No
62			1			1			Yes	Yes	No	No
63	1		1						Yes	Yes	No	No
64												
65		1	1						Yes	No	No	No
66	1	1							Yes	Yes	No	No
67	1	1	1	1					Yes	Yes	No	No

68		1				1	1	1	Yes	No	No	No
69			1						Yes	No	No	No
70	1	1	1	1					Yes	Yes	No	No
71	1	1	1	1					Yes	Yes	No	No
72	1	1		1		1			Yes	Yes	No	No
73		1		1		1	1		Yes	Yes	No	No
74					1			1	Yes	No	No	No
75				1					Yes	No	No	No
76						1			Yes	Yes	No	No
77					1	1	1		Yes	No	No	No
78		1	1	1					No	Yes	No	No
79	1	1	1	1					Yes	Yes	No	No
80		1	1	1					Yes	Yes	No	No
81	1		1	1					Yes	Yes	No	No
82	1	1	1	1					Yes	Yes	No	No
83	1		1	1					Yes	No	No	No
84	1	1	1	1					Yes	No	No	No
85					1		1		Yes	No	No	No
86	1		1	1					Yes	Yes	No	No
87	1	1	1	1					Yes	No	No	No
88	1	1	1	1					Yes	No	No	No
89	1		1	1					Yes	Yes	No	No
90	1	1	1	1					Yes	Yes	No	No
91	1				1	1		1	Yes	No	No	No
92	1	1	1	1					Yes	Yes	No	No
93		1	1	1	1				Yes	Yes	No	No
94	1	1	1	1					Yes	Yes	No	No
95	1	1	1	1					Yes	Yes	No	No
96	1	1	1						Yes	Yes	No	No
97	1	1	1	1					Yes	Yes	No	No
98	1	1	1	1					Yes	Yes	No	No
99	1	1	1	1					Yes	Yes	No	No
100	1	1	1	1					Yes	No	No	No
101			1	1		1	1		Yes	No	No	No
102						1	1		Yes	No	No	No
103	1	1	1	1					Yes	Yes	No	No

104	1	1	1	1					Yes	Yes	No	No
105	1	1	1	1					Yes	No	No	No
106	1	1	1	1					Yes	Yes	No	No
107	1	1							Yes	No	No	No
108						1	1		Yes	Yes	No	No
109	1	1	1	1					Yes	Yes	No	No
110												
111		1							Yes	No	No	No
112	1		1						Yes	No	No	No
113		1							Yes	No	No	Yes
114	1		1	1					Yes	No	No	Yes
115												
116												
117	1	1	1	1					Yes	Yes	No	No
118						1	1		Yes	No	No	No
119					1	1	1	1	Yes	No	No	No
120	1	1			1				Yes	No	No	No
121					1	1	1	1	Yes	No	No	No
122					1	1			Yes	No	No	No
123					1	1			Yes	No	No	No
124		1			1				Yes	No	No	No
125		1										
126	1	1	1			1			Yes	No	No	No
127												
128		1	1	1					Yes	No	No	No
129					1							
130												
131		1	1	1					Yes	No	No	No
132								1	Yes	No	No	No
133		1	1	1		1			Yes	Yes	No	No
134	1					1	1	1	Yes	No	No	No
135	1	1	1	1					Yes	Yes	No	No
136	1	1	1	1					Yes	yes	No	No
137	1	1	1	1					Yes	Yes	No	No
138	1	1	1	1					Yes	No	No	No
139		1							Yes	No	No	No

140	1			1	1				Yes	No	No	No
141	1	1	1	1					Yes	Yes	No	No
142								1	Yes	No	No	No
143			1			1	1	1	Yes	No	No	No
144	1	1	1	1					Yes	No	No	No
145		1	1						Yes	Yes	No	No
146	1	1	1						Yes	Yes	No	No
147		1	1						Yes	Yes	No	No
148	1		1						Yes	Yes	No	No
149	1	1	1						Yes	Yes	No	No
150	1		1						Yes	No	No	No
151		1	1						Yes	No	No	No
152	1		1						Yes	Yes	No	No
153		1		1					Yes	Yes	No	No
154	1	1		1					Yes	Yes	No	No
155		1		1					Yes	Yes	No	No
156	1			1					Yes	Yes	No	No
157	1	1		1					Yes	Yes	No	No
158	1			1					Yes	Yes	No	No
159		1		1					Yes	No	No	No
160	1			1					Yes	Yes	No	No
161						1	1		Yes	No	No	No
162												
163												
164	1	1	1	1					Yes	Yes	No	No
165					1	1	1	1	Yes	No	No	No
166	1	1	1	1					Yes	No	No	No
167												
168							1	1	No	No	No	No
169	1		1	1		1			Yes	No	No	No
170		1	1	1					Yes	No	No	No
171		2	1	1					Yes	Yes	Yes	No
172												
173	1	1	1	1					Yes	Yes	No	No
174					1	1	1	1	Yes	No	No	No
175		1	1						Yes	Yes	No	No

176	1	1	1						Yes	Yes	No	No
177		1	1						Yes	Yes	No	No
178	1		1						Yes	Yes	No	No
179	1		1						Yes	No	No	No
180		1	1						Yes	No	No	No
181	1		1						Yes	Yes	No	No
182	1	1	1	1					Yes	Yes	No	No
183	1	1		1					Yes	Yes	No	No
184	1	1	1	1					No	No	No	No
185		1							Yes	No	No	No
186	1	1	1	1					Yes	No	No	No
187			1	1					No	No	No	No
188					1			2	No	No	No	No
189	1	1	1	1					Yes	No	No	No
190					1				Yes	No	No	No
191				1					No	No	No	No
192	1	1	1	1					Yes	Yes	No	No
193	1	1	1	1					Yes	No	No	No
194	1	1	1	1					Yes	No	No	No
195			1		1				Yes	No	No	No
196												
197	1	1	1	1					Yes	Yes	No	No
198				1	1			1	Yes	No	No	No
199	1	1	1	1					Yes	Yes	No	No
200	1	1	1	1					Yes	Yes	No	No
201	1	1	1	1					No	No	No	No
202					1	1	1	1	Yes	Yes	No	No
203	1	1	1	1					No	Yes	No	No
204	1	1	1	1					No	No	No	No
205	1	1	1	1					Yes	Yes	No	No
206												
207					1	1	1	1	Yes	No	No	No
208												
209					1	1	1	1	No	No	No	No
210					1			1	Yes	No	No	No
211				1	1			1	Yes	No	No	No

212												
213												
214	1	1	1						No	Yes	No	No
215	1	1	1						Yes	Yes	Yes	No
216												
217					1				Yes	No	No	No
218	1			1	1				Yes	No	No	No
219	1	1	1	1					Yes	Yes	No	No
220	1	1	1	1					Yes	Yes	No	No
221	2	2	2						Yes	Yes	No	No
222	1	1	1	1					Yes	No	No	No
223	1	1	1	1					Yes	No	No	No
224	1	1	1	1					No	No	No	No
225					1	1	1	1	Yes	No	No	No
226												
227					1	1	1	1	No	No	No	No
228	1		1	1					Yes	Yes	No	No
229	1		1	1					Yes	No	No	No
230												
231												
232												
233					1	1	1	1	No	No	No	No
234	1		1	1					No	Yes	No	No
235					1	1	1	1	No	No	No	No

Table A-4
Orientation of major road and configuration of turning lanes for the inventory intersections

		Lane #s - Major															
		Through				Left Turn				Through|Left Combo				Right Turn			
ID	Major Orient.	NB	SB	EB	WB	NB	SB	EB	WB	NB	SB	EB	WB	NB	SB	EB	WB
1	NW-SE																
2	NS	2	2			1	1										
3	NE-SW																
4	NW-SE																
5	NS	2	2			1	1										
6	NE-SW																
7	NE-SW																
8																	
9	NS	2	2														
10	NW-SE																
11	NW-SE																
12	NW-SE																
13	NW-SE																
14	NW-SE																
15	NW-SE																
16	NW-SE																
17	NW-SE																
18	NW-SE																
19	NW-SE																
20	NW-SE																
21	NW-SE																
22	NW-SE																
23	NW-SE																
24	NW-SE																
25	NW-SE																
26	NW-SE																
27	NW-SE																
28	NW-SE																
29	NS	2	2														
30	NS					1								1			
31	EW			1	1			1	1							1	
32	NS	2	2			1	1							1	1		
33	NE-SW																
34	NE-SW																

35	NE-SW																
36	NE-SW																
37	NE-SW																
38	NE-SW																
39	NE-SW																
40	NE-SW																
41	EW			1	1			1	1								
42	NW-SE																
43	NW-SE																
44	NW-SE																
45	NW-SE																
46	EW			2	1			1					1				
47	NE-SW																
48	EW			2	2			1	1								
49	EW			1	1							1	1				
50	EW																2
51	NW-SE																
52	EW			2	2			1	1							1	1
53	NE-SW																
54	NE-SW																
55	NE-SW																
56	NE-SW																
57	NE-SW																
58	NE-SW																
59	NE-SW																
60	EW				2												
61	EW				1								1				
62	EW				2												
63	EW				1								1				
64	EW				3												
65	EW				1												
66	EW				2												
67	NE-SW																
68	NE-SW																
69	NE-SW																
70	NW-SE																
71	NW-SE																
72	NE-SW																
73	NW-SE																
74	NE-SW																
75	NE-SW																
76	NE-SW																
77	NE-SW																

78	EW				1							1					
79	EW			1	1							1	1				
80	EW			1	2							1					
81	EW			2	1								1				
82	EW			1	1							1	1				
83	EW			2	1								1				
84	EW			1	2							1					
85																	
86	NE-SW																
87	NE-SW																
88	NE-SW																
89	EW			1									1				
90	NE-SW																
91	EW			3	3			1	1							1	1
92	NE-SW																
93	NE-SW																
94	NE-SW																
95	NE-SW																
96	EW								1								1
97	NE-SW																
98	NE-SW																
99	EW			2	2			1	1							1	1
100	NE-SW																
101	NW-SE																
102	NE-SW																
103	EW			2	2			1	1								
104	EW			2	2			2	1								
105	EW			2	1			1	1								2
106	EW			2	2			1	1								
107	EW			2	2												
108	EW			2	2												
109	EW			2	2			1	1								
110	EW			2	2			1	1								
111	EW			1	2							1					
112	EW			2	1								1				
113	EW			1	1			1									1
114	EW			1	1			1	1								
115	NE-SW																
116																	
117	NE-SW																
118	NE-SW																
119	NE-SW																
120	NE-SW																

121	NE-SW																
122	NE-SW																
123	NE-SW																
124	EW			2	2				1								
125	NE-SW																
126	NW-SE																
127																	
128	EW			2	2				1								
129	NW-SE																
130	NW-SE																
131	NW-SE																
132	NW-SE																
133	NW-SE																
134	NW-SE																
135	NW-SE																
136	NS									1	1				1		
137	NW-SE																
138	NW-SE																
139	EW			2	2			1	2							1	
140	NW-SE																
141	EW			2	2			1	1								
142	NW-SE																
143	NE-SW																
144	NS									1	1						
145	EW				2												
146	EW				1								1				
147	EW				2												
148	EW				1								1				
149	EW				1								1				
150	EW				1								1				
151	EW				1												
152	EW				1								1				
153	EW			1								1					
154	EW			2													
155	EW			1								1					
156	EW			2													
157	EW			1								1					
158	EW			2													
159	EW			1								1					
160	EW			2													
161	NE-SW																
162	NE-SW																
163	NE-SW																

164	NS	2	2			1	1										
165	NS	2	2			1	1							1			
166	NS	2	2			1	1								1		
167	NW-SE																
168	NW-SE																
169	NS	2	2			1	1										
170	NS	2								1							
171	EW			1	2							1					
172	EW			2	2			1	1							1	1
173	EW			2	2			1	1								
174	EW			1	1							1	1				1
175	EW				2												
176	EW				2				1								
177	EW				2								1				
178	EW				2								1				
179	EW				2								1				
180	EW				2												
181	EW				1								1				
182	EW								1				1				1
183	NW-SE																
184	NE-SW																
185	EW			1	1							1	1				
186	NE-SW																
187	NE-SW																
188	NE-SW																
189	NE-SW																
190																	
191																	
192	NS	1	1			1	1								1		
193	NS	2	2			1	1										
194	NS	2	2			1	1							1	1		
195	NS	2	2			1	1							1			
196																	
197	NW-SE																
198	NW-SE																
199	NW-SE																
200	NW-SE																
201	NW-SE																
202	NW-SE																
203	NW-SE																
204	NW-SE																
205	NW-SE																
206																	

207	NE-SW																
208	NE-SW																
209	NE-SW																
210	NE-SW																
211	NE-SW																
212	NE-SW																
213	NS	1	1														
214	NS	2	2														
215	NS	1	1				1										
216																	
217	NW-SE																
218	NW-SE																
219	NS	2	2			2	2							1	1		
220	NW-SE																
221	NW-SE																
222	NS	2	2			1	1										
223	NS	2	2			1	1										
224	NE-SW																
225	NE-SW																
226	NE-SW																
227	NE-SW																
228	EW			2	2				1								
229	EW			1					1								
230	NE-SW																
231	NE-SW																
232	NE-SW																
233																	
234	NE-SW																
235	NS	2	1			1	2							1			

Table A-5
Orientation of major road and configuration of turning lanes for the inventory intersections

		Lane #s - Major															
		Through				Left Turn				Through|Left Combo				Right Turn			
ID	Major Orient.	NEB	SWB	NWB	SEB	NEB	SWB	NWB	SEB	NEB	SWB	NWB	SEB	NEB	SWB	NWB	SEB
1	NW-SE			2	2												
2	NS																
3	NE-SW	2	2			1	1										
4	NW-SE			2	2			1	1							1	1
5	NS																
6	NE-SW	2	2			1	1							1	1		
7	NE-SW	2	2			1	1										
8																	
9	NS																
10	NW-SE			2	2			1	1							1	
11	NW-SE			3	3				1							1	
12	NW-SE			3	3			1	2							1	1
13	NW-SE			3	3			1	1								
14	NW-SE			2	2			1	1								1
15	NW-SE			2	2			1	1							1	1
16	NW-SE			3	3			2	1							1	1
17	NW-SE			2	2			1	1							1	1
18	NW-SE			3	3			1	1								1
19	NW-SE			2	2			1	1							1	1
20	NW-SE			2	2			2	1							1	1
21	NW-SE			3	3			1	1								
22	NW-SE			2	2			1	1							1	1
23	NW-SE			3	3			2	2							1	1
24	NW-SE			2	2			1	1							1	1
25	NW-SE			2	2			1	1							1	1
26	NW-SE			2	2			2	2							1	1
27	NW-SE			2	2			1	1							1	1
28	NW-SE			3	3			1	1								
29	NS																
30	NS																
31	EW																
32	NS																
33	NE-SW	2	2			1	1							1	1		
34	NE-SW	2	2			1	1								1		

35	NE-SW	2	2			1	1										
36	NE-SW	2	2			2	1										
37	NE-SW	3	3			1	2							1	1		
38	NE-SW	3	3			1	2							1	1		
39	NE-SW	2	3				1							1			
40	NE-SW	2	2			1	2							1			
41	EW																
42	NW-SE			2	2			1	1							1	1
43	NW-SE			2	2			2	2							1	1
44	NW-SE			2	2			1	1								
45	NW-SE			2	2				1							1	
46	EW																
47	NE-SW	2	2			1	1										
48	EW																
49	EW																
50	EW																
51	NW-SE			2	2			1	1				1				
52	EW																
53	NE-SW	2	2			1											
54	NE-SW	2	2			1	1										
55	NE-SW	2	2			1	1										
56	NE-SW	2	2			1	1							1			
57	NE-SW	1	1			1									1		
58	NE-SW	2	2				1							1			
59	NE-SW	2	2														
60	EW																
61	EW																
62	EW																
63	EW																
64	EW																
65	EW																
66	EW																
67	NE-SW	2	2			1	1								1		
68	NE-SW	2	2			1	1										
69	NE-SW	2	2			1	1										
70	NW-SE			2	2			1	2							1	1
71	NW-SE			2	2			1	1								
72	NE-SW	2	2			1	1										
73	NW-SE			2	2			1	1								
74	NE-SW	2	3			1	1								1		
75	NE-SW	2	3			1	1										
76	NE-SW	2	3			1	1										
77	NE-SW	2	2			1	1							1	1		

78	EW																
79	EW																
80	EW																
81	EW																
82	EW																
83	EW																
84	EW																
85																	
86	NE-SW	3	2			1									1		
87	NE-SW	2	2			2	1							1	1		
88	NE-SW	2	2			1	1							1	1		
89	EW																
90	NE-SW	2	2			1	1							1	1		
91	EW																
92	NE-SW	2	2			1	1							1	1		
93	NE-SW	2	2			1	1							1	1		
94	NE-SW	2	2			1	1							1	1		
95	NE-SW	2	2			2	1							1	1		
96	EW																
97	NE-SW	2	2			1	1							1	1		
98	NE-SW	2	2			1	1							1	1		
99	EW																
100	NE-SW	2	2			1	1										
101	NW-SE			1	1							1	1				1
102	NE-SW									1	1				1		
103	EW																
104	EW																
105	EW																
106	EW																
107	EW																
108	EW																
109	EW																
110	EW																
111	EW																
112	EW																
113	EW																
114	EW																
115	NE-SW	2	2				1										
116																	
117	NE-SW	2	2			2	1							1	1		
118	NE-SW	2	1								1						
119	NE-SW	2	2			1	1										
120	NE-SW	2	2				2							1			

121	NE-SW	1	1							1	1			1			
122	NE-SW	2	2				1										
123	NE-SW	2	2				1										
124	EW																
125	NE-SW	1	1							1	1			1			
126	NW-SE			1	1							1	1				
127																	
128	EW																
129	NW-SE			2	2			1	1								1
130	NW-SE			2	2			1	1							1	
131	NW-SE			1	1			1	1								
132	NW-SE				1							1					1
133	NW-SE			1	1				1							1	
134	NW-SE			1	1			1	1							1	
135	NW-SE			1	1			1	1								
136	NS																
137	NW-SE			1	1			1	1							1	
138	NW-SE			2	2			2	2							1	1
139	EW																
140	NW-SE			2	2				1							1	
141	EW																
142	NW-SE			2	2			1	1								
143	NE-SW	1	1			1	1										
144	NS																
145	EW																
146	EW																
147	EW																
148	EW																
149	EW																
150	EW																
151	EW																
152	EW																
153	EW																
154	EW																
155	EW																
156	EW																
157	EW																
158	EW																
159	EW																
160	EW																
161	NE-SW					1											
162	NE-SW	2	1			1									1		
163	NE-SW	2	2				1										

164	NS																
165	NS																
166	NS																
167	NW-SE			1	1			1	1							1	1
168	NW-SE											1	1			1	1
169	NS																
170	NS																
171	EW																
172	EW																
173	EW																
174	EW																
175	EW																
176	EW																
177	EW																
178	EW																
179	EW																
180	EW																
181	EW																
182	EW																
183	NW-SE			2	2			1									
184	NE-SW	2	2			1	1							1	1		
185	EW																
186	NE-SW	2	2			1	1							1			
187	NE-SW	2	2				1							1			
188	NE-SW	2	2			1	1							1			
189	NE-SW	2	2			1	2							1	1		
190																	
191																	
192	NS																
193	NS																
194	NS																
195	NS																
196																	
197	NW-SE			2	2			2	2							1	
198	NW-SE			2	2			1	1								
199	NW-SE			2	2			2	2							1	1
200	NW-SE			2	2			1	1							1	
201	NW-SE			2	2			1	1								
202	NW-SE			2	2			1	1								
203	NW-SE			2	2			1	1								
204	NW-SE			1	1			1	1							1	
205	NW-SE			2	2			1	1								
206																	

207	NE-SW	2	2			1	1										
208	NE-SW	2	2				1							1			
209	NE-SW	2	2			1	1							1	1		
210	NE-SW	1	1							1	1						
211	NE-SW	2	2			1											
212	NE-SW	2	1			1					1						
213	NS																
214	NS																
215	NS																
216																	
217	NW-SE			2	2			1									
218	NW-SE			2	2												
219	NS																
220	NW-SE			2	2			1	2								
221	NW-SE			2	2			2	1							1	1
222	NS																
223	NS																
224	NE-SW	3	3			1	1										
225	NE-SW	2	3			1	2							1	1		
226	NE-SW	2	2			1	1							1	1		
227	NE-SW	3	3			1	1										
228	EW																
229	EW																
230	NE-SW	1								1							
231	NE-SW	2	1												1		
232	NE-SW	1	1							1	1						
233																	
234	NE-SW	1	1			1									1		
235	NS																

Table A-6
Orientation of Minor road and configuration of turning lanes for the inventory intersections

		Lane #s - Minor															
		Through				Left Turn				Through|Left Combo				Right Turn			
ID	Minor St. Orientation	NB	SB	EB	WB	NB	SB	EB	WB	NB	SB	EB	WB	NB	SB	EB	WB
1	NE-SW																
2	EW			1	1			1	1								
3	EW			1	1			1	1								
4	EW			2	2												
5	EW			1	1			1	1								
6	NW-SE																
7	EW			2	2											1	1
8																	
9	EW			2	2												
10	N-SW									1							
11	NE-SW																
12	NE-SW																
13	NE-SW																
14	EW											1	1			1	1
15	N-SW	1				1								1			
16	NE-SW																
17	EW			2	1			1	1							1	
18	NE-SW																
19	NE-SW																
20	NE-SW																
21	NE-SW																
22	EW												1				
23	NE-SW																
24	NW-SE																
25	NE-SW																
26	NE-SW																
27	NE-SW																
28	NE-SW																
29	NE-W												1				
30	EW			2	2												
31	NS									1				1			
32	EW			1	1			2	1							1	1
33	NW-SE																
34	NW-SE																

35	NW-SE																
36	NW-SE																
37	NW-SE																
38	NW-SE																
39	NW-SE																
40	NW-SE																
41	NS										1						
42	NE-SW																
43	NE-SW																
44	NE-SW																
45	NE-SW																
46	NS		1				1										
47	NW-SE																
48	NS	1	2			1					1			1			
49	NS									1	1						
50	NW-SE																
51	NE-SW																
52	NS	2	2			2	2								1		
53	NW-SE																
54	NW-SE																
55	NW-SE																
56	NW-SE																
57	NW-SE																
58	NW-SE																
59	NW-SE																
60	NS									1							
61	NS		1							1							
62	NS	1								1							
63	NS		2														
64	NS									1							
65	NS	3															
66	NS		1														
67	NW-SE																
68	NW-SE																
69	NW-SE																
70	NE-SW																
71	NE-SW																
72	NW-SE																
73	NE-SW																
74	NW-SE																
75	NW-SE																
76	NW-SE																
77	NW-SE																

78	NS									1							
79	NS	1	1			1	1										
80	NS	1								1							
81	NS		1								1						
82	NS									1	1						
83	NS		2								1						
84	NS	2								1							
85																	
86	NW-SE																
87	NS	2	2			1	2							1	1		
88	NW-SE																
89	NS										1						
90	NS									1	1						
91	NS	1	2			1	2							1			
92	NS									1	1			1	1		
93	NE-SW																
94	NS		1				1								2		
95	NS						2				1				1		
96	NS	2	1								1						
97	NS	1	1			1	1								1		
98	NS	2	2			2	1								1		
99	NE-SW																
100	NS	2	2			1	1										
101	EW			1	1			1	1								
102	NW-SE																
103	NS									1	1						
104	NS						1				1				1		
105	NS	2	1			1	2								1		
106	NS	1								1	1				1		
107	NS	1	1			1	1							1	1		
108	NS									1							
109	NS	2	2			1	2								1		
110	NS	1				2	1								1		
111	NS	1								1							
112	NS		1								1						
113	NS	1								1				1			
114	NS										1						
115	NW-SE																
116																	
117	NW-SE																
118	NW-SE																
119	NW-SE																
120	NS					1				1				1			

121	NS									1	1						
122	NW-SE																
123	NW-SE																
124	NS					1								1			
125	NS					1				1	1			1			
126	NS									1	1						
127																	
128	NS					1								1			
129	NE-SW																
130	NS						2								1		
131	EW											1					
132	NE-SW																
133	NE-SW																
134	NE-SW																
135	NE-SW																
136	EW				1				1				1				
137	NE-SW																
138	NE-SW																
139	NE-SW																
140	NS		2												1		
141	NS									1				1			
142	NE-SW																
143	EW											1	1			1	1
144	EW											1	1				1
145	NS									1							
146	NS	1	1			1	1										
147	NS	1								1							
148	NS		1														
149	NS		1							1							
150	NS		3														
151	NS	2								1							
152	NS		1														
153	NS	1															
154	NS	1	1				1										
155	NS	2															
156	NS		1								1						
157	NS	1									1						
158	NS		3								1						
159	NS	3															
160	NS										1						
161	NW-SE																
162	NW-SE																
163	NW-SE																

164	EW								1			1					1
165	EW											1	1				1
166	EW								1			1				1	1
167	NE-SW																
168	NE-SW																
169	EW											1	1				
170	EW			2	1			1	1								
171	NS	1								1				1			
172	NS	2	1			1					1			1			
173	NS									1	1						
174	NS	1	2				1			1							
175	NS									1							
176	NS	1	1			1											
177	NS	1				1											
178	NS		1											1			
179	NS		3														
180	NS	2								1							
181	NS		1												1		
182	NS	1	1							1	1						
183	NE-SW																
184	NE-SW																
185	NS										1						
186	NS	1	1			1	1										
187	NW-SE																
188	NS					1				1				1			
189	NS	2	2			1	1										
190																	
191																	
192	NW-SE																
193	EW											1	1				
194	NE-SW																
195	EW							1					1			1	1
196																	
197	NE-SW																
198	NE-SW																
199	NE-SW																
200	NE-SW																
201	NE-SW																
202	NE-SW																
203	NE-SW																
204	NE-SW																
205	NE-SW																
206																	

207	EW											1	1				
208	NW-SE																
209	EW			2	2			2	2							1	
210	NW-SE																
211	EW								1								1
212	EW							1								1	
213	EW																
214	EW								1								1
215	EW								1								1
216																	
217	EW											1	1				
218	NE-SW								1								
219	EW			2	2			2	2							1	1
220	NE-SW																
221	NE-SW																
222	EW			1				1					1				1
223	EW											1	1				1
224	NW-SE																
225	NW-SE																
226	NW-SE																
227	NW-SE																
228	NS						1				1				1		
229	NS		1								1						
230	NW-SE																
231	NW-SE																
232	NW-SE																
233																	
234	EW											1				1	
235	EW			1	1			1	1							1	1

Table A-7
Orientation of major road and configuration of turning lanes for the inventory intersections

		Lane #s - Minor															
		Through				Left Turn				Through|Left Combo				Right Turn			
ID	Minor St. Orientation	NEB	SWB	NWB	SEB	NEB	SWB	NWB	SEB	NEB	SWB	NWB	SEB	NEB	SWB	NWB	SEB
1	NE-SW						1								1		
2	EW																
3	EW																
4	EW																
5	EW																
6	NW-SE							1				1	1			1	1
7	EW																
8																	
9	EW																
10	N-SW										1				1		
11	NE-SW									1	1				1		
12	NE-SW	2	2			2	1								2		
13	NE-SW					1	1							1	1		
14	EW																
15	N-SW		1				1										
16	NE-SW	2	1			1	1							1	1		
17	EW																
18	NE-SW					2	1							1	1		
19	NE-SW									1	1			1	1		
20	NE-SW					1				1	1			1	1		
21	NE-SW					1	1							1	1		
22	EW																
23	NE-SW	2	2			2	2							1	1		
24	NW-SE			1	1			1	1								1
25	NE-SW									1	1				1		
26	NE-SW	2	2			2	2							1	1		
27	NE-SW	1	1							1	1						
28	NE-SW					1	1							1	1		
29	NE-W									1							
30	EW																
31	NS																
32	EW																
33	NW-SE			2	2			2	2								1

34	NW-SE								1								1
35	NW-SE			1	1			1	1							1	
36	NW-SE							1	1			1	1			1	1
37	NW-SE				1				1							2	
38	NW-SE			2	2			2	2							2	
39	NW-SE							2								1	
40	NW-SE				1				1			1				1	
41	NS																
42	NE-SW	1	1							2	2			1	1		
43	NE-SW	2	2														
44	NE-SW					1					1			1	1		
45	NE-SW						2								1		
46	NS																
47	NW-SE											1	1				
48	NS																
49	NS																
50	NW-SE			2				1									
51	NE-SW	1	1			1	1			1	1						
52	NS																
53	NW-SE											1	1				
54	NW-SE				1				1			1				1	
55	NW-SE			1				1	1				1				1
56	NW-SE			2				1					1				
57	NW-SE								1								1
58	NW-SE				1				2							1	1
59	NW-SE			1				1					1				
60	NS																
61	NS																
62	NS																
63	NS																
64	NS																
65	NS																
66	NS																
67	NW-SE											1	1				1
68	NW-SE			2	1			1	1								1
69	NW-SE				1				1			1				1	
70	NE-SW	2	1			1	1								1		
71	NE-SW									1	1						
72	NW-SE				1				1			1					
73	NE-SW	1	1			1	1										
74	NW-SE								1			1	1			1	1
75	NW-SE								1			1					1
76	NW-SE			1	1			1	1								

77	NW-SE			2	2			1	2							1	1
78	NS																
79	NS																
80	NS																
81	NS																
82	NS																
83	NS																
84	NS																
85																	
86	NW-SE								1							1	1
87	NS																
88	NW-SE			1	1			1	1							1	1
89	NS																
90	NS																
91	NS																
92	NS																
93	NE-SW									1	1				1		
94	NS																
95	NS																
96	NS																
97	NS																
98	NS																
99	NE-SW		1				1			1				1			
100	NS																
101	EW																
102	NW-SE											1	1			1	
103	NS																
104	NS																
105	NS																
106	NS																
107	NS																
108	NS																
109	NS																
110	NS																
111	NS																
112	NS																
113	NS																
114	NS																
115	NW-SE							1								1	
116																	
117	NW-SE			2	2			1	2							1	1
118	NW-SE											1					
119	NW-SE			1				1					1			1	1

120	NS																
121	NS																
122	NW-SE							1								1	
123	NW-SE											1					
124	NS																
125	NS																
126	NS																
127																	
128	NS																
129	NE-SW					1				1	1			1	1		
130	NS																
131	EW																
132	NE-SW					1								1			
133	NE-SW						1								1		
134	NE-SW	2	2			1	1							1			
135	NE-SW	2	2			1	1							1	1		
136	EW																
137	NE-SW																
138	NE-SW	2	2			2	1							1	1		
139	NE-SW					1				1				1			
140	NS																
141	NS																
142	NE-SW									1	1			1	1		
143	EW																
144	EW																
145	NS																
146	NS																
147	NS																
148	NS																
149	NS																
150	NS																
151	NS																
152	NS																
153	NS																
154	NS																
155	NS																
156	NS																
157	NS																
158	NS																
159	NS																
160	NS																
161	NW-SE			2				1									
162	NW-SE								2								1

163	NW-SE							1								1	
164	EW																
165	EW																
166	EW																
167	NE-SW	1	1			1	1							1	1		
168	NE-SW					1					1			1			
169	EW																
170	EW																
171	NS																
172	NS																
173	NS																
174	NS																
175	NS																
176	NS																
177	NS																
178	NS																
179	NS																
180	NS																
181	NS																
182	NS																
183	NE-SW					1								1			
184	NE-SW	2	2			1	2							1	1		
185	NS																
186	NS																
187	NW-SE							1								1	
188	NS																
189	NS																
190																	
191																	
192	NW-SE			2	2			1	2							1	
193	EW																
194	NE-SW					1	1			1	1			1	1		
195	EW																
196																	
197	NE-SW	2	2			1	2							1	1		
198	NE-SW									1	1			1	1		
199	NE-SW	2	2			2	2								1		
200	NE-SW	2	2			1	2								1		
201	NE-SW									1	1				1		
202	NE-SW	1	1							1	1				1		
203	NE-SW									1	1			1	1		
204	NE-SW	1	1			1	1								1		
205	NE-SW									1	1			1	1		

206																	
207	EW																
208	NW-SE							1								1	
209	EW																
210	NW-SE			2	2			1	1								
211	EW																
212	EW																
213	EW																
214	EW																
215	EW																
216																	
217	EW																
218	NE-SW																
219	EW																
220	NE-SW		1				1			1				1	1		
221	NE-SW					1	1			1	1			3	1		
222	EW																
223	EW																
224	NW-SE											1	1				1
225	NW-SE							2	1							2	1
226	NW-SE											1	1				1
227	NW-SE			1				1					1				1
228	NS																
229	NS																
230	NW-SE											1	1				
231	NW-SE						2										
232	NW-SE									1	1						
233																	
234	EW																
235	EW																

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