

REMOTELY DETERMINE LANE STATUS AT BORDER LAND PORTS OF ENTRY

by

Dan Middleton, Lorenzo Cornejo, and Swapnil Samant

Project performed by

Center for International Intelligent Transportation Research

Report No. 185917-00010

Project No. 185917-00010

Title: Remotely Determine Lane Status at Border Land Ports of Entry

September 2017

Report prepared by

Center for International Intelligent Transportation Research

Texas A&M Transportation Institute

4050 Rio Bravo, Suite 212

El Paso, Texas 79902

TEXAS A&M TRANSPORTATION INSTITUTE

The Texas A&M University System

College Station, Texas 77843-3135

TABLE OF CONTENTS

	<i>Page</i>
List of Figures	ii
List of Tables	ii
Disclaimer and Acknowledgments	iii
Executive Summary	4
Introduction.....	4
Methodology	4
Results.....	5
Recommendations.....	5
Chapter 1: Introduction	6
Background.....	6
Project Objective.....	6
Project Description.....	7
Chapter 2: Methodology	8
Introduction.....	8
Preliminary Activities	8
Activities in College Station	9
Activities in El Paso.....	11
Chapter 3: Field Data Results	15
Introduction.....	15
Wavetronix SmartSensor Matrix/Click 650.....	16
Exploring Click 650.....	16
Accessing Click 650 Web Interface.....	16
Downloading Graphs and Tables.....	16
Results.....	17
Wavetronix SmartSensor Matrix	19
LeddarTech IS16.....	20
Chapter 4: Conclusions And Recommendations	21
Conclusions.....	21
Recommendations.....	21
Reference	23

LIST OF FIGURES

	<i>Page</i>
Figure 1. Layout of RELLIS Campus.....	10
Figure 2. Photo of Trailer next to Toll Lanes.	12
Figure 3. Aerial View of Zaragoza/Ysleta POE.	12
Figure 4. General LeddarTech Detection Fan.....	14
Figure 5. Detectors and Camera Shown in Retracted Horizontal Orientation.....	15
Figure 6. Wavetronix-Click 650 Features.....	16
Figure 7. Graphs Tab-Web Interface.	17

LIST OF TABLES

	<i>Page</i>
Table 1. City of El Paso Counts and Hours Open on July 21, 2017.....	18
Table 2. Matrix/Click 650 Vehicle Counts July 21, 2017.	19

DISCLAIMER AND ACKNOWLEDGMENTS

This research was performed by the Center for International Intelligent Transportation Research, a part of the Texas A&M Transportation Institute. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein.

The research team thanks Ms. Ana G. Aguirre with the City of El Paso for sharing count data from the Zaragoza Port of Entry. The team also thanks the technical support teams at Wavetronix headquarters in Provo, Utah, and LeddarTech in Quebec for their expert assistance in learning how to test both systems in new and unfamiliar ways.

EXECUTIVE SUMMARY

INTRODUCTION

Lane status information (open or closed) has significant value to stakeholders. This research investigated methods to automate this monitoring of lanes remotely in ways that do not interfere with the operation of the port of entry. Reasons for sharing lane status with the stakeholder community include the following:

- Allow passenger and freight carriers to make an informed decision about departure times, mode choice and bridge selection.
- Enable better mobility analysis for the LPOEs.
- Enable modelers to reliably calibrate models for land ports of entry (LPOEs).
- Develop better short-term bridge crossing time estimation algorithms.

METHODOLOGY

Researchers narrowed the initial list of potential candidate solutions to two vehicle detectors: the Wavetronix SmartSensor Matrix along with its companion Click 650, and the LeddarTech IS16 LED scanner. Upon identifying the two systems, the Texas A&M Transportation Institute began to assemble the components needed to install and test the two systems. Limited testing occurred at the Texas A&M University RELIS campus using a portable trailer to mount the detector components. Upon successful testing and increased confidence that the two detectors would adequately meet the project objectives, researchers planned a full-blown test in El Paso.

The plan for installing the proposed detectors and the work necessary at the Zaragoza southbound passenger site was as follows:

- Install Wavetronix Matrix and Click 650.
- Install LeddarTech IS16 oriented in sidefire mode to cover the first two to three lanes.
- Set up trailer camera to monitor all seven lanes and record video as ground truth.
- Connect cables from each sensor and the camera to trailer connections.
- Following connection on-site the field crew did the following:
 - Terminated wiring from both sensors.
 - Installed phone modem.
 - Installed computer loaded with appropriate software.
 - Connected power to all installed systems.
 - Checked all systems for proper operation.
 - Troubleshoot any problems as required.
 - Collect field data.

Problems with the recorded video forced researchers to find other means to verify field results. For the Matrix, this alternative used the City of El Paso counts as baseline data. For the LeddarTech data, researchers worked with the LeddarTech technical support group to develop a Microsoft Excel solution by monitoring vehicle detections. This was a long and tedious process that, in the end, was unsuccessful.

RESULTS

The results of the Matrix vehicle counts for July 21, 2017, compared to City of El Paso counts indicate some significant differences in hourly numerical values. However, based on these data, the Matrix would provide adequate lane status (open or closed) for the four or five lanes nearest the detector.

For the LeddarTech, preliminary results based mostly on observation indicate that the detector could probably determine lane status for as many as three lanes at the height and offset it was mounted for these tests. It could probably count additional lanes if mounted higher than 17 ft. To be effective as a long-term solution for determining lane status, however, it would need to have software developed to count and store traffic data based on specified heights and offsets

RECOMMENDATIONS

Both of the detectors tested in this research are potential solutions for providing lane status. However, decision-makers should consider that mounting a detector over each lane (e.g., the LeddarTech IS16) could provide both vehicle counts and lane status. That solution would defy the objective of being remote but would generate accurate counts. In some cases, a simpler solution might also meet this need such as:

- Where overhead electronic signs are used, connect to the sign wiring to determine lane status.
- Where gates are used, use electrical contacts at the closure point.
- Also, where gates are used, install a device (e.g., compass) to monitor the direction (azimuth) of the gate.

Since this research was the first attempt to deploy the LeddarTech IS16 off the lanes, more research is needed to develop guidelines on how it should be positioned to optimize its performance. Also, the additional tests might also evaluate the other option cited in this report to position it to view license plates instead of a sidefire orientation.

CHAPTER 1: INTRODUCTION

BACKGROUND

Currently, U.S. Customs and Border Protection (CBP) publishes the number of lanes open at the Land Ports of Entry (LPOEs) on their website. This information is updated once every hour in most cases. However, it has been observed that in some cases this information is not updated for several hours and in other cases this information has been unreliable. Given the current situation, there is currently no means available to determine which lanes are open and how many total lanes are open at any given port of entry in the El Paso Region. The operating agency knows this information but might not know in advance which lanes are open at any given time or how long they will remain open. The Texas A&M Transportation Institute (TTI) has requested this information from the operating agency in the past with no success.

This type of information has significant value to stakeholders. This research investigated methods to automate this monitoring of lanes remotely in ways that do not interfere with the operation of the POE. In some cases, there is a sensitivity to the use of cameras facing CBP authorities, so visible light devices were not included. Reasons for sharing lane status with the stakeholder community include the following:

- Allow passenger and freight carriers to make an informed decision about departure times, mode choice and bridge selection.
- Enable better mobility analysis for the LPOEs.
- Enable modelers to reliably calibrate models for LPOEs.
- Develop better short-term bridge crossing time estimation algorithms.

One of the options for monitoring lanes involves a detector that was evaluated in previous Center for International Intelligent Transportation Research (CIITR) research—the LeddarTech IS16. Earlier findings indicated that its count accuracy was excellent for counting either passenger or commercial vehicles. However, its typical mounting requirements places it directly over lanes pointing downward. Since accurate lane counts would also meet the needs of this project, the LeddarTech in its “normal” orientation is one solution for determining which lanes are open. However, a secondary thought in pursuing this project was to find a sensor or methodology that could be more “remote” or at a greater distance from lanes to be monitored. Therefore, researchers chose two detection systems that could be mounted away from the lanes being monitored. Based on guidance from the manufacturer, researchers chose the IS16 for one of the systems but oriented in a less typical orientation—sidefire facing the side of passing vehicles. The other system was a radar detector from Wavetronix called the SmartSensor Matrix.

PROJECT OBJECTIVE

The objective of this project was to identify and test sensors or methodologies to remotely determine whether lanes are open or closed.

PROJECT DESCRIPTION

This project investigated sensors and/or methodologies to remotely determine whether lanes at LPOEs are open or closed. This project involved the following tasks:

- Task 1. Literature Search.
- Task 2. Identify Viable Technologies or Systems.
- Task 3. Acquire Test System and Establish Test Plan.
- Task 4. Conduct Testing of Most Viable Options.
- Task 5. Project Management and Reporting.

CHAPTER 2: METHODOLOGY

INTRODUCTION

Previous projects funded through the CIITR program had investigated the LeddarTech IS16 detector but in all cases it had been mounted above the lanes being monitored, oriented vertically downward. Installed in this manner, the detector could only cover one lane; although if the emphasis is on an accurate count of traffic, the vertical orientation appears to be optimal. This research tested the LeddarTech in a side-fire orientation based on recommendations from LeddarTech technical support personnel.

The search for solutions also determined that the Wavetronix SmartSensor Matrix along with its companion Click 650 unit should also meet project objectives. The Matrix is a radar detector designed for monitoring intersection approaches with a range sufficient to cover distances of over 100 ft. Therefore, it should be able to cover all seven lanes at the El Paso test location, the southbound Zaragoza passenger entrance.

PRELIMINARY ACTIVITIES

In the initial stages of this project TTI conducted a survey of border crossings in the El Paso area to determine a list of options for meeting project objectives. An early effort to identify as many options as possible resulted in the following list of potential candidates:

- Where overhead electronic signs are used, connect to the sign wiring to determine lane status.
- Where gates are used, use electrical contacts at the closure point.
- Also, where gates are used, install a device (e.g., compass) monitor the direction (azimuth) of the gate.

The survey found that many lanes do not use gates and some do not use overhead signs, so those options could only be used in the appropriate situations. The search then turned to vehicle detectors that might be used to remotely determine lane status. The criteria that were included in the search included cost, accuracy, ease of setup, and data storage availability preferably onboard the device.

Early discussions with the LeddarTech manufacturer's technical support staff indicated that for determining lane activity the sensor could be mounted in other ways than vertical to cover a larger area. The two suggested methods were as follows:

- Orient the sensor in an approximately horizontal orientation almost parallel with the direction of traffic facing either the front or rear of vehicles in each lane to be monitored. The sensor would be mounted about 8 ft. high to minimize occlusion. The license plates needed to be in the field of view because reflective surfaces return a much brighter signal than non-reflectorized surfaces, resulting in more accurate counts of vehicles.
- The second orientation involved mounting the detector higher than the first method at a minimum of 15 ft. above the pavement and turned 90° to the direction of traffic (sidefire).

The fan of the detector would be vertical in this case with a few of the 16 segments covering each lane nearest the detector. These tests used this second method with the goal of covering at least the nearest three lanes.

Initial contacts with the local Wavetronix distributor near College Station also involved discussions about how to mount the detector to cover the necessary lanes at Zaragoza. Its range was sufficient to cover all seven lanes but its mounting height had to be sufficient to minimize occlusion in case taller vehicles passed in front of smaller vehicles. Its mounting height on the data collection trailer would provide a good indication of possible future mounting heights and locations if a determination was made to mount it permanently.

Activities in College Station

Upon identifying the two detection systems that appeared to be most viable, TTI began to assemble the components needed to install and test the two systems. Fortunately, there was no need to purchase additional equipment for this project, instead relying on existing equipment available from earlier TTI research projects.

Tests of the Wavetronix SmartSensor Matrix at the RELIS campus began with scheduling an area on Runway 17L as shown in Figure 1. This exercise used a two-wheel TTI trailer with extendible pole and Matrix mounted to the pole raised to a height of 15 ft. A representative of a local Wavetronix distributor, Twincrest Technologies, provided support to set up the detector. Once the detector was set up, researchers drove a passenger car through the detection zone to get familiar with the detector and how it might function at an LPOE.

Operation of the SmartSensor Matrix detector was fairly straightforward, but the installation process at RELIS did not include a Click 650 at that time since the Wavetronix distributor did not think that its inclusion would be critical. Operating alone, the Matrix does not store data, so this project would require both the Matrix and the Click 650 to operate as a system before or during final testing in El Paso.

The local Wavetronix distributor admitted that he was not up to date on how to store vehicle count data with the Click 650 although he had installed the Matrix on many occasions for more traditional intersection detection for interfacing with a traffic signal controller. He thought the latest version of the Click 650 firmware would allow the unit to store count data and meet the objectives of this project. In hindsight, researchers might have chosen a different path if more complete information had been available. In reality, the Click 650 was intended to be used only with a traffic signal controller and cabinet, but this project had not planned on using those components at the border.

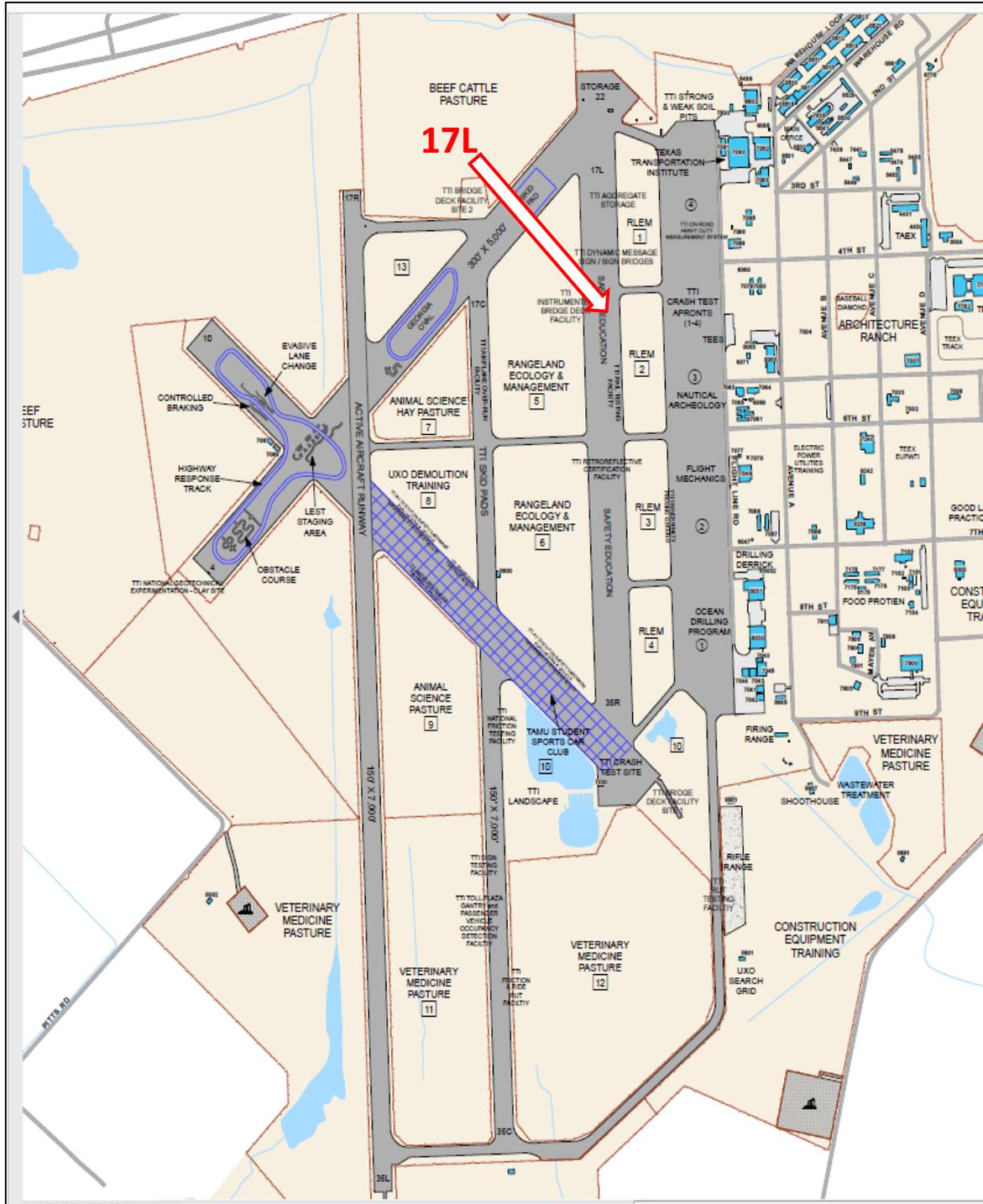


Figure 1. Layout of REllis Campus.

Equipment Procurement

As noted earlier, there was no need to purchase equipment, relying instead on previously procured equipment for other research projects. Smaller components were purchased such as clamps for securing detectors to the trailer-mounted pole, electrical tape, and duct tape.

Connecting to grid power at the toll booth required the use of an existing extension cable. The trailer batteries would normally be used but they were not charged sufficiently for this purpose.

Activities in El Paso

The methodology used to accomplish the objectives of this research followed these basic steps, although not necessarily in the order indicated:

- Determined equipment needs for the Ysleta/Zaragoza border POE.
- Searched for best sites on the U.S. side at Zaragoza to mount the sensors to count southbound passenger traffic.
- Submitted an email to City of El Paso officials requesting permission to test sensors.

The plan for installing the proposed detectors and the work necessary at the Zaragoza passenger site was as follows:

- Passenger vehicle southbound entrance to Mexico:
 - Installed Wavetronix Matrix and Click 650.
 - Installed LeddarTech IS16 oriented in sidefire mode to cover the first two to three lanes.
 - Set up trailer camera to monitor all seven lanes and record video as ground truth.
 - Connected cables from each sensor and the camera to trailer connections.
 - Following connection on-site, the field crew did the following:
 - Terminated wiring from both sensors.
 - Installed phone modem.
 - Installed computer loaded with appropriate software.
 - Connected power to all installed systems.
 - Checked all systems for proper operation.
 - Troubleshoot any problems as required.

A few weeks prior to beginning data collection, TTI personnel in El Paso contacted the City of El Paso to request permission to collect the necessary data to evaluate the two selected systems. The planned data collection would require parking a data collection trailer at the southbound passenger entrance during the week of July 17. TTI had used this site previously and was familiar with setup at this site to accomplish project goals. It would require parking the trailer and mounting the LeddarTech IS16 LED scanner and Wavetronix SmartSensor Matrix and Click 650 to the trailer-mounted pole. This pole was prewired and had the necessary fasteners for mounting either one or two cameras for recording ground truth video. TTI strapped the two test sensors to the pole using temporary metal straps to keep the sensors secure, running the cabling loosely along the pole such that raising the pole would not damage the cables. The requested location was at the toll booth next to lane 7 (east side of the toll area).

Figure 2 shows the location of the trailer in relation to the seven lanes operated at the toll facility. Figure 3 shows an aerial view of the southbound toll lanes for passenger cars used for this research. Traffic passing through this facility must first pay a toll then go through a CBP facility just to the south before actually crossing the border into Mexico.



Figure 2. Photo of Trailer next to Toll Lanes.



Source: Google Earth.

Figure 3. Aerial View of Zaragoza/Ysleta POE.

TTI moved the data collection trailer to the site on July 17 and parked it there for the entire week. The trailer provided a means to position both detection systems beside the traffic being monitored and raised to a height of 17 ft. Continuous grid power was made available through a power cable extended from the nearest toll booth to the trailer. The field crew also set up a Wi-Fi network on-site to make the test systems accessible by the technical support teams.

Determining a Wavetronix solution to store vehicle count data without a cabinet required spending an inordinate amount of time with the Wavetronix technical support group in Provo, Utah. This was accomplished after researchers traveled to El Paso, since earlier information made this task seem easier than it actually was. When the TTI research team initially contacted the Wavetronix support group, they were uncertain as to whether their system would meet the needs of this project without the use of either a traffic signal cabinet or controller or both. They set up multiple experiments in their lab to test the system before guiding the TTI team in the field. After about three days of tests, Wavetronix was able to get the system to count and store vehicle records. In the meantime, the TTI team was working to get the LeddarTech IS16 detector fully functional in the new orientation.

An on-site laptop had both the Wavetronix and LeddarTech firmware loaded. Even though researchers had installed and tested the LeddarTech at the border on previous occasions, they were less certain about installing it in the proposed orientation. The manufacturer did not specify the vertical angle, indicating only that its segments would need to cover the desired lanes. As indicated in Figure 4, its fan from top to bottom forms a 45° angle so the installers attempted to rotate the sensor so the bottom of the fan would be at about the near edge of the closest lane (lane 1). The initial plan was to collect some data with the sensor and send the data and recorded video to the LeddarTech technical team for their analysis. Adjustments to the angle would be made based on their assessment. However, problems with the recorded video precluded the technicians from conducting their usual analysis and providing the needed guidance.

TTI collected LeddarTech data for five days during the week of July 17 along with recorded video to be used as ground truth. Due to scheduling conflicts with both the field crew and the LeddarTech support group, the data and recorded video were not processed until a few weeks later. By that time, TTI had moved the data collection trailer back to TTI offices in El Paso. Technical support personnel informed TTI in late August that using the video as ground truth would not be feasible due to problems with the video.



Figure 4. General LeddarTech Detection Fan.

CHAPTER 3: FIELD DATA RESULTS

INTRODUCTION

Field results come from data collected using the El Paso office's data collection trailer parked at the southbound passenger toll booth during the week of July 17, 2017. Figure 5 shows a closer view of the two detectors and the camera with the pole in its retracted horizontal orientation. Keep in mind that the test position of these components would be rotated 90° from that shown in this figure. Not shown is the Wavetronix Click 650 since it was located in the trailer cabinet.

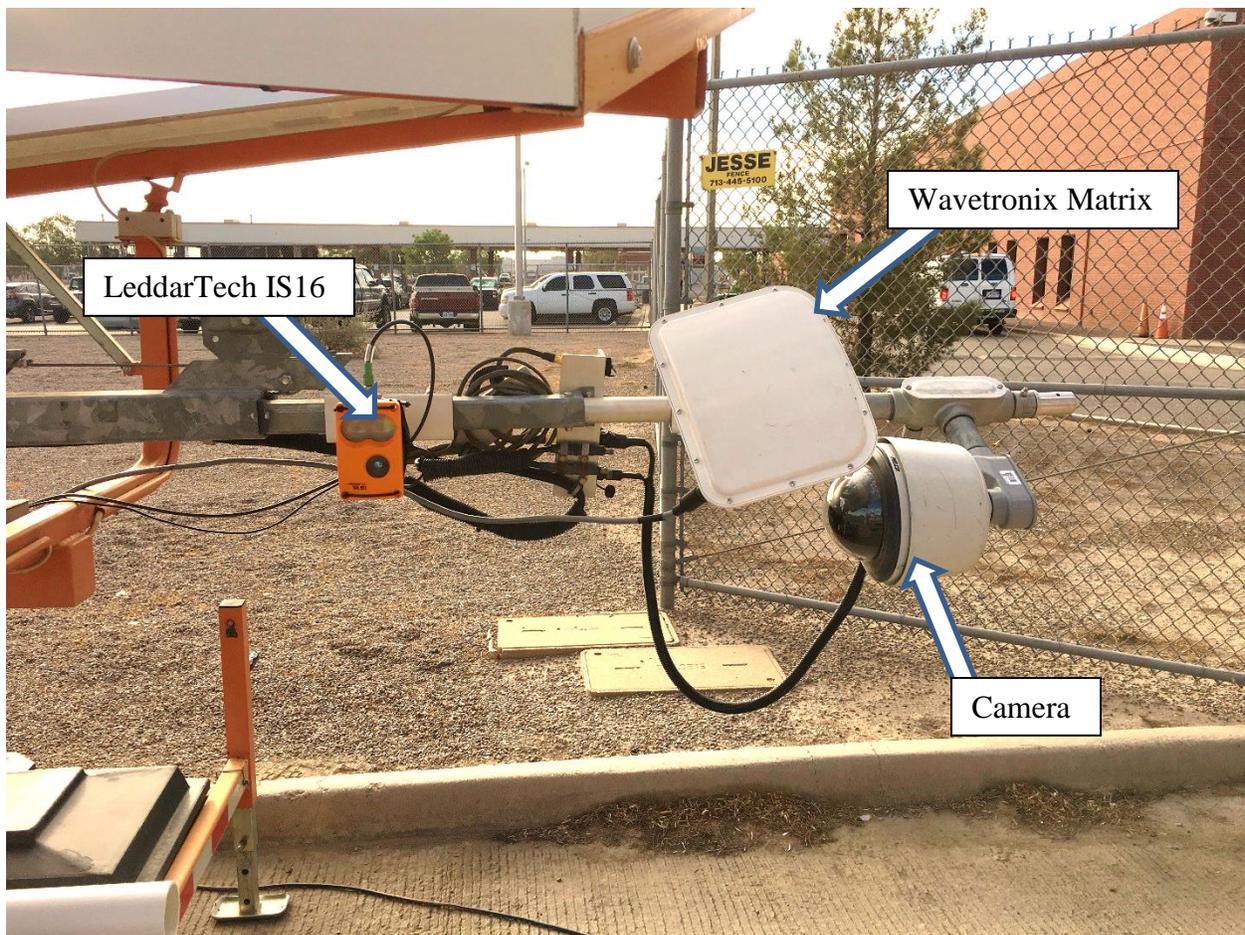
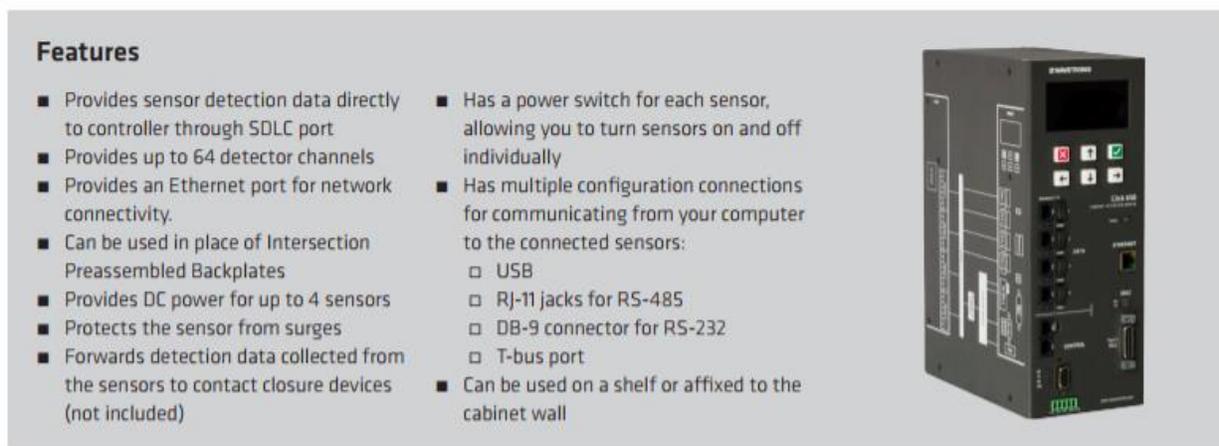


Figure 5. Detectors and Camera Shown in Retracted Horizontal Orientation.

WAVETRONIX SMARTSENSOR MATRIX/CLICK 650

Exploring Click 650

Click 650 is a cabinet interface device that can communicate with Wavetronix SmartSensor Matrix and Advance traffic controllers in one compact case. It also serves as a power, surge protector, and Ethernet connectivity for all users. It allows users to set up sensors and to access different settings via web interface. Using the Click 650 web interface, users can map sensor channels to detector channels, monitor the connection between the device and the sensors, and view graphs and tables based on the last seven days of data (1). Figure 6 provides additional information on the Click 650.



Source: (1).

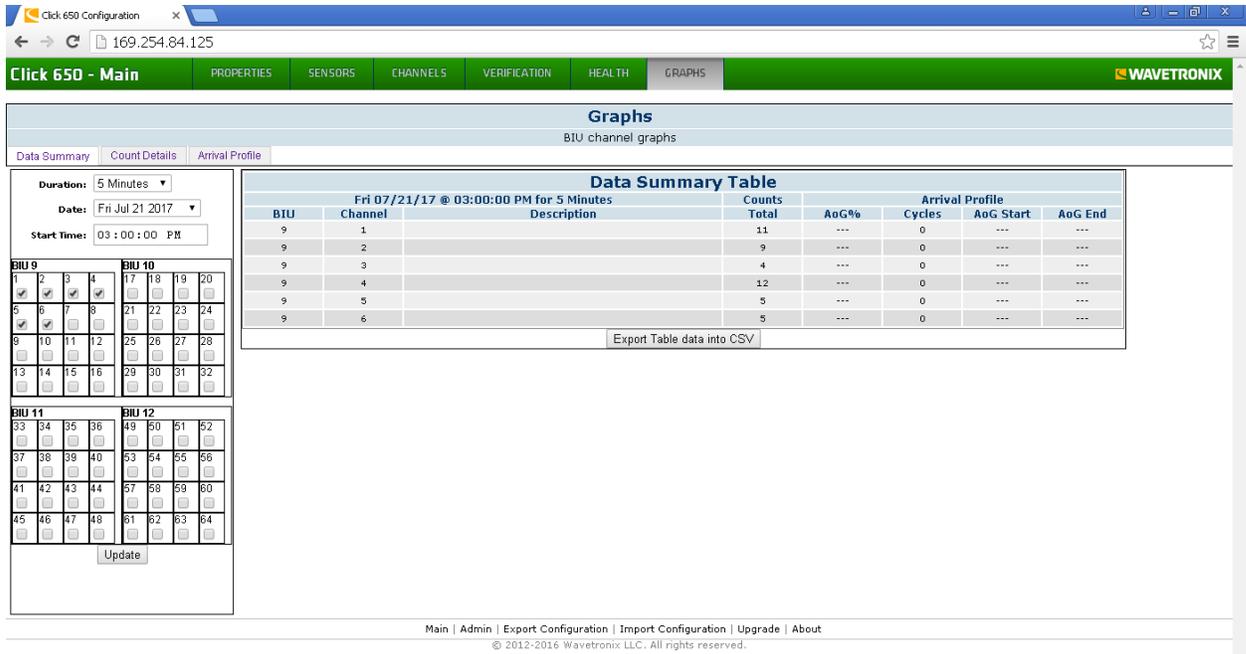
Figure 6. Wavetronix-Click 650 Features.

Accessing Click 650 Web Interface

From the Click 650 main menu screen, the user can select from the dropdown menu Network Setup to obtain the IP address to communicate via web browser. The IP address can then be input into any web browser (e.g., 169.254.84.125). Once the IP address is entered into the web browser, the user can access the web interface.

Downloading Graphs and Tables

One of the tabs in the Click 650 web interface allows users to generate tables and graphs for volume counts based on the last seven days of data collected. Figure 7 is an example. From the graph tab in the Click 650 web interface, users can select between data summary, count details and arrival profile. For the purpose of this research, only the data summary tab was used.



Source: (1).

Figure 7. Graphs Tab-Web Interface.

Data Summary

This tab allows users to generate a table with traffic volume and arrival profile. To create a data summary table, users can select the duration of the analysis (i.e., 5 minutes, 15 minutes, hour, day, or week) located on the top left of the web page. The next dropdown menu is for the user to select a date (only available data from the last seven days), and the Start Time field to choose the time for the data. The user then has to select which channels are needed from the Bus Interface Unit boxes. All the channels that are defined in the SmartSensor Matrix will automatically be selected. Then click Update.

RESULTS

The results are provided for each hour of a selected day during the week of July 17, 2017. Table 1 provides hourly counts during July 21, 2017 from the City of El Paso. For the results comparison for the two test systems, these data provided the best ground truth since the recorded video was not reliable. Besides, the city's counts were based on a redundant three-level system involving an overhead scanning detector, a pressure treadle, and an inductive loop. TTI did not test the reliability of the city system but previous experience indicates that the system is well maintained and highly accurate. For a second comparison, the city reported the following times that lanes were open that Friday, July 21, 2017:

- Lane 1 –
 - First shift opens at 11:00 a.m. and closes at 3:30 p.m.
 - Second shift opens at 4:30 p.m. and closes at 9:00 p.m.
- Lane 2 – opens at 10:00 a.m. and closes at 10:00 p.m.
- Lane 3 – open 24 hours.

- Lane 4 –
 - First shift opens at 7:00 a.m. and closes at around 3:00 p.m.
 - Second shift opens at 4:00 p.m. and closes at 10 p.m.
- Lane 5 – open 24 hours.
- Lane 6 – opens at 3:00 p.m. to 12:00 a.m.
- Lane 7 – opens at 1:00 p.m. and closes at around 10:00 p.m.

Table 1. City of El Paso Counts and Hours Open on July 21, 2017.

Hour	Lane 1 ^a	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6	Lane 7
00:00 to 01:00	1	0	0	0	32	68	0
01:00 to 02:00	0	0	0	0	63	0	1
02:00 to 03:00	0	0	0	0	27	0	0
03:00 to 04:00	0	0	0	0	34	0	1
04:00 to 05:00	0	0	0	0	30	0	0
05:00 to 06:00	0	0	17	0	69	0	0
06:00 to 07:00	0	0	86	0	111	0	0
07:00 to 08:00	0	0	132	84	132	0	0
08:00 to 09:00	0	0	80	166	124	0	0
09:00 to 10:00	0	0	59	161	177	0	0
10:00 to 11:00	0	133	42	202	45	0	0
11:00 to 12:00	103	131	37	32	123	0	1
12:00 to 13:00	99	90	36	124	104	0	0
13:00 to 14:00	140	145	41	175	21	0	8
14:00 to 15:00	116	136	42	158	125	0	2
15:00 to 16:00	173	74	50	37	281	119	0
16:00 to 17:00	56	188	44	92	134	106	15
17:00 to 18:00	157	154	44	149	97	53	50
18:00 to 19:00	143	130	56	139	93	42	41
19:00 to 20:00	146	139	47	132	79	39	42
20:00 to 21:00	163	18	19	148	117	23	52
21:00 to 22:00	19	0	17	139	121	68	46
22:00 to 23:00	0	0	14	16	165	111	1
23:00 to 24:00	0	0	8	0	149	91	0

^a Shaded cells indicate hours closed according to the City of El Paso.

Based on Table 1 results, not all periods indicated as closed result in zero vehicle counts. In this case, that result might have happened due to clocks not being synchronized. Determining whether a lane is closed or open based on independent vehicle counts should not be expected to be 100 percent accurate since factors beyond the control of the detector could affect the apparent count leading to a conclusion about lane status. Choosing the minimum threshold (non-zero values) to claim that a lane is closed might vary as well. For example, this minimum threshold might be different for peak versus off-peak conditions. If the detection system is able to detect

pedestrians, the minimum value should be greater than zero for that reason since shift changes generate pedestrian activity. One might use a few days of historical data as a guide for setting the count thresholds for determining open or closed status.

Wavetronix SmartSensor Matrix

Table 2 shows the results of the Matrix vehicle counts for July 21, 2017. These results compared to City of El Paso counts indicate some significant differences in hourly numerical count values (lane 1 is closest to the detector). However, based on these data, the Matrix would provide adequate lane status (open or closed) for the four or five lanes nearest the detector. Its lane 6 results are significantly different from the baseline numerical values provided by the city.

Table 2. Matrix/Click 650 Vehicle Counts July 21, 2017.

Hour	Vehicle Counts					
	Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Lane 6
00:00 to 01:00	0	0	0	0	27	66
01:00 to 02:00	0	0	0	4	68	1
02:00 to 03:00	1	0	0	0	27	1
03:00 to 04:00	0	0	1	1	33	2
04:00 to 05:00	0	0	0	0	30	1
05:00 to 06:00	0	0	17	1	62	2
06:00 to 07:00	0	0	73	4	82	8
07:00 to 08:00	0	1	119	83	119	21
08:00 to 09:00	1	1	77	122	120	31
09:00 to 10:00	1	2	61	122	143	66
10:00 to 11:00	0	84	47	147	68	71
11:00 to 12:00	96	104	60	26	115	21
12:00 to 13:00	83	80	49	122	111	26
13:00 to 14:00	115	112	81	135	47	40
14:00 to 15:00	105	108	62	150	134	46
15:00 to 16:00	34	18	80	36	97	118
16:00 to 17:00	7	13	89	13	68	102
17:00 to 18:00	32	15	182	19	97	126
18:00 to 19:00	23	9	174	23	97	90
19:00 to 20:00	21	10	160	18	95	141
20:00 to 21:00	75	15	55	58	95	158
21:00 to 22:00	12	0	20	111	126	92
22:00 to 23:00	23	3	15	18	128	101

^a Shaded cells indicate hours closed based on observation and limited knowledge of historical counts.

Back to the discussion under Table 1, the Matrix detects pedestrians so the low numbers in some shaded cells is likely due to toll booth activity involving people walking near the booth. Shaded cells in Table 2 are the authors’ initial estimate of times when the lane was likely closed. Even though these closure times compare well with actual closure times for at least lanes 1

through 5 provided by the City of El Paso, historical data would probably result in a more accurate assessment of lane status derived from vehicle counts.

LeddarTech IS16

Researchers worked with the LeddarTech technical staff to determine vehicle counts based on the IS16 being oriented vertically. Analysts spent several days attempting to synchronize the recorded video with the LeddarTech output but without success. The team then decided to develop a spreadsheet to evaluate each 15-minute interval and microscopically follow each segment every few milliseconds to attempt to identify detections. One problem with this approach is that several segments might indicate detections, but without ground truth (e.g., recorded video), there was no conclusive way to determine when discrete detections occurred. A tall vehicle could easily occlude a smaller vehicle behind it or it might cause a false detection in the adjacent lane. After extensive trial, the team did not pursue this method any further. At that point, the project had gone past its normal end date so additional data collection was not an available option.

Preliminary results based mostly on observation indicate that the LeddarTech could probably determine lane status for as many as three lanes at the height and offset it was mounted for these tests. It could probably count additional lanes if mounted higher than 17 ft. as it was installed at the Zaragoza port of entry. To be effective as a long-term solution for determining lane status, however, it would need to have software developed to count and store traffic data based on given heights and offsets.

In sidefire orientation even with optimum positioning and height, some lanes would end up with only a few detector segments covering a more distant lane. These more distant lanes would easily be affected by occlusion by taller vehicles due to the flatter angle. For these reasons, determine status of more than three lanes would be unlikely.

Researchers believe this detector has merit for this application but only where the detection zone width is no more than three lanes wide (or approximately 45 ft.). For wider detection areas, the sensor could be mounted on both sides and probably perform well for up to six lanes. Its low cost would be a positive factor in selecting it over other alternatives, but it would need some development work to make it a stand-alone device that could operate continuously and provide reliable real-time lane closure information.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Determining whether a lane is open or closed based on vehicle counts should be based on multiple factors, and choosing the minimum threshold to declare a lane closed might vary as well. For example, this minimum might be different for peak versus off-peak conditions. The other consideration in setting the minimum value is whether the test system detects pedestrians. In the case of the Wavetronix SmartSensor Matrix, it does detect pedestrians so its low numbers in some one-hour periods is likely due to toll booth activity involving people walking around the booth.

The results of the Matrix vehicle counts for July 21, 2017 compared to City of El Paso counts indicate some significant differences in hourly numerical values. However, based on these data, the Matrix would provide adequate lane status (open or closed) for the four or five lanes nearest the detector.

For the LeddarTech IS16 detector, preliminary results based mostly on observation indicate that it could probably determine lane status for as many as three lanes. It could probably count additional lanes if mounted higher than 17 ft. as it was installed at the Zaragoza port of entry. To be effective as a long-term solution for determining lane status, however, it would need to have software developed to count and store traffic data based on given heights and offsets.

In sidefire orientation even with optimum positioning and height, some lanes would end up with only a few of the 16 detector segments covering more distant lanes. These more distant lanes would easily be affected by occlusion by taller vehicles due to the flatter angle. For these reasons, determining the status of more than three lanes would probably not be feasible.

Researchers believe this detector has merit for this application but only where the detection zone width is no more than three lanes wide (or approximately 45 ft.). For wider detection areas, a sensor could be mounted on both sides and probably cover up to six lanes. Its low cost would be attractive in selecting it over other alternatives, but it would need some development work to make it a stand-alone device that could operate continuously and provide reliable real-time lane closure information.

RECOMMENDATIONS

Both of the detectors tested in this research are potential solutions for providing lane status. However, decision-makers should consider that mounting a detector over each lane (e.g., the LeddarTech IS16) could provide both vehicle counts and lane status. That solution would defy the objective of being remote but would generate accurate counts. In some cases, a simpler solution might also meet this need such as:

- Where overhead electronic signs are used, connect to the sign wiring to determine lane status.

- Where gates are used, use electrical contacts at the closure point.
- Also, where gates are used, install a device (e.g., compass) to monitor the direction (azimuth) of the gate.

Since this research was the first attempt to deploy the LeddarTech IS16 off the lanes, more research is needed to develop guidelines on how it should be positioned to optimize its performance. Also, the additional tests might evaluate the other option noted earlier in this report to position it to view license plates instead of using a sidefire orientation.

The Wavetronix SmartSensor Matrix also appears to be viable for remotely monitoring lane status. The Matrix operating alone does not store data onboard but its companion unit, the Click 650, can be manipulated to store data without an equipment cabinet. However, this is not a straightforward process, so additional development effort is needed before this system should be considered as a widespread solution.

REFERENCE

1 Click 650 User Guide, Wavetronix, Provo, Utah, February 2017.