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EVALUATION OF SENSYS WIRELESS VEHICLE DETECTION SYSTEM: RESULTS FROM THE FIRST THREE MONTHS

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16. Abstract

The Sensys Wireless Vehicle Detection System uses wireless magnetometers embedded in the pavement that communicate without wires to an access point connected to a standard detector rack. This research evaluated the detection performance of this system at two locations: a signalized intersection with three approaching lanes (at stop bar and advance zones), and a railroad grade crossing, as a potential backup option for crossing gates applications. Video images and the time of activation/deactivation of the sensors and loop detectors (placed at exactly the same location as the sensors), were collected after the system was installed by Sensys Networks, yielding some initial results (initial setup). Subsequently, Sensys Networks was provided with the initial results (false, missed, stuck-on, and dropped calls) and were allowed to readjust the system (modified setup) so that the best performance could be obtained. Thus, this report includes results from the initial and the modified setups at the two selected locations. At the railroad location, false calls due to adjacent vehicles ranged from 12.1% to 53.7%, missed calls were low (<1%), and stuck-on calls due to trains and cars were rare (but up to 30 min long). At the signalized intersection, false calls were more frequent at the stop bar (13.5% to 19.6%) than at the advance zones (0.7% to 2.4%). Missed calls were low at the stop bar (<0.5%), and ranged between 0.9% and 10% at the advance zones. Stuck-on calls and dropped calls were very rare and only found at stop bar zones.

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EXECUTIVE SUMMARY

Wireless magnetic-field based vehicle sensors, such as the Sensys Networks system evaluated in this report, eliminate the need for cutting pavement for loop detector installation. This study evaluated detection performance of Sensys wireless sensors at two instrumented intersections in Rantoul, IL. At one signalized intersection, six sensors were placed at stop bar and advance detection zones; and at a highway-railroad grade crossing location, two sensors were placed close to the path of train. This report contains the findings for the first three months after installation. Video images and the time of activation of the sensors and loop detectors, installed for this purpose, were used in the evaluation. This report includes results from the initial and the modified setups. At the railroad location, false calls due to adjacent vehicles ranged from 12.1% to 53.7%, missed calls were low (<1%), and stuck-on calls due to trains and cars were rare. At the signalized intersection, false calls were more frequent at the stop bar (13.5% to 19.6%) than at the advance zones (0.7% to 2.4%). Missed calls were low at the stop bar (<0.5%), and ranged between 0.9% and 10% at the advance zones. Stuck-on calls and dropped calls were very rare and were only found at stop bar zones.

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CHAPTER 1 INTRODUCTION

Different vehicle detection technologies have been used in recent years, aiming to provide more accurate detection, more flexibility and ease in installation, and less maintenance compared to the widely used inductive loops. Among these new technologies are video detection, advanced microwave detectors, and wireless magnetic-field based sensors such as the Sensys system. A typical installation of the Sensys system consists of wireless sensors, an access point, and a contact closure card that interfaces with the traffic controller. This system offers vehicle detection without the need of hard wiring a detector into the pavement, like loop detectors. Instead, wireless sensors are embedded inside the pavement by drilling a hole of approximately 4 inches in diameter and 2 ¼ inches in depth. The sensors use low power radio signals to provide two-way communications with an access point that is usually mounted on a roadside pole. The access point is connected via wires to a contact closure card that is plugged into a standard detector rack. If the distance between the sensors and the access point is greater than about 150ft, a repeater may facilitate the communication between sensors and access point.

This report presents the preliminary results of an evaluation of the Sensys wireless vehicle detection system. The Sensys system was installed at a signalized intersection at stop bar and advance locations and at a railroad grade crossing as potential backup sensor for loop detectors in quad-gate railroad grade crossing applications. Four measures of performance are used (false, missed, stuck-on, and dropped calls) to determine the detection errors. The performance of the system is evaluated based on an automatic preliminary detection of potential errors comparing the sensors with loop detectors, and a later visual verification of all potential errors using video images of the locations.

Data for the evaluation of the Sensys system was collected and analyzed during two separate time periods. The first period is called initial setup and represents the Sensys system after the initial setup by a Sensys representative. The second period is called modified setup, and it represents conditions after the initial setup was modified by a Sensys representative. In other words, the Sensys representatives were given an opportunity to improve the system performance after some information on the detection errors was provided to them by the research team.

Results from the initial and the modified setups, as well as a detailed quantification of the detection errors and their causes are included in this report. It is noted, however, that the results presented here are based on limited data and that additional datasets are being collected for a more comprehensive evaluation of the Sensys system performance.

The next section briefly describes past experiences with the Sensys system and their results, followed by the methodology and the system installation and setup. Then, the results and findings are presented.

CHAPTER 2 BRIEF LITERATURE REVIEW

A brief account of recent research related to the performance of the Sensys wireless vehicle detection system is included in this section. In 2006, the California Center for Innovative Transportation evaluated the Sensys system on freeways, as potential replacement for loop detectors. This study examined the installation procedures, the quality of the wireless data link from the sensors directly to the access point (no repeaters were used), and the data quality. An area of 2.7 miles was monitored using cameras from high-rise buildings and the sensors were tested on timeliness, completeness, validity, and accuracy, using four loops and four sensors during two weeks from 5 a.m. to 10 p.m. each day. It was concluded that more than 99% of the records sent by the sensors were received by the access point within 0.5 seconds without loss of data, with a detection (and traffic measurement) accuracy of 95%, and miscounts less than 2% (mainly due to missed motorcycles and double counting of heavy vehicles).

The Texas Transportation Institute (TTI) in 2006 also evaluated the accuracy of the Sensys system for a freeway application, and found average count errors of +/- 1% in 15-min intervals, comparable to loop detectors. Also in 2006, a report from Florida A&M and Florida State University described, for a freeway application, average error counts of +/- 1% (between -4.1% and +2.5% in 15min counts) and average speed errors of -1.4% (between -3% and +0% for 15min counts). On a different setting, the University of California at Berkeley (2006) studied the accuracy of speed reported by the Sensys system at about 150m from an intersection and reported speed errors between 0.3% and 6.9% and frequent failure to detect motorcycles.

On the other hand, a study by ARRB Consulting and La Trobe University in 2007 analyzed the battery life of the sensors, estimating a useful life of about 10 years with traffic volumes close to 3500 vph. Similarly, TTI and the University of Texas A&M evaluated the sensor battery life after 1.5 years of operation under traffic volumes between 7000 and 15000 vehicles per lane per day, estimating a life span of 8.5 to 10 years for the sensors.

CHAPTER 3 METHODOLOGY

The evaluation of the Sensys system was performed using two types of data: (1) activation/deactivation times of loops and Sensys wireless sensors (timestamps) and (2) video images. The timestamps provide accurate data that allow the automation of the initial stages of the analysis using computer algorithms and the use of large datasets. Timestamps were collected using an input/output (I/O) device to monitor vehicle presence as identified by each inductive loop and wireless sensor detector. The I/O device verifies the state of the six loops and the six sensors once every 50 milliseconds. Also, video images were fed as an input to a quad processor, along with a real-time graphical depiction of the status (vehicle/no vehicle) of the loops and sensors generated by I/O device. This graph provides an additional tool to visually confirm if a call took place in any loop or sensor. The recorded video images were also used to provide visual verification of the potential error automatically identified with the computer algorithms and the timestamps. In addition, the video images served as a ground truth to verify that there were no errors by the loops and helped ascertain the lighting/weather/traffic condition at the study location.

All hardware required for data collection was housed in separate cabinets than those used to operate the intersection. Thus, the data collection devices did not interfere with traffic operations at the intersections.

Four measures of performance (MPs) were used to quantify the detection errors and to evaluate Sensys performance: false calls, missed calls, dropped calls, and stuck-on calls. These MPs were estimated for each sensor separately by automatically detecting <u>potential</u> errors using the computer algorithms, and then by <u>manually</u> verifying every potential error before labeling it as an actual detection error. The automated error detection enabled the use of large datasets and avoided issues related to small data bases.

The computer code developed to accomplish the automated steps of the analysis reads the timestamps from both loops and wireless sensors, establishing if there was a discrepancy between them. A time window of 1 second was used when comparing the activation/deactivation times of loops and sensors, allowing for a slightly different detection time given the different characteristics of the two technologies. A discrepancy does not necessarily mean an error. The concepts used to define MPs, as well as the logic used in the computer code, are briefly discussed below.

3.1. MISSED CALLS

Missed calls occur when a wireless sensor fails to detect a vehicle. These errors could have adverse safety effects due to potential red light runners in cases where the corresponding phase is not called by the controller. In terms of timestamps, for every loop call if there is no corresponding Sensys call, it is considered a potential missed call. The algorithm identifies loop calls and searches for Sensys calls in a 1-second window before the start of loop call, and 1 second after the end of the loop call. If no sensor call is found in this window, this is counted as a potential missed call.

3.2. FALSE CALLS

False calls are defined as calls placed by the wireless sensors when there was no vehicle present over the sensor or when multiple calls were created by the same vehicle. Thus, based on the cause of the false activations, false calls were divided into two subgroups: flickering and non-flickering. Flickering false calls refer to multiple calls placed by the sensor for the same vehicle (a truck or a smaller vehicle) while it was occupying the detection area, whereas non-flickering false calls were caused by small and heavy vehicles when they travelled in the adjacent lane regardless the direction of travel. Therefore, vehicles traveling westbound as well as vehicles traveling eastbound could generate non-flickering false calls, especially on the sensor in the left turn lane.

False calls could have a negative effect in the operational efficiency of the intersection. In the algorithm, for every call by a wireless sensor, if there is no corresponding call from the loop detector, it is considered a potential false call. The algorithm identifies the sensor calls and then searches for a loop call placed in a 1-second window before the beginning of the sensor call and 1 second after the sensor call is dropped. If the call is not found, it is considered a potential false call.

3.3. DROPPED CALLS

Dropped calls occur when a call by the wireless sensor is dropped while the vehicle is still present. If the sensor prematurely drops the call placed to the controller, this may prevent the corresponding phase from being called, generating potential safety issues due to red light runners. In terms of timestamps, if the sensor call is terminated more than 5 seconds before the end of loop call, it is considered as a potential dropped call.

3.4. STUCK-ON CALLS

Stuck-on calls are defined as the calls that occur when the wireless sensor indicates that the vehicle is still present, but the vehicle had departed. Stuck-on calls affect the operational efficiency of the signalized intersection. In the algorithm, if a sensor call continues to be active more than 10 seconds after the end of the loop call, it is counted as a potential stuck-on call.

CHAPTER 4 SENSYS SYSTEM INSTALLATION AND SETUP

As mentioned before, two locations were selected to perform the evaluation of Sensys system: 1) an urban signalized intersection, where both stop bar and advance detection zones are evaluated; and 2) a railroad grade-crossing equipped with entry gates, to evaluate the potential use of the Sensys system as a backup for loop detectors in quad-gate applications. Details of the geometry and the installation of the system at each of the two selected locations are presented next.

4.1. DESCRIPTION OF RAILROAD GRADE CROSSING AT CHANDLER RD & US ROUTE 45

Sensys detectors were installed in the eastbound lanes of Chandler Road just west of U.S. Route 45. At this location, railroad tracks run parallel to U.S. Route 45, and the grade crossing of the tracks and Chandler Road is protected by entry gates and flashing lights in both directions of travel. Eastbound Chandler Road has one lane per direction west of the railroad tracks, but it splits into two lanes east of the tracks: one for left turn and one for the thru and right movements.

Two 6ft x 6ft inductive loop detectors were installed between April 14 and 16, 2008, one on each of the two lanes. The loops were located just past the railroad tracks with the leading edge of the loops at about 5 feet from the tracks. In addition, one Sensys wireless vehicle detector was installed on each of the two lanes. The sensor on the left-turn lane was just outside of the leading edge of the loop (between the loop and the track), and the sensor on the thru lane was just inside of the leading edge of the loop. The Sensys installation used no repeaters since the access point was within 150ft from the sensors. The intersection layout, the eastbound approach, and the detail of the loops and sensors are shown in Figure 1.

The initial installation did not include a camera to record video images, but an Iteris color camera was added on June 11, 2008, to record video images of the eastbound approach, as explained below.

4.2. DESCRIPTION OF INTERSECTION OF CENTURY BLVD & VETERANS PKWY

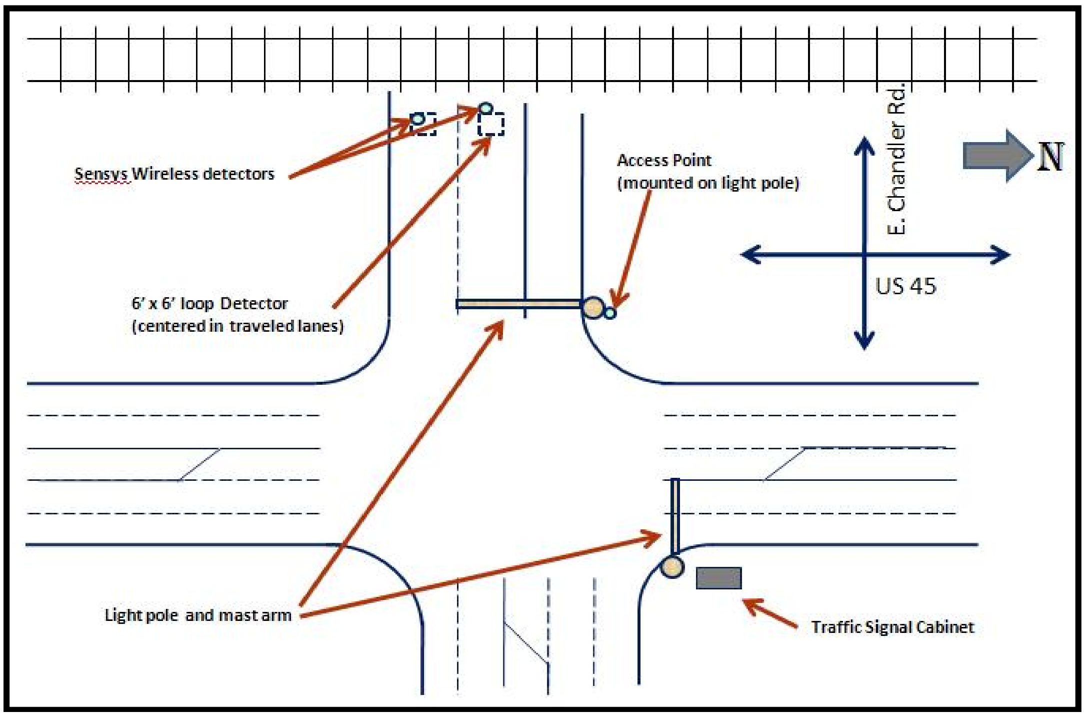
The eastbound approach of this intersection was selected for the evaluation. This approach has two left-turn lanes and a shared right-thru lane. An inductive loop (6ft x 6ft) had been installed in each lane at stop bar and advance location (about 250ft upstream) providing a total of six detection zones. At the center of each loop, a Sensys wireless detector was installed. Thus, three sensors installed at the stop bar locations and three sensors at the advance locations. The sensors were embedded in the pavement centered inside the loops, so that the detection area of the two detection technologies was as similar as possible.

In addition to the sensors, the installation of the Sensys system also required the use of one access point and two repeaters. One of the repeaters was installed on the mast arm of the traffic lights facing the vehicles on the opposite direction (in the receiving lanes) and linked the communications between the three stop bar detectors and the access point. A second repeater did so for the advance detectors and was installed at a light pole, as illustrated in Figure 2. Sample images of the access point and the subject approach are also shown in Figure 2 for illustration purposes.

A camera from Autoscope video detection system was used to record video images of the eastbound approach for later visual confirmation of the detection errors, and for the identification of their potential causes.

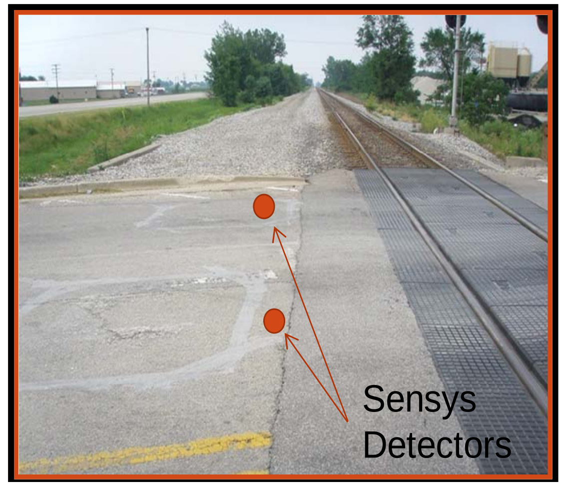
4.3. SENSYS SYSTEM INSTALLATION

The Sensys system was installed by a Sensys representative at the two selected locations on April 22, 2008. In addition, a private contractor was hired to perform the core drilling in the pavement and the lane closures needed to complete the installation. In this case, at least one lane was kept open to traffic at all times, so vehicles could still be processed at the intersection and at the railroad locations. The process of drilling one core and placing one sensor was performed in about 10 minutes, including the time to pour the epoxy that sealed the drilled hole. An additional 5 minutes were needed before opening a lane back to traffic in order to let the epoxy of the last sensor to harden.



A – Diagram of intersection of Chandler Road and U.S. Route 45.

B - Eastbound approach.

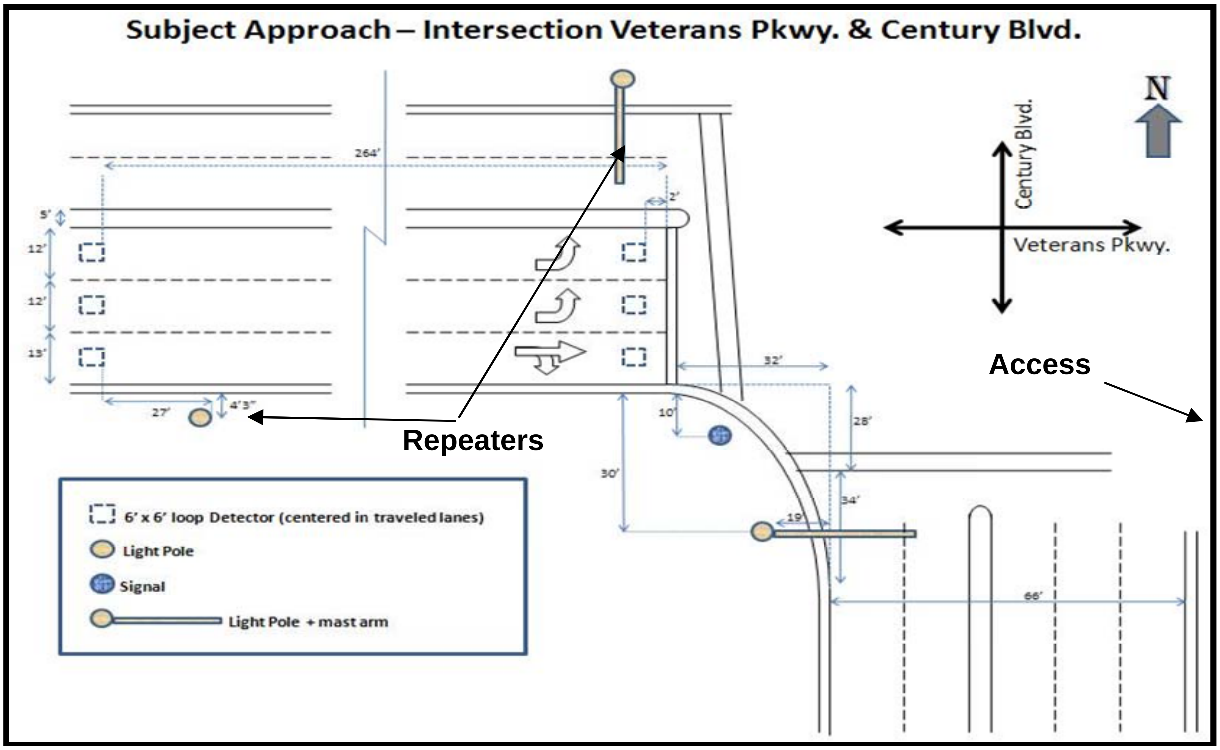


C - Detail loops and Sensys detectors.

Figure 1. Layout and sample images from the railroad grade crossing location.

The installation of the access point and the repeaters followed the installation of the sensors. Once the decision on the location of the access points and the repeaters (if needed) was made, a bucket truck fixed the devices using the brackets and fasteners included in the system package. It is noted that a cable needs to be run between the cabinet that houses the equipment and the access point. The existing conduit for traffic light was used to bring the cable from one side of the street to the other side.

Finally, the Sensys representative set the system configuration at the cabinet using their proprietary software. However, unlike the installation of the other hardware components, this stage required the most time and its duration was in the order of hours. Once the Sensys representative finalized this stage, the installation was completed.



A - Diagram intersection of Veterans Pkwy and Century Blvd.

B - Detail access point.

C – Eastbound approach.

Figure 2. Layout and sample images from the intersection of Veterans pkwy and Century Blvd.

4.4. EVENTS FOLLOWING THE INITIAL INSTALLATION

The chronology of events from the initial installation until to the modified installation is summarized in this Section. An account of the activities posterior to the initial installation is important because these activities could be faced elsewhere at similar installations.

- April 28, 2008: In a visit to the railroad installation, it was noticed that the Sensys contact closure card in the detector rack had lost power. A Sensys Support Engineer, contacted by phone, tried to log onto the system remotely but could not gain access to it. When the card was unplugged and plugged back again to the detector rack, the card functioned for short periods of time (less than 1 day), after which the card lost power again. It is noted that later in that week, a piece of the circuitry from the Sensys card seemed to have burnt. The Support Engineer proposed to replace the existing Sensys card for a new card and also checking/redoing the connection of the cable connecting to the access box (and from there to the access point). For this purpose, it was planned to send a new Sensys card and new ethernet clip connectors by mail.
- May 8-9, 2008: A new Sensys contact closure card (that arrived on May 7) was used to replace the damaged card at the railroad location. However, the manual setting changes directly executed from the dip switches on the card did not allow for changes in the system configuration, and the sensors were operating on pulse mode and not on presence mode (contrary to the settings in the initial setup). A second site visit from the Support Engineer was scheduled to help solve these issues since the remote connection to the access point was still not possible.
- May 15, 2008: The Sensys Support Engineer visited the railroad location and used the Sensys software to access the system at the railroad location. The system was configured to the same parameters as in the initial configuration.
- May 30, 2008: A visit to the railroad location revealed that the recently replaced Sensys CC card was not operating correctly, and it was losing power even though the card was connected to the detector rack.
- June 11, 2008: A new version of the Iteris video detection system that uses a color camera was installed at the railroad location. The Village of Rantoul and representatives from IDOT provided help in this installation. The camera image is captured using a quad processor, to allow for a simultaneous recording of a live depiction of the status of the Sensys sensors and loop detectors. This setup is similar to that at the intersection of Century Blvd and Veterans Pkwy. At this point, the failures of the Sensys CC card previously observed did not reappear, and the Sensys system functioned correctly at the railroad location, except for the remote connection capabilities (not working properly). From this point on, data was collected continuously at the two locations.

4.5. MODIFIED SETUP

After collecting data for some period, data from different days and times were selected and analyzed to assess the performance of the initial setup. The preliminary results were shared with Sensys representatives (on August 29, 2008) so they could make modifications to the setup, if they thought they could improve the system's performance. Later, on September 11, 2008, Sensys representatives visited the two locations and updated the systems configurations. The changes included an update of the sensor and repeater firmware to its version 1.6.7 (displayed internally by the software as V 47.3.3 for the sensors, and V 47.1.7 for the repeaters) at the two locations. Addition changes made that day are as follows:

- At the Railroad Grade Crossing: the count recalibrate time out was set to the "off" position to take away the ability of the sensors to recalibrate by themselves. This was done to prevent stuck-on calls after trains were stopped for long time at the crossing (this caused the recalibration of the background to a new one that included the train). Also, the reference vehicle type for both lanes was set to "5", which is for passenger cars (in the initial setup, it was 5 for the thru lane and 7 for the left lane).

- At the intersection of Veterans Pkwy and Century Blvd: the stop bar sensors were set to “Stop Bar 3” mode, in order to making them more reactive to changes in the magnetic field around them.

Following the changes, data collection started at both locations for the “modified setup” conditions. In the next section, the performance of the modified setup will be presented separately from the performance in the initial setup conditions.

CHAPTER 5 RESULTS

This report presents results of the evaluation of Sensys wireless vehicle detection system after the first three month of installation. The system operated under the initial setup and modified setup conditions. These results are based on limited datasets and further data is being collected to perform a more comprehensive analyses. The subsequent reports of this study will contain the analyses of extended data at the two locations.

5.1. RAILROAD GRADE CROSSING AT CHANDLER RD & U.S. ROUTE 45

For each setup (initial and modified), 140 hrs of data (from 10 different days) were used in the analyses. Data from the selected days were obtained for the following times: 6am – 8am, 8am – 11am, 12pm – 3pm, 4pm – 7pm, and 8pm – 11pm. These time slots were selected to represent the performance of the Sensys system at different times of day (daytime, nighttime, etc) on those selected days.

Traffic volume was low on the eastbound approach of Chandler Road, and on average, about 36 vehicles per hour crossed the tracks in the eastbound direction. However, because of the length of the observation period, data was obtained from about 10000 vehicles for the initial and the modified setups combined. In terms of train volume, a total of 291 trains were observed during the selected periods, as it is described in detail in Table 1. It is noted that vehicular traffic and train volumes were similar in the initial and the modified setups.

	Initial Setup (140 hr)		Modified Setup (140 hr)	
Train type	**Frequency**	**%**	**Frequency**	**%**
Freight	99	67.8%	97	66.9%
Passenger	43	29.5%	48	33.1%
Maintenance Equipment	4	2.7%	0	0.0%
Total	**146**	**100.0%**	**145**	**100.0%**

Table 1. Total train volumes for initial and modified setup.

Trains at the crossing did activate the Sensys detectors, generating calls in addition to those generated by vehicles. However, not all trains had the same effects and the number of activations due to trains varied from a single sustained activation that lasted the whole time the train was present, to multiple shorter activations that significantly increased the total number of calls placed by the sensors. Thus, Sensys detected moving trains as long sustained activations or as multiple flickering calls (activation/deactivation). The total number of calls generated by trains and by vehicles at each of the two sensors is shown in Table 2.

SETUP	SENSOR	Total Activations	Activations due to Trains		Activations due to Vehicles	
			Number	% from total activations	Number	% from total activations
Initial Setup (42 hr)	Left-turn Lane	725	485	66.9%	240	33.1%
	Thru Lane	1486	249	16.8%	1237	83.2%
Modified Setup (140 hr)	Left-turn Lane	3510	687	19.6%	2823	80.4%
	Thru Lane	5400	560	10.4%	4840	89.6%

Table 2. Sensys activations due to trains and vehicles at railroad grade crossing.

It was observed that when a train stopped at the crossing, there was a chance of the sensor dropping the train call. This was observed only in the initial setup in 3 out of 4 times that a train stopped. Also, it was noted that the sensors put in a new call as the train left the crossing or started moving again.

The behavior of the sensors after the trains departed was also analyzed. In the initial setup, in some cases the sensors did not drop the train call after its departure (the call was stuck-on). However, in the modified setup the occurrence of these cases was reduced and only one such case was found. The detailed effect of trains on the Sensys detectors after the trains departed is shown in Table 3.

	Frequency	
EFFECT ON SENSYS	Initial Setup	Modified Setup
None	137	144
Both sensors remained stuck-on for about 5 minutes	3	0
One sensor remained stuck-on for about 5 minutes. Other dropped after train departed	3	0
One sensor remained stuck-on for about 5 minutes. Other dropped after vehicle traveled over	2	0
One sensor remained stuck-on, but dropped after vehicle traveled over	1	0
One sensor remained stuck-on for about one hour after a train departed (multiple trains passed, but call did not drop)	0	1
Total	**146**	**145**

Table 3. Effect of trains on Sensys detectors after train departed.

In the initial setup, all of the train calls that were stuck-on lasted for at most 5 minutes, time after which the sensor reset itself and readjusted the background information, preventing it from being stuck-on for longer periods. In the modified setup, on the other hand, the occurrence of these stuck-on calls was reduced since the background could not be adjusted to the train presence. However, one long stuck-on call, lasting for about one hour, was found after a train departed. This stuck-on call was not dropped even after several trains/vehicles passed near/over the sensor, and it was deactivated after a small vehicle passed over the detector (this vehicle was not particularly special). From the video images, no clear reason was found for this long call.

It is also noted that when there was no stuck-on call after train departure, all vehicles standing in queue to cross immediately after the train departure were properly detected.

The performance of the sensors in terms of the four MPs is described next.

5.1.1. Missed Calls

A relatively low percentage of missed vehicles were observed in both setups, with an improved performance in the modified setup (0.33% missed) compared to the initial setup (0.95% missed). Detailed description of all cases of missed vehicles is given in Table 4. In general, most of the vehicles missed in the initial setup were traveling between the two sensors (17 vehicles), whereas in the modified setup fewer vehicles traveling between lanes were missed (4 vehicles). Also, motorcycles and bicycles were likely to be missed, with 7 occurrences in each of the two setups.

	Initial Setup (140 hr)			Modified Setup (140 hr)		
Cause	Missed Calls		Total	Missed Calls		Total
	Left Turn	Right-Thru		Left Turn	Right-Thru	
AUTOMOBILE Missed between lanes	8	8	**16**	1	1	**2**
PICKUP TRUCK Missed between lanes	4	4	**8**	2	2	**4**
SUV Missed between lanes	5	5	**10**	1	1	**2**
AUTOMOBILE/SUV Missed when traveling directly over detector	6	0	**6**	1	1	**2**
MOTORCYCLE missed	0	5	**5**	0	7	**7**
BICYCLIST missed	0	2	**2**	0	0	**0**
Total Missed Calls	**23**	**24**	**47**	**5**	**12**	**17**
Total Traffic Volume (from loops)	**1013**	**3957**	**4970**	**1300**	**3848**	**5148**
Total Missed / Total Traffic Volume	**2.27%**	**0.61%**	**0.95%**	**0.38%**	**0.31%**	**0.33%**

Table 4. Description of missed calls at railroad grade crossing.

5.1.2. False Calls

False calls, not counting the activations due to trains, were found for both sensors mainly due to flickering calls and vehicles in the adjacent lanes. In the initial setup, false calls in the left-turn lane were 29.2%, comprised of 15.8% flickering calls and 13.4% non-flickering calls, and in the thru lane were 12.1%, comprised of 10.9% flickering and 1.2% non-flickering calls. On the other hand, in the modified setup, false calls were 53.7% in the left-turn lane, comprised of 16.5% flickering calls and 37.2% non-flickering calls, and in the thru lane they were 16.6%, comprised of 12.3% flickering calls and 4.3% non-flickering calls. The detailed description of the extent of the false calls due to small vehicles and trucks is presented in Table 5. Note that the comparisons from Table 5 are based on the 140 hrs from the modified setup and 42 hrs from the initial setup.

SETUP	SENSOR	Activations due to Vehicles		False Calls - Visually Verified Errors											
				Total		Small adjacent vehicles		Adjacent Trucks		Opposite Dir - Small Vehicles		Opposite Dir - Trucks		Flickering Calls	
		Number	% from total activations	Number	% from activations due to vehicles	Number	% from activations due to vehicles	Number	% from activations due to vehicles	Number	% from activations due to	Number	% from activations due to vehicles	Number	% from activations due to vehicles
Initial Setup (42 hr)	Left-turn Lane	240	33.1%	70	29.2%	6	2.5%	4	1.7%	14	5.8%	8	3.3%	38	15.8%
	Thru Lane	1237	83.2%	150	12.1%	11	0.9%	3	0.2%	0	0.0%	1	0.1%	135	10.9%
Modified Setup (140 hr)	Left-turn Lane	2823	80.4%	1515	53.7%	115	4.1%	61	2.2%	392	13.9%	481	17.0%	466	16.5%
	Thru Lane	4840	89.6%	804	16.6%	45	0.9%	159	3.3%	3	0.1%	0	0.0%	597	12.3%

Table 5. Detail of false calls at railroad grade crossing.

5.1.3. Stuck-on Calls

Only one stuck-on call caused by a vehicle was observed in the two setups. This stuck-on call was found in the modified setup, and it was initiated and terminated by a small vehicle. Several trains and vehicles passed near/over the sensors during the stuck-on call (it lasted for 30 min) without deactivating it. No clear cause for this long activation was observed from the video images.

5.1.4. Dropped Calls

No clear cases have been observed for dropped calls. Only situations in which potentially the call was dropped were found, but the camera angle was not clear enough to determine if the system effectively dropped the call while the vehicle body was still over the detector.

5.2. INTERSECTION OF CENTURY BLVD & VETERANS PKWY

The analysis presented in this report is based on 26 hrs of data from the initial setup and 26 hrs from the modified setup. Results from each detection zone are described in terms of the four MPs previously defined (false, missed, stuck-on, and dropped calls).

5.2.1. Zone 1

A slightly higher percentage of false calls was observed in the initial setup (19.6%), compared to the modified setup (16.8%). These false calls were comprised mostly by flickering calls (18.7% in initial, and 9.6% in the modified setup), which were generated when the sensor placed multiple calls for the same vehicle while it was occupying the detection area, followed by non-flickering calls (0.9% in the initial, and 7.2% in the modified setup) due to trucks and smaller vehicles traveling in the adjacent lane. Out of those vehicles causing non-flickering calls when traveling in the adjacent lane, 5 were trucks in the initial and 34 in the modified setup, and 12 were smaller vehicles in the initial and 77 in the modified setup, including 4 vehicles traveling in the opposite direction in the modified setup.

	Dataset	Zone 1											
		Total Activations		False Calls (non-flickering)		False Calls (flickering)		Missed Calls		Stuck-on Calls		Dropped Calls	
		SENSYS	Loop	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Initial Setup (26 hours)	July 16 (12 hours - day and night)	862	695	7	0.8%	170	19.7%	2	0.3%	0	0.0%	2	0.3%
	June 17 (6 hours)	376	309	7	1.9%	61	16.2%	0	0.0%	0	0.0%	0	0.0%
	Jun 27 (17:00 - 19:00)	201	150	1	0.5%	54	26.9%	0	0.0%	0	0.0%	0	0.0%
	July 2 (17:00 - 19:00)	206	173	0	0.0%	34	16.5%	0	0.0%	0	0.0%	0	0.0%
	July 15 (21:00 - 22:00)	29	23	0	0.0%	6	20.7%	0	0.0%	0	0.0%	0	0.0%
	June 19 (21:00 - 22:00)	48	43	2	4.2%	4	8.3%	0	0.0%	0	0.0%	0	0.0%
	July 20 (21:00 - 22:00)	23	24	0	0.0%	1	4.3%	0	0.0%	0	0.0%	0	0.0%
	July 21 (21:00 - 22:00)	51	47	0	0.0%	5	9.8%	1	2.1%	0	0.0%	0	0.0%
	Total	**1796**	**1464**	**17**	**0.9%**	**335**	**18.7%**	**3**	**0.2%**	**0**	**0.0%**	**2**	**0.1%**
Modified Setup (26 hours)	Sept 15 (8:00-11:00)	151	116	19	12.6%	16	10.6%	1	0.9%	0	0.0%	0	0.0%
	Sept 19 (12:00-15:00)	208	182	12	5.8%	15	7.2%	0	0.0%	0	0.0%	1	0.5%
	Sept 23 (20:00-23:00)	74	66	5	6.8%	3	4.1%	0	0.0%	0	0.0%	0	0.0%
	Oct 11 (12:00-15:00)	202	180	18	8.9%	8	4.0%	0	0.0%	0	0.0%	0	0.0%
	Oct 11 (16:00-18:00)	134	116	6	4.5%	17	12.7%	0	0.0%	0	0.0%	0	0.0%
	Oct 14 (12:00-15:00)	145	120	19	13.1%	11	7.6%	0	0.0%	1	0.7%	0	0.0%
	Oct 14 (16:00-18:00)	187	184	2	1.1%	14	7.5%	0	0.0%	0	0.0%	0	0.0%
	Oct 18 (8:00-11:00)	189	133	7	3.7%	52	27.5%	0	0.0%	0	0.0%	0	0.0%
	Oct 18 (16:00-18:00)	112	106	8	7.1%	3	2.7%	0	0.0%	0	0.0%	0	0.0%
	Oct 20 (18:00-20:00)	130	108	15	11.5%	8	6.2%	0	0.0%	0	0.0%	0	0.0%
	Total	**1532**	**1311**	**111**	**7.2%**	**147**	**9.6%**	**1**	**0.1%**	**1**	**0.1%**	**1**	**0.1%**

Table 6. Sensys detection errors in zone 1.

Missed calls, on the other hand, were low in the initial setup (0.2%) with only three occurrences, two of which happened when vehicles were traveling between lanes and one when a motorcycle was not detected. Missed calls did not increase in the modified setup and only one case was found when two motorcycles traveling next to each other (inside the lane) were not detected. Similarly, a total of three dropped calls were found in the two setups, two in the initial and one in the modified setup, and all three occurred when a call from a motorcycle was terminated while it was standing inside the detection zone.

5.2.2. Zone 2

In the modified setup, false calls accounted for 15.4% of the total number of calls, comprised of 7.6% of non-flickering calls, and 7.8% of flickering calls. A similar percentage of total false call (14.6%) was observed in the initial setup; however, they were mostly comprised of flickering calls (13.6%) and about 1% of non-flickering calls. Non-flickering calls in the modified setup were generated by vehicles in the adjacent lanes, with 173 activations (16 due to trucks and 157 due to smaller vehicles), in addition to 14 activations that occurred without any vehicle being present in any of the lanes. On the other hand, in the initial setup there were 26 non-flickering calls, generated by 12 trucks and 14 smaller vehicles.

	Zone 2													
	Dataset	Total Activations		False Calls (non-flickering)		False Calls (flickering)		Missed Calls		Stuck-on Calls		Dropped Calls		
		SENSYS	Loop	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	
Initial Setup (26 hours)	July 16 (12 hours - day and night)	1200	1026	16	1.3%	164	13.7%	0	0.0%	0	0.0%	0	0.0%	
	June 17 (6 hours)	562	467	5	0.9%	93	16.5%	0	0.0%	0	0.0%	0	0.0%	
	Jun 27 (17:00 - 19:00)	296	262	1	0.3%	34	11.5%	0	0.0%	0	0.0%	0	0.0%	
	July 2 (17:00 - 19:00)	339	301	2	0.6%	37	10.9%	0	0.0%	0	0.0%	0	0.0%	
	July 15 (21:00 - 22:00)	73	62	0	0.0%	11	15.1%	0	0.0%	0	0.0%	0	0.0%	
	June 19 (21:00 - 22:00)	65	59	0	0.0%	6	9.2%	0	0.0%	0	0.0%	0	0.0%	
	July 20 (21:00 - 22:00)	60	54	1	1.7%	5	8.3%	0	0.0%	0	0.0%	0	0.0%	
	July 21 (21:00 - 22:00)	54	44	1	1.9%	9	16.7%	0	0.0%	0	0.0%	0	0.0%	
	Total	**2649**	**2275**	**26**	**1.0%**	**359**	**13.6%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	
Modified Setup (26 hours)	Sept 15 (8:00-11:00)	208	178	16	7.7%	16	7.7%	0	0.0%	0	0.0%	0	0.0%	
	Sept 19 (12:00-15:00)	330	283	18	5.5%	29	8.8%	1	0.4%	0	0.0%	0	0.0%	
	Sept 23 (20:00-23:00)	146	127	9	6.2%	8	5.5%	0	0.0%	0	0.0%	0	0.0%	
	Oct 11 (12:00-15:00)	323	271	33	10.2%	17	5.3%	0	0.0%	0	0.0%	0	0.0%	
	Oct 11 (16:00-18:00)	197	179	12	6.1%	9	4.6%	0	0.0%	0	0.0%	0	0.0%	
	Oct 14 (12:00-15:00)	250	211	20	8.0%	19	7.6%	0	0.0%	0	0.0%	0	0.0%	
	Oct 14 (16:00-18:00)	349	332	7	2.0%	32	9.2%	0	0.0%	0	0.0%	0	0.0%	
	Oct 18 (8:00-11:00)	190	154	32	16.8%	5	2.6%	0	0.0%	0	0.0%	0	0.0%	
	Oct 18 (16:00-18:00)	216	183	27	12.5%	12	5.6%	0	0.0%	0	0.0%	0	0.0%	
	Oct 20 (18:00-20:00)	241	190	11	4.6%	44	18.3%	0	0.0%	0	0.0%	0	0.0%	
	Total	**2450**	**2108**	**185**	**7.6%**	**191**	**7.8%**	**1**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	

Table 7. Sensys detection errors in zone 2.

Only one missed call was found in Zone 2 (in the modified setup), when a motorcycle traveling over the edge of the loop was not detected by the wireless sensor. No stuck-on or dropped calls were observed in the initial or the modified setup.

5.2.3. Zone 3

False calls in Zone 3 remained similar in the modified setup (13.6%) compared to the initial setup (14.2%), and were comprised mostly by flickering calls (13.3% in the initial, and 8% in the modified setup), followed by non-flickering calls (1% in the initial and 5.6% in the modified setup). Trucks (10 in the initial and 47 in the modified setup) and smaller vehicles (12 in the initial and 58 in the modified setup) traveling in the adjacent lane caused the non-flickering calls.

Only one vehicle was missed (a motorcycle), and this occurred in the initial setup. Also, two stuck-on calls were observed in the initial setup, each of them lasting for about 5 minutes. No clear indication of the cause of the stuck-on calls was found the video images. No dropped calls were observed in any of the two setups.

	Dataset	Zone 3											
		Total Activations		False Calls (non-flickering)		False Calls (flickering)		Missed Calls		Stuck-on Calls		Dropped Calls	
		SENSYS	Loop	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Initial Setup (26 hours)	July 16 (12 hours - day and night)	1067	920	14	1.3%	140	13.1%	0	0.0%	0	0.0%	0	0.0%
	June 17 (6 hours)	406	349	7	1.7%	55	13.5%	0	0.0%	2	0.5%	0	0.0%
	Jun 27 (17:00 - 19:00)	245	221	1	0.4%	27	11.0%	0	0.0%	0	0.0%	0	0.0%
	July 2 (17:00 - 19:00)	268	237	0	0.0%	33	12.3%	0	0.0%	0	0.0%	0	0.0%
	July 15 (21:00 - 22:00)	61	53	0	0.0%	9	14.8%	1	1.9%	0	0.0%	0	0.0%
	June 19 (21:00 - 22:00)	85	70	0	0.0%	12	14.1%	0	0.0%	0	0.0%	0	0.0%
	July 20 (21:00 - 22:00)	68	51	0	0.0%	17	25.0%	0	0.0%	0	0.0%	0	0.0%
	July 21 (21:00 - 22:00)	68	60	0	0.0%	8	11.8%	0	0.0%	0	0.0%	0	0.0%
	Total	**2268**	**1961**	**22**	**1.0%**	**301**	**13.3%**	**1**	**0.1%**	**2**	**0.1%**	**0**	**0.0%**
Modified Setup (26 hours)	Sept 15 (8:00-11:00)	156	126	23	14.7%	7	4.5%	0	0.0%	0	0.0%	0	0.0%
	Sept 19 (12:00-15:00)	243	216	13	5.3%	17	7.0%	0	0.0%	0	0.0%	0	0.0%
	Sept 23 (20:00-23:00)	144	132	3	2.1%	9	6.3%	0	0.0%	0	0.0%	0	0.0%
	Oct 11 (12:00-15:00)	236	205	12	5.1%	19	8.1%	0	0.0%	0	0.0%	0	0.0%
	Oct 11 (16:00-18:00)	151	140	5	3.3%	9	6.0%	0	0.0%	0	0.0%	0	0.0%
	Oct 14 (12:00-15:00)	228	200	19	8.3%	13	5.7%	0	0.0%	0	0.0%	0	0.0%
	Oct 14 (16:00-18:00)	275	231	4	1.5%	48	17.5%	0	0.0%	0	0.0%	0	0.0%
	Oct 18 (8:00-11:00)	138	115	13	9.4%	11	8.0%	0	0.0%	0	0.0%	0	0.0%
	Oct 18 (16:00-18:00)	153	141	6	3.9%	3	2.0%	0	0.0%	0	0.0%	0	0.0%
	Oct 20 (18:00-20:00)	160	140	7	4.4%	14	8.8%	0	0.0%	0	0.0%	0	0.0%
	Total	**1884**	**1646**	**105**	**5.6%**	**150**	**8.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**

Table 8. Sensys detection errors in zone 3.

5.2.4. Zone 4

False calls accounted for 1.1% and 2.4% of the total activations in the initial and the modified setup, respectively. These false calls were comprised of 0.6% non-flickering calls and 0.5% flickering calls in the initial setup, and of 1.5% non-flickering calls and 0.9% flickering calls in the modified setup. The seven non-flickering calls from the initial setup were caused by two trucks and five smaller vehicles in the adjacent lane, and the 16 in the modified setup were caused by seven trucks and nine smaller vehicles.

In contrast, missed calls were significantly higher than false calls. For the initial setup, they accounted for about 10% of the total number of loop activations, with 133 vehicles (10 motorcycles and 123 small vehicles) not being detected. It is noted that most of the small vehicles traveled between center and median lanes, and that all motorcycles traveled close to the center of the lane without placing a call. For the modified setup, missed calls were reduced to 5.7%, or 68 vehicles missed, out of which three were motorcycles and the rest were small vehicles. Most vehicles were traveling between lanes, but four vehicles were missed when traveling straight over the sensor.

No stuck-on or dropped calls were found in any of the two setups.

	Dataset	Zone 4											
		Total Activations		False Calls (non-flickering)		False Calls (flickering)		Missed Calls		Stuck-on Calls		Dropped Calls	
		SENSYS	Loop	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Initial Setup (26 hours)	July 16 (12 hours - day and night)	553	641	3	0.5%	3	0.5%	58	9.0%	0	0.0%	0	0.0%
	June 17 (6 hours)	246	278	2	0.8%	2	0.8%	29	10.4%	0	0.0%	0	0.0%
	Jun 27 (17:00 - 19:00)	118	138	0	0.0%	0	0.0%	17	12.3%	0	0.0%	0	0.0%
	July 2 (17:00 - 19:00)	145	160	0	0.0%	1	0.7%	15	9.4%	0	0.0%	0	0.0%
	July 15 (21:00 - 22:00)	15	18	0	0.0%	0	0.0%	3	16.7%	0	0.0%	0	0.0%
	June 19 (21:00 - 22:00)	34	40	1	2.9%	0	0.0%	2	5.0%	0	0.0%	0	0.0%
	July 20 (21:00 - 22:00)	17	20	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	July 21 (21:00 - 22:00)	30	41	1	3.3%	0	0.0%	9	22.0%	0	0.0%	0	0.0%
	Total	**1158**	**1336**	**7**	**0.6%**	**6**	**0.5%**	**133**	**10.0%**	**0**	**0.0%**	**0**	**0.0%**
Modified Setup (26 hours)	Sept 15 (8:00-11:00)	101	108	6	5.9%	1	1.0%	11	10.2%	0	0.0%	0	0.0%
	Sept 19 (12:00-15:00)	160	169	0	0.0%	2	1.3%	9	5.3%	0	0.0%	0	0.0%
	Sept 23 (20:00-23:00)	51	58	1	2.0%	0	0.0%	3	5.2%	0	0.0%	0	0.0%
	Oct 11 (12:00-15:00)	159	168	1	0.6%	0	0.0%	5	3.0%	0	0.0%	0	0.0%
	Oct 11 (16:00-18:00)	90	108	0	0.0%	0	0.0%	9	8.3%	0	0.0%	0	0.0%
	Oct 14 (12:00-15:00)	93	105	2	2.2%	0	0.0%	8	7.6%	0	0.0%	0	0.0%
	Oct 14 (16:00-18:00)	153	167	1	0.7%	0	0.0%	6	3.6%	0	0.0%	0	0.0%
	Oct 18 (8:00-11:00)	112	116	3	2.7%	3	2.7%	6	5.2%	0	0.0%	0	0.0%
	Oct 18 (16:00-18:00)	88	95	1	1.1%	1	1.1%	5	5.3%	0	0.0%	0	0.0%
	Oct 20 (18:00-20:00)	85	95	1	1.2%	3	3.5%	6	6.3%	0	0.0%	0	0.0%
	Total	**1092**	**1189**	**16**	**1.5%**	**10**	**0.9%**	**68**	**5.7%**	**0**	**0.0%**	**0**	**0.0%**

Table 9. Sensys detection errors in zone 4.

5.2.5. Zone 5

False calls in the initial and the modified setup were 1.0% and 1.7%, respectively. In the initial setup, they were comprised of 0.1% non-flickering calls and 0.9% flickering calls, and in the modified setup, non-flickering calls were 0.4% and flickering calls were 1.3%. The non-flickering calls were due to vehicles traveling in the adjacent lanes (two in the initial and 10 in the modified setup).

Missed calls were higher than false calls, with 4.4% of the vehicles missed in the initial setup (118 vehicles were not detected, including eight motorcycles), and 3.2% in the modified setup (79 vehicles: 72 small vehicles traveling between lanes, two small vehicles traveling straight over the sensor, and five motorcycles).

No stuck-on or dropped calls were found in any of the two setups.

	Dataset	Zone 5											
		Total Activations		False Calls (non-flickering)		False Calls (flickering)		Missed Calls		Stuck-on Calls		Dropped Calls	
		SENSYS	Loop	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Initial Setup (26 hours)	July 16 (12 hours - day and night)	1108	1221	2	0.2%	14	1.3%	56	4.6%	0	0.0%	0	0.0%
	June 17 (6 hours)	504	554	0	0.0%	6	1.2%	25	4.5%	0	0.0%	0	0.0%
	Jun 27 (17:00 - 19:00)	275	291	0	0.0%	2	0.7%	9	3.1%	0	0.0%	0	0.0%
	July 2 (17:00 - 19:00)	305	337	0	0.0%	0	0.0%	17	5.0%	0	0.0%	0	0.0%
	July 15 (21:00 - 22:00)	68	72	0	0.0%	1	1.5%	3	4.2%	0	0.0%	0	0.0%
	June 19 (21:00 - 22:00)	66	74	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	July 20 (21:00 - 22:00)	60	65	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	July 21 (21:00 - 22:00)	52	65	0	0.0%	0	0.0%	8	12.3%	0	0.0%	0	0.0%
	Total	**2438**	**2679**	**2**	**0.1%**	**23**	**0.9%**	**118**	**4.4%**	**0**	**0.0%**	**0**	**0.0%**
Modified Setup (26 hours)	Sept 15 (8:00-11:00)	189	203	2	1.1%	4	2.1%	11	5.4%	0	0.0%	0	0.0%
	Sept 19 (12:00-15:00)	308	321	1	0.3%	8	2.6%	7	2.2%	0	0.0%	0	0.0%
	Sept 23 (20:00-23:00)	137	150	0	0.0%	1	0.7%	6	4.0%	0	0.0%	0	0.0%
	Oct 11 (12:00-15:00)	295	318	2	0.7%	4	1.4%	9	2.8%	0	0.0%	0	0.0%
	Oct 11 (16:00-18:00)	189	212	0	0.0%	1	0.5%	9	4.2%	0	0.0%	0	0.0%
	Oct 14 (12:00-15:00)	237	257	2	0.8%	4	1.7%	11	4.3%	0	0.0%	0	0.0%
	Oct 14 (16:00-18:00)	348	371	0	0.0%	2	0.6%	5	1.3%	0	0.0%	0	0.0%
	Oct 18 (8:00-11:00)	173	200	2	1.2%	1	0.6%	7	3.5%	0	0.0%	0	0.0%
	Oct 18 (16:00-18:00)	195	213	1	0.5%	2	1.0%	7	3.3%	0	0.0%	0	0.0%
	Oct 20 (18:00-20:00)	209	226	0	0.0%	2	1.0%	7	3.1%	0	0.0%	0	0.0%
	Total	**2280**	**2471**	**10**	**0.4%**	**29**	**1.3%**	**79**	**3.2%**	**0**	**0.0%**	**0**	**0.0%**

Table 10. Sensys detection errors in zone 5.

5.2.6. Zone 6

In the initial setup, a total of 0.8% false calls were found, comprised of 0.3% non-flickering calls and 0.5% flickering calls. Similarly, in the modified setup there was a total of 1.3% false calls, comprised of 0.4% non-flickering calls and 0.9% of flickering calls. The non-flickering calls were due to vehicles in the adjacent lane: five due to trucks in the initial setup, and four trucks and two cars in the modified setup.

Missed calls accounted for 3.1% of the total number of vehicles in the initial setup, with 63 of them not being detected (including three motorcycles). It is noted that most of the missed vehicles were traveling above the sensor without placing a call, contrary to other zones where most vehicles were changing lanes. In the modified setup, 16 vehicles (all automobiles) were not detected (0.9%), indicating a slight reduction compared to the initial setup.

No stuck-on or dropped calls were found in any of the two setups.

	Dataset	Zone 6											
		Total Activations		False Calls (non-flickering)		False Calls (flickering)		Missed Calls		Stuck-on Calls		Dropped Calls	
		SENSYS	Loop	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Initial Setup (26 hours)	July 16 (12 hours - day and night)	893	926	2	0.2%	6	0.7%	32	3.5%	0	0.0%	0	0.0%
	June 17 (6 hours)	349	366	1	0.3%	1	0.3%	14	3.8%	0	0.0%	0	0.0%
	Jun 27 (17:00 - 19:00)	216	224	0	0.0%	1	0.5%	5	2.2%	0	0.0%	0	0.0%
	July 2 (17:00 - 19:00)	244	256	1	0.4%	0	0.0%	7	2.7%	0	0.0%	0	0.0%
	July 15 (21:00 - 22:00)	49	52	0	0.0%	0	0.0%	3	5.8%	0	0.0%	0	0.0%
	June 19 (21:00 - 22:00)	69	67	1	1.4%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	July 20 (21:00 - 22:00)	51	51	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	July 21 (21:00 - 22:00)	57	59	0	0.0%	1	1.8%	2	3.4%	0	0.0%	0	0.0%
	Total	**1928**	**2001**	**5**	**0.3%**	**9**	**0.5%**	**63**	**3.1%**	**0**	**0.0%**	**0**	**0.0%**
Modified Setup (26 hours)	Sept 15 (8:00-11:00)	130	130	0	0.0%	2	1.5%	1	0.8%	0	0.0%	0	0.0%
	Sept 19 (12:00-15:00)	217	221	0	0.0%	0	0.0%	1	0.5%	0	0.0%	0	0.0%
	Sept 23 (20:00-23:00)	128	133	1	0.8%	0	0.0%	3	2.3%	0	0.0%	0	0.0%
	Oct 11 (12:00-15:00)	208	209	0	0.0%	4	1.9%	4	1.9%	0	0.0%	0	0.0%
	Oct 11 (16:00-18:00)	143	145	0	0.0%	1	0.7%	2	1.4%	0	0.0%	0	0.0%
	Oct 14 (12:00-15:00)	206	206	1	0.5%	2	1.0%	1	0.5%	0	0.0%	0	0.0%
	Oct 14 (16:00-18:00)	245	241	1	0.4%	4	1.6%	1	0.4%	0	0.0%	0	0.0%
	Oct 18 (8:00-11:00)	121	122	2	1.7%	0	0.0%	2	1.6%	0	0.0%	0	0.0%
	Oct 18 (16:00-18:00)	148	146	1	0.7%	3	2.0%	1	0.7%	0	0.0%	0	0.0%
	Oct 20 (18:00-20:00)	142	144	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Total	**1688**	**1697**	**6**	**0.4%**	**16**	**0.9%**	**16**	**0.9%**	**0**	**0.0%**	**0**	**0.0%**

Table 11. Sensys detection errors in zone 6.

CHAPTER 6 CONCLUSIONS

This report contains the findings of the evaluation of the Sensys Wireless Vehicle Detection System using data from the first three months after installation. The installation was the best setup the manufacturer representatives recommended at that time, and they personally monitored the installation and system configuration at the two sites. However, after the findings of this report were presented to the manufacturer, the company indicated that although the set up was their best at that time, relocating the sensors at the stop bar detection zones may result in improved system performance. The manufacturer has been given another opportunity to put new sensors at the location that they believe would improve the performance of their system. Data for the “new best” set up is being collected and will be published in a separate report. Also, the findings using data from adverse weather conditions (during winter and storms) collected when the “old best set up” was in place will be presented in a separate report.

6.1. RAILROAD GRADE CROSSING ON THE EASTBOUND APPROACH OF CHANDLER ROAD & U.S. ROUTE 45

Sensys wireless detectors were activated when trains were at the grade crossing, placing either sustained or flickering calls for as long as the trains were present. In the initial setup, a few of the calls caused by the trains remained stuck-on, for periods of at most 5 minutes, after the train departed and subsequently the sensors reset themselves. The occurrence of stuck-on calls due to trains was reduced in the modified setup by not allowing adjusting the magnetic background. Yet one case was observed in which a stuck-on call lasted for one hour after the train departure. In is noted that when the train call was not stuck-on, all vehicles passing over the detectors just after the train departure were detected properly.

Missed calls for the two sensors were in the order of less than 1% in both the initial and the modified setups, with less vehicles being missed when traveling between the lanes in the modified setup. However, motorcycles were found likely to be missed in both setups.

False calls due to vehicles in the adjacent lanes were a significant proportion of the total number of sensor calls. The left-turn lane had a higher number of false calls (29.2% in the initial setup and 53.7% in the modified setup) compared to the thru lane (12.1% in the initial setup and 16.6% in the modified setup). Specifically, in the initial setup, the false calls in the left-turn lane (29.2%) were comprised of 15.8% flickering calls and 13.4% non-flickering calls, and in the thru lane (12.1%) they were comprised of 10.9% flickering calls and 1.2% non-flickering calls. On the other hand, false calls in the modified setup in the left-turn lane (53.7%) were comprised of 16.5% flickering calls and 37.2% non-flickering calls, and false calls in the thru lane (16.6%) were comprised of 12.3% flickering calls and 4.3 non-flickering calls. It is also noted that vehicles traveling in the adjacent lane in the opposite direction placed more false calls than vehicles in the adjacent lane in the same direction. Only one stuck-on call, due to a small vehicle and lasting about 30 minutes, was found in the two setups combined, and no clear cases of dropped calls were observed.

6.2. INTERSECTION OF CENTURY BLVD & VETERANS PKWY

At the stop bar zones, false calls occurred on all three zones and the proportions in the modified setup (between 13.5% and 16.8%) were comparable to the initial setup (between 14.2% and 19.6%). A significantly higher number of false calls for all three zones in the modified setup was due to flickering false calls (7.8% to 9.6%) compared to non-flickering calls (5.6% to 7.6%), whereas in the initial setup the false calls due to flickering were more significant (13.3% to 18.7%) compared to the non-flickering calls (0.9% to 1.0%). Non-flickering calls were due to both trucks and smaller vehicles in the adjacent lanes and traveling either in the same or the opposite direction. There were just a few missed calls, in initial and modified setups and mostly observed for motorcycles. The stuck-on and dropped calls virtually did not exist; only two stuck-on calls were found in the two setups combined, each lasting for about 5 minutes, and three dropped calls from motorcycles.

At the advance zones, false calls were far less than at the stop bat zones, and varied between 0.7% and 2.4% for the two setups; the percentages for the three zones in the modified setup were slightly higher than those for the initial setup. False calls were due to flickering calls (0.5% to 1.3%) and due to vehicles in the adjacent lanes, both trucks and smaller vehicles (0.1% to 1.5%). In contrast to stop bar zones, missed calls were higher than false calls and ranged between 3.1% and 10.0% in the initial setup, and between 0.9% and 5.7% in the modified setup. It is noted that missed calls for all three advance zones decreased in the modified setup. Most missed calls were due to vehicles traveling between lanes, but also motorcycles and vehicles were missed while traveling straight over the sensors, particularly in zone 6. No stuck-on or dropped calls were observed at advance zones in the initial or the modified setup.