EVALUATION OF THE ICONE AS A PORTABLE TRAFFIC DATA COLLECTION DEVICE

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16. Abstract

Traffic engineering requires information and data that can quantitatively describe the system and its demand. But, assembling data and information for systems as massive as the current highway system or street networks can be an enormous task. Collection and analysis of traffic data encompasses a variety of methodologies and techniques ranging from simple manual techniques to sophisticated and complex technologies like sensors and detectors.

The objective of the study was to evaluate the accuracy and performance of the iCone and recommend its applicability and general practice methodology to the Kansas Department of Transportation (KDOT).

The two iCone devices were tested at ten different test locations including a closed course study in Kansas. Primarily, the iCones were tested for their accuracy of count data and not speed data. After the closed course study statistical analysis suggested that there was a difference of 1 mph between the means of the speeds for data from the iCone and the pneumatic road tubes. The researchers recommended that the iCone could be used in conjunction with a dynamic changeable message sign to monitor speeds in work zones or residential areas. Also, if multiple iCone units were used in conjunction with police enforcement, it could be an effective measure to monitor speeds at different locations by a single police officer and reduce load on police officers for monitoring speed violations.

The data analysis results suggested that the iCone was not a reliable device for vehicular count data. The increase in the overall percentage error was a believed to be a function of the increased sample size and the research team would not recommend KDOT to use the iCone for collecting count data for longer periods. The researchers recommended that the best location to use the iCone would be a two-way, two-lane level highway with clear sight distances and any other location with complex geometrics would result in inaccurate data collection.

Finally, the researchers concluded that there was no particular orientation of the iCone that provided anticipated results with 100 percent accuracy and factors such as: topography and road geometry could alter the data collected by the iCone. The researchers recommended the iCone to be oriented parallel to the adjacent roadway to obtain the best results.

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ABSTRACT

Traffic engineering requires information and data that can quantitatively describe the system and its demand. But, assembling data and information for systems as massive as the current highway system or street networks can be an enormous task. Collection and analysis of traffic data encompasses a variety of methodologies and techniques ranging from simple manual techniques to sophisticated and complex technologies like sensors and detectors.

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CHAPTER 1. INTRODUCTION

1.1 Background

Traffic engineering requires information and data that can quantitatively describe the system and its demand. But, assembling data and information for systems as massive as the current highway system or street networks can be an enormous task. Collection and analysis of traffic data encompasses a variety of methodologies and techniques ranging from simple manual techniques to sophisticated and complex technologies like sensors and detectors.

The most challenging issue in the different areas of Intelligent Transportation Systems (ITS) has been increasing the accuracy of traffic detector data. The goals of data users' desire to get an accurate detector within budget constraints, and manufacturers' goal to produce devices with the least error at the lowest expenses have propelled the demand to evaluate detectors (*1*).

One of the new portable traffic monitoring ITS devices is the iCone. It is a battery-powered radar device contained in a road construction traffic barrel with all of its other electronic components located inside. It can be used for various traffic monitoring purposes such as speed, vehicle count, and queue analysis when deployed along the roadside. Because of its portability and ease of mobility along the road, it could be a good device to collect data in work zones (*2*).

1.2 Objective of the Study

The objective of the study was to evaluate the accuracy and performance of the iCone and recommend its applicability and general practice methodology to the Kansas Department of Transportation (KDOT).

1.3 Summary of the Report

The report for this study summarized the information and data collected and analyzed in the following sections:

- Literature review and summary of literature,
- Field testing and results, and
- Conclusion and recommendations.

CHAPTER 2. LITERATURE REVIEW

Kuhn and Bailey evaluated the iCone as a new product against 'dual-loop' detectors to compare speed values collected by the iCone against speed data from the in-ground dual-loop stations (*3*). Data were collected for more than eight weeks at five different dual-loop stations at the Berkeley Highway Laboratory (BHL) Test-bed: a 2.7 mile section of I-80 between Powell St. in Emeryville and Gilman St., Berkeley, CA from June to August 2011. The test location was a straight and level urban freeway with five or six lanes in each direction of travel. Since the iCone reported aggregated data over a period of two minutes the researchers aggregated the loop detector speeds into two minute periods to reconcile the difference in data collection. The data analysis focused on the signed average error of the iCone speed value and the loop value to obtain an understanding of the iCone's performance in a multi-lane setting. It was found that the average speed error was significantly lower (near 0 mph) for the lane closest to the iCone whereas average speed error for the lane furthest from the iCone ranged from 10 to 15 mph. The study concluded that the iCone selected its best targets from the nearest lane, and hence that lane was more frequently represented than the other lanes. The study also observed the iCone count data and concluded that it did not vary as significantly as the loop count data that varied dramatically during different times of the day. The researchers believed that this was an indication that congestion produced 'noisier' radar data that altered the iCone's selection of a 'good' reading in a given two-minute period.

Chandler, et al. tested the ability of iCone to provide real-time traffic conditions in work zones for the California Department of Transportation (Caltrans) (*4*). The study determined the effective applicability of the information collected by the device in improving the safety and mobility in work zones. Caltrans had twelve of these portable traffic monitoring devices (PTMD) available for testing over a period of five months and distributed them to a number of Caltrans districts including District 2 in Northeastern California, District 4 in the San Francisco Bay Area, and District 5 along the coastline, District 7 in Los Angeles, and District 12 in Orange County. Following some traffic count testing conducted by a few districts the devices were provided to District 4 for conducting work zone-focused tests. The district deployed the devices on variety of sites such as: the Bay Bridge between Oakland and San Francisco (Labor Day weekend 2009, five lanes section), I-680 in Walnut Creek (one day, six lanes section), Highway 101 on Golden Gate Bridge (Labor Day weekend 2009, five lanes section), I-880 in Oakland (Labor Day weekend 2009, four lanes section), and in Pasadena (Jan. 1, 2010 and Jan. 7, 2010). On comparing and verifying with the speed data from the permanent traffic monitoring devices, the study found that the PTMD speed data was sufficiently accurate. The researcher recommended to use the device in a location within the range of the device (approximately 300 feet) and indicated that the presence of a barrier (e.g., concrete barrier) would be beneficial to screen the unwanted data. At one location during the study, the Caltrans staff believed that the distortion in the data were due to the presence of a concrete barrier on all sides causing the concrete to act as a reflector and resulting in reflection of the radar waves back and forth. In Orange County, the Caltrans staff used the PTMD for traffic counts on one-lane ramps and two-lane undivided highways and found that the data were in acceptable range when compared with data from pneumatic tube counters. Finally, the study concluded that the device had benefits such as cost- effective traffic counting.

SRF Consulting Group in conjunction with Street Smart Rental examined the iCone for four main types of operational scenarios that included: closure restrictions and traffic control modifications, enforcement, mobility measurement and traffic responsive systems (*5*). The study also evaluated the accuracy of the iCone speed data against loop detectors at three locations in Minnesota. At the Non-Intrusive Technologies (NIT) test site, the iCone data were compared against data from two loop detectors for each of three traffic lanes considered simultaneously, as well as data for the lane closest to the iCone. The absolute percent difference was four percent on the iCone and loop detector data for all three lanes at the same time and five percent for iCone and loop detector data for the lane closest to the iCone. At the second test site, the iCone data were compared against data from loop detector stations with a single loop in each lane and at the third test site, iCone data were compared with the data from two loop detectors. At both the test sites, the loop detectors recorded erratic speeds: eight to twelve miles per hour higher than the iCone speed at the second test site and thirteen miles per hour higher at the third test site. Interestingly, at both the test sites both the data sets showed similar trends in traffic speeds.

Ravani, et al. evaluated the accuracy of the iCone system against Remote Traffic Microwave Sensor (RTMS) i.e. a handheld LIDAR device for accuracy of traffic speeds and against manual traffic counts for accuracy of traffic volume measurement (*6*). A set of tests were conducted on a north-south segment of La Rue Road, a two-way, four-lane street with a median (about one lane width) near the University of California, Davis on November 12, 2010 using three iCones and one LIDAR unit. It was found that, the average speeds from the iCone nearest to the location of the LIDAR were closer to the LIDAR speeds than average speeds from iCones across five lanes. Comparison of the iCone traffic count data with the manual traffic counts showed that the iCones were inaccurate in traffic volume counting. The difference in count data were believed to be a consequence of the fact that the iCone stopped recording for 2.25 seconds between measurements to prevent duplication in data. The study also conducted tests to evaluate the iCone for sensitivity to orientation and sensitivity to position. For the orientation test, three iCones were placed at the same distance from the center of the nearest lane (16 feet) and oriented at different angles towards the road (0°, 20°, and 40°), respectively. For the position test, the three iCones were placed at 16 feet, 28 feet, and 28 feet from the center of the target lane and oriented parallel to the adjacent road. Later, the outer iCones were oriented 5° towards the target lane. The results showed that there were no significant differences in the speeds measured and speed measurements were not sensitive to the placement of the iCone. The researchers recommended the use of the iCones parallel to the road and then rotating the iCone slightly towards the center of the road.

Staszcuk and McGowen evaluated the accuracy, reliability, and usability of the Advanced Traveler Information Systems (ATIS) such as: Blufax, LPR, iCone and Adaptir (*7*). The researchers deployed the four systems on a construction project at five different sites in Redding, CA for a period of two weeks. The researchers evaluated the usability of these portable systems based on setup times, ease of system use, usefulness, and impact of the systems on drivers. To evaluate the accuracy of the iCone and Adaptir systems, five-minute average speeds were used to determine the difference in recorded speeds. It was found that the iCone and Adaptir system measured speeds within 10 mph of each other at least 99 percent of the time at all three locations. The study revealed that the iCone had in fact missed many vehicles in the inside lane just like the LPR system. The iCone unit was assumed to have a true traffic capture rate (100 percent) at one of the locations that was a single-lane facility but had a poorer capture rate (55 percent) on a two-lane facility. The study evaluated the iCone system as easy to use since it needed a setup time of approximately five minutes and did not involve any tedious setting up procedure.

2.1 Summary of Literature

- Kuhn and Bailey's evaluation of the iCone yielded that the average speed error was significantly lower (near 0 mph) for the lane closest to the iCone whereas average speed error for the lane furthest from the iCone ranged from 10 to 15 mph (*3*).
- Chandler et al. in their study recommended to use the PTMD device at a location within its range (approximately 300 feet) and indicated that the presence of a barrier (for e.g. concrete barrier) would be beneficial to screen the unwanted data (for e.g. median barrier if data for one lane were desired) (*4*).
- In a study conducted by the SRF consulting group, it was found that the absolute percent difference between the iCone and loop detector data for all three lanes at the same time for one location, was four percent and for the lane closest to the iCone was five percent (*5*). For the other two locations, the loop detectors recorded erratic speeds but both the devices showed similar trends in traffic speeds.
- Ravani's evaluation of the iCone found that, the average speeds from the iCone nearest to the location of the LIDAR were closer to the LIDAR speeds than average speeds from iCones located across five lanes (*6*). The researchers recommended the use of the iCone parallel to the road at first and then rotating the iCone slightly towards the center of the road.
- Staszcuk and McGowen's evaluation of the iCone revealed that the iCone had a better capture rate on single lane facilities than two-lane facilities (*7*).

The literature reported herein was useful during the field tests elaborated in Chapter 3 and also supported some of the recommendations mentioned in Chapter 4.

CHAPTER 3. FIELD TESTS

The two iCones were tested by the transportation research team at the University of Kansas for several scenarios and conditions. A summary of the tests conducted by the KU research team for the iCones were listed in Table 1.

Table 1. Summary of the Preliminary Tests Conducted using the iCone

Test No.	Date	Location	Goal of the test	Number of iCones used	Video Data
1	5/11/2014	East Lot, Park and Ride, KU	To evaluate the precision of data collected by iCone with road tube data.	1	Yes
2	6/11/2014	23rd and Iowa, Lawrence, KS	To evaluate the performance of iCone in long queue lengths.	1	Yes
3	6/18/2014	15th and Engel Hill Road, Lawrence, KS	To evaluate the performance of iCone on vertical curves.	2	Yes
4	6/24/2014	Naismith Drive, Lawrence, KS	To evaluate the performance of iCone for traffic moving away from iCone and performance in the presence of multiple lanes.	2	Yes
5	7/8/2014	Kentucky Street and Tennessee Street, Lawrence, KS	To evaluate the performance of iCone for traffic on a one-way facility at different orientations.	2	Yes
6	7/22/2014	US-24 Near Williamstown, KS	To evaluate the performance of iCone for traffic on a two-lane, two-way road.	2	Yes
7	8/5/2014 to 8/7/2014	US-56 Near Burlingame, KS	To evaluate the performance of iCone for traffic on a two-lane, two-way road near a work zone.	2	Yes
8	8/12/2014 to 8/14/2014	K-31 Near Melvern, KS	To evaluate the performance of iCone for traffic on a two-lane, two-way road near a work zone.	2	Yes
9	8/19/2014 to 8/21/2014	US-24 Near Beloit, KS	To evaluate the performance of iCone for traffic on a two-lane, two-way road near a work zone.	2	Yes
10	8/26/2014 to 8/27/2014	US-50 Near Newton, KS	To evaluate the performance of iCone for traffic on a two-lane, two-way road near a work zone.	2	Yes

3.1 Test Location 1

Objective

To evaluate the precision of data collected by the iCone in comparison to pneumatic road tubes.

Procedure

A team of five members performed the experiment on May 11, 2014 in the East Lot of Park and Ride facilities at the University of Kansas. Three vehicles were used for the experiment: one minivan, one sedan, and one motorcycle and three members of the research team were assigned to drive each vehicle while the rest of the team coordinated activities and was responsible for the functioning of the test equipment. A sample size of 90 data points were generated by the experiment with each driver having to run the test section 30 times. The first 15 runs were at a speed of 20 to 25 mph and the next 15 runs at 30 to 35 mph, each over the same section. The experiment ended when all the three drivers had completed their required 30 runs. The equipment was setup as shown in Figure 1. Traffic cones were placed on the test section which assisted the drivers to identify the start of the speeding zone. The road tubes used for the experiment were placed eight feet apart from each other and the iCone was ten feet further away from the road tubes. Speeds of the vehicles were maintained in the speed zone to ensure correct data collection. Also, one of the team members was assigned to direct the drivers to depart from their starting position 75 seconds after the vehicle ahead of them had started. This was done to ensure that only a single vehicle was detected by the iCone in any one minute.

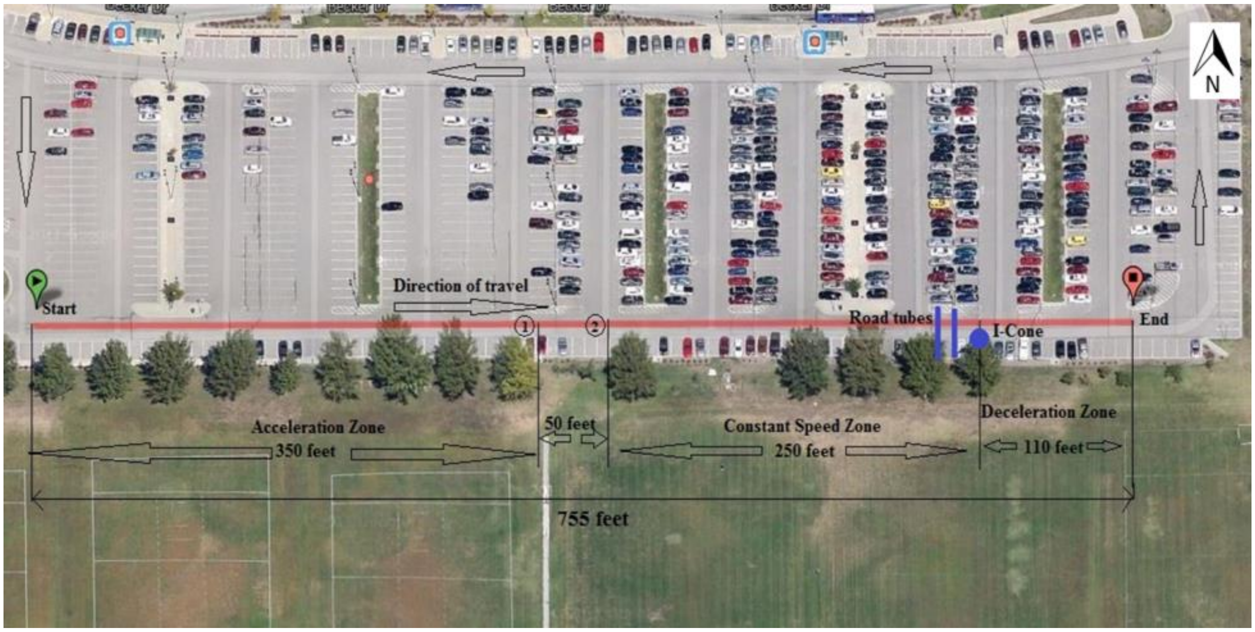

Figure 1. Layout for the Park and Ride iCone test.


Figure 2. Park and Ride iCone test setup.

Results

Statistical analysis suggested that there was a difference of 1 mph between the means of the speeds for data from the iCone and the pneumatic road tubes. In addition, the vehicle count by the iCone exceeded the count recorded by the road tubes by 47 percent and 25 percent for the two speed ranges, respectively. Table 2 listed the results from the closed-course study.

Table 2. Closed-course Test Results

iCone		Pneumatic Road Tube		Results	
Count	**Avg. Speed (mph)**	**Speed (mph)**	**Count**	**Error in Counts (percent)**	**Error in Speed (percent)**
75	22.3	23.3	51	47.06	-4.46
60	31.8	32.9	48	25.00	-3.23

The closed-course study was conducted to get familiar with the device and its functioning. The results from this study were used to design the tests conducted later.

3.2 Test Location 2

Objective

To evaluate accuracy of iCone data collection for long queue lengths.

Procedure

The test was conducted on June 11, 2014 for the eastbound approach at the intersection of 23rd and Iowa, Lawrence, Kansas. It was a sunny day with temperature of 81˚F and ESE winds of 10 mph. The equipment was setup as shown in the Figure 2 near the intersection of 23rd and Iowa, Lawrence, Kansas. A research team of two members conducted the experiment using one iCone and three video cameras. The iCone was placed on the median 350 feet from the intersection at Clinton Parkway and Crestline Drive facing the oncoming eastbound traffic. A total of three cameras were stationed on either side of the intersection at Clinton Parkway and Crestline drive to capture the queue lengths and real-time vehicular volumes during the study hour. Data were collected for the evening peak hour from 5 p.m. to 6 p.m.

Figure 3. Layout for 23rd and Iowa iCone test.


Figure 4. 23rd and Iowa iCone test setup.

Results

The device performed as expected for the intersection and interesting conclusions were made from the test. First, there was no consistent trend in speed and the highest observed average speed was 41.4 mph and lowest was 7 mph. The total average speed for the entire study hour was 23.6 mph.

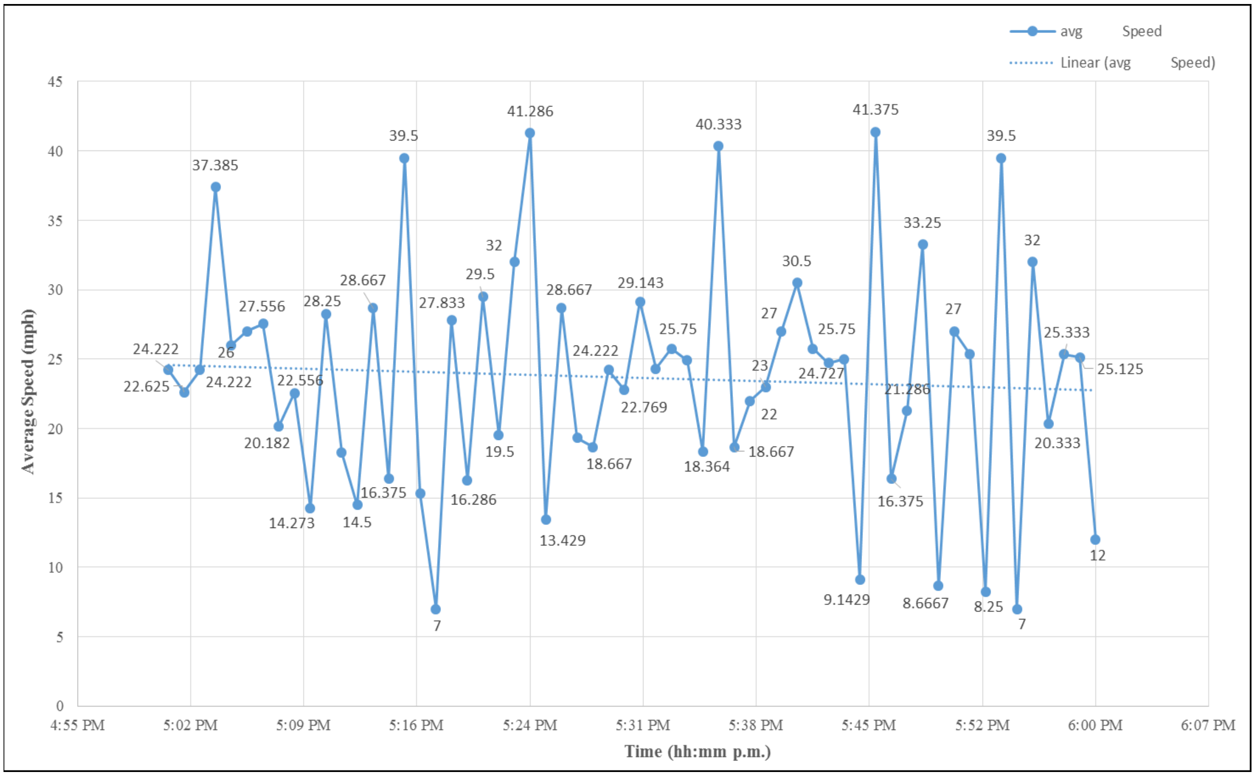

Figure 5. Variations of average speeds with time during the study hour.

Traffic flow characteristics could be easily observed from the graph in Figure 5. If speeds of 15 mph to 35 mph were considered as upper and lower limits, from the graph it was observed that there were 13 data points that acted as outliers. The six data points above the highest average speed range of 35 mph suggested that the green phase was active and the queue was being cleared. Higher average speeds indicated that the vehicles were moving swiftly and there was no queue formation during that period of time. On the other hand, the seven data points that fell below the minimum average speeds suggested that the traffic signal's red phase was active and a long queue was being formed at the intersection. All the other data points in the range of 15 mph to 35 mph suggest steady but slow movement of vehicles at the intersection. The data points that fell in the speed range mentioned gave a precise insight of the situation that existed at the intersection at a particular time. For example, from the graph at 5:25 p.m. the red phase was in progress at the intersection of 23rd and Iowa which slowed the vehicles resulting in lower average speeds. On the other hand, at 5:27 p.m. when the green phase was active vehicles began moving more swiftly resulting in higher average speeds both evident from the graph. Thus, the graph was an excellent indicator of the conditions that existed at the intersection.

3.3 Test Location 3

Objective

To evaluate accuracy of iCone data collection for oncoming traffic and traffic moving away on vertical curves.

Procedure

The iCones were tested for accuracy of their data for oncoming traffic and traffic moving away on vertical curves. The iCones were setup to collect data on the eastbound and westbound approaches at the intersection of 15th street and Engel Hill Road, Lawrence, KS as shown in Figure 5. A research team of three members performed the experiment using two iCones and two video cameras. During the test, the iCones were oriented in three different directions to identify the most suitable direction in which iCones should be oriented to ensure precise data collection. At first, both the iCones were oriented parallel to the adjacent traffic lanes, second they were oriented 30̊ towards the center of the traffic lane, and lastly 30̊ away from the adjacent traffic lane.

Figure 6. Layout for the 15th and Engel Hill Road iCone test.

Figure 7. 15th and Engel Hill Road iCone test setup.

Results

Data were collected for all the three orientations by the iCone. iCone 1, located on a crest on Engel Hill Road, had a smaller percentage error when oriented parallel to the adjacent traffic lane and 30° towards the adjacent traffic lane. Conversely, iCone 2 located at the base of the curve had large errors regardless of orientation. Since both iCones had varying results no specific recommendations could be made at that time.

Table 3. iCone 1 Test Results

Orientation	iCone Count	Video Data			Percent Total Difference
		Oncoming	Outgoing	Total	
30° away from traffic lane	83	68	88	156	-46.79
Parallel to the traffic lane	129	46	75	121	6.61
30° toward the traffic lane	160	59	116	175	-8.57

Table 4. iCone 2 Test Results

Orientation	iCone Count	Video Data			Percent Total Difference
		Oncoming	Outgoing	Total	
30° away from traffic lane	77	28	36	64	20.31
Parallel to the traffic lane	202	48	101	149	35.57
30° toward the traffic lane	203	65	93	158	28.48

The iCone located on the crest of Engel Hill Road collected good data for the parallel and 30° towards the traffic lane orientation. For the remainder of the cases the percentage errors were large.

3.4 Test Location 4

Objective

To evaluate accuracy of the data collected by the iCone for oncoming traffic and traffic moving away from the iCone.

Procedure

The iCones were tested for accuracy of their data collection for oncoming traffic and traffic moving away. The iCones were setup to collect data as shown in the Figure 7. A research team of three members performed the experiment using two iCones and two video cameras. iCone 1 was placed facing north for the southbound approach near Allen Field House and iCone 2 was located on the median facing the oncoming southbound traffic near Naismith Drive. During the test duration, iCone 1 was oriented in three different directions. First, parallel to the adjacent traffic lane, second 30° away from the adjacent traffic lane, and finally 30° towards the adjacent traffic lane to identify the most suitable direction for precise data collection. iCone 2 was oriented parallel to the adjacent traffic lane, 30° towards the traffic moving away, and finally 30° towards oncoming traffic. The iCones were turned off before data were collected for the next orientation and were to be kept in the off mode for around 20 minutes to ensure separation in data sets. Both iCones were situated at a distance of approximately 450 feet from each other to avoid interference of radar waves from each other.

Figure 8. Layout for the Naismith Drive iCone test.

Figure 9. Allen Field House iCone setup.

Figure 10. Naismith Drive and Allen Field House iCone setup.

Results

The analyzed data suggested that the vehicle count by the iCone near Naismith Hall exceeded the actual data for all the three orientations tested. Also, the device near Allen Field house did not perform as anticipated. The device did not give an accurate count of traffic data for the lane adjacent to the device for both the orientations that were tested.

Table 5. Allen Field House iCone Test Results

Orientation	iCone Count	Video Data			Percent Total Difference
		Oncoming	Outgoing	Total	
30° away from traffic lane	27	88	120	208	-87.02
Parallel to the traffic lane	121	114	75	189	-35.98
30° towards the traffic lane	69	93	87	180	-61.67

Table 6. Naismith Drive Test Results

Orientation	iCone Count	Video Data			Percent Total Difference
		Oncoming	Outgoing	Total	
30̊ toward traffic moving away	223	106	108	214	4.21
Parallel to the traffic lane	225	69	104	173	30.06
30̊ toward oncoming traffic	222	114	86	200	11.0

The results suggested that the iCone performed better when oriented towards the traffic moving away. But, no specific conclusions were made at the time on which orientation produced the best results.

3.5 Test Location 5

Objective

To evaluate the performance of iCone for traffic on one-way facilities for different orientations.

Procedure

The iCones were tested for accuracy of their data collection for traffic counts on one-way streets in Lawrence, KS. The iCones were setup to collect data as shown in the Figure 10 on July 8, 2014 on Kentucky Street and Tennessee Street. A research team of three members performed the experiment using two iCones and two video cameras. iCone 1 on Kentucky Street was placed facing south for the oncoming northbound traffic and iCone 2 on Tennessee Street was placed facing south to southbound traffic moving away from the iCone. During the test duration, both iCones were oriented in four different directions. First, parallel to the adjacent traffic lane, second 30̊ away from the adjacent traffic lane, third 30̊ towards the adjacent traffic lane, and finally perpendicular to the adjacent traffic lane to identify the most suitable direction for precise data collection. The iCones were turned off before data were collected for the next orientation and were to be kept in the off mode for around 20 minutes to ensure separation in data sets.

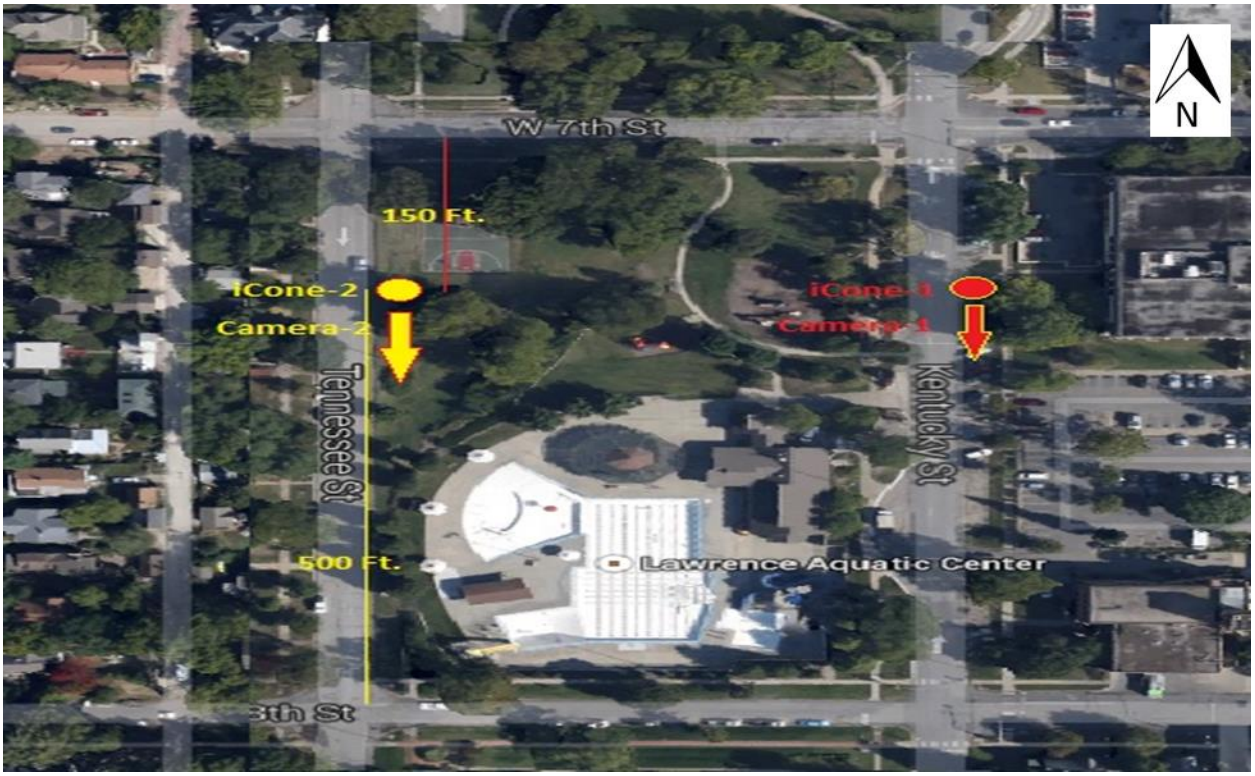

Figure 11. Layout for the Kentucky Street and Tennessee Street iCone setup.


Figure 12. Tennessee Street iCone setup.

Figure 13. Kentucky Street iCone setup.

Results

Table 7 and Table 8 showed results from the data that were collected by the iCones and comparison of that data with the actual data from the video. Also, Figure 14 showed the variation in the data collected by the iCone and video data.

Table 7. Kentucky Street iCone Data Reduction Results

Orientation	iCone Count	Video Data			Percent Total Difference
		Right Lane	Left Lane	Total	
30° away from the traffic lane	140	98	49	147	-4.76
Parallel to the traffic lane	239	145	77	222	7.66
30° towards the traffic lane	220	138	66	204	7.84
Perpendicular to the traffic lane	151	128	84	212	-28.77

Table 8. Tennessee Street iCone Data Reduction Results

Orientation	iCone Count	Video Data			Percent Total Difference
		Right Lane	Left Lane	Total	
30̊ away from the traffic lane	118	99	111	210	-43.81
Parallel to the traffic lane	278	132	134	266	4.51
30̊ towards the traffic lane	196	110	130	240	-18.33
Perpendicular to the traffic lane	184	141	132	273	-32.60

The results showed that the iCone performed best when it was oriented parallel to the traffic lane with average error being under 10 percent for both the cases.

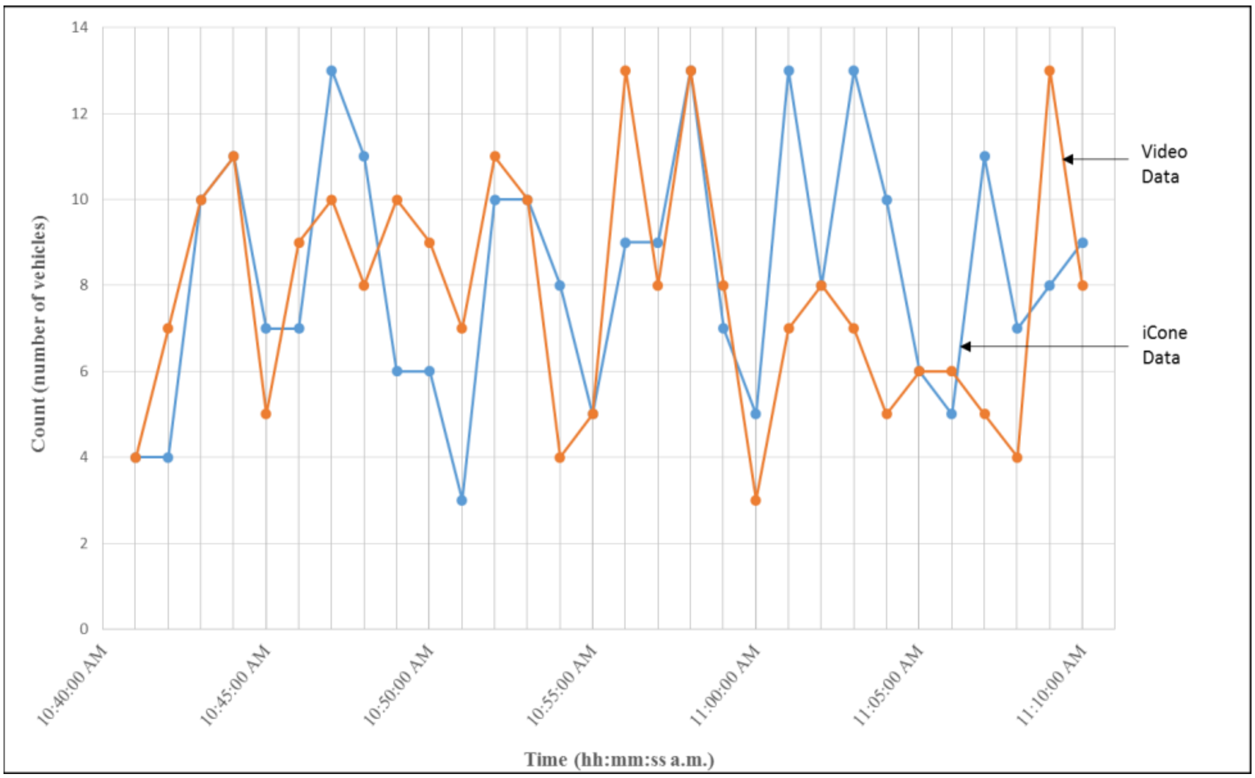

Figure 14. Variation in iCone count data and video data.

3.6 Test Location 6

Objective

To compare the data from the two iCones for traffic on a two-lane, two-way facility at different orientations at higher speeds.

Procedure

The iCones were tested for accuracy of their data collection for traffic counts on US-24: a two-lane, two-way rural highway with a posted speed limit of 65 mph near Williamstown, KS. The iCones were setup to collect data as shown in the Figure 13 on July 22, 2014. A research team of three members performed the experiment using two iCones and three video cameras. Both the iCones were setup facing east and collected data for both directions of traffic. The iCones were 1,400 feet apart from each other to ensure that there was no interference in the radar waves and manipulation in data. During the test duration, iCone 1 was oriented parallel to the adjacent traffic lane and iCone 2 was oriented in two different directions. First; iCone 2 was positioend parallel to the adjacent traffic lane, second it was positioned 30° away from the adjacent traffic lane and finally 60° away from the adjacent traffic lane to identify the most suitable orientation for precise data collection. The iCones were turned off before data were collected for the next orientation and were to be kept in the off mode for around 20 minutes to ensure separation in data sets. The data from both the iCones were then compared to determine the accuracy in the data collected.

Figure 15. Layout for the iCone setup on US-24 near Williamstown, KS.

Figure 16. iCone test setup on US-24 near Williamstown, KS.

Results

Data reduction showed that the iCone oriented 30° towards or away from the traffic lane missed more than 13 percent of vehicles while the iCone oriented parallel to the adjacent traffic lane counted 6 to 13 percent of vehicles twice.

Table 9. Williamstown iCone Test Data Reduction Results

Orientation	iCone Count	Video Data			Percent Total Difference
		Oncoming	Outgoing	Total	
30° away from the traffic lane	166	81	119	200	-17.00
iCone Parallel to the traffic lane	213	81	119	200	6.50
iCone Parallel to the traffic lane	161	60	82	142	13.38
30° towards the traffic lane	123	60	82	142	-13.38

The results showed that the parallel orientation produced the least average errors in both the scenarios. Also, when oriented towards or away from the traffic lanes iCone collected data for fewer vehicles.

3.7 Field Evaluation of the iCone on Two-Lane, Two-Way Rural Highways in Kansas

Objective

To evaluate the iCone as a portable traffic data collection device.

Procedure

After several preliminary tests in Lawrence, KS, the iCones were evaluated as portable traffic data collection devices at four different locations in rural Kansas. The four test locations were listed previously in Table 1 and were essentially two-lane, two-way rural highways with a posted speed limit ranging from 55 mph to 65 mph and near an ongoing work zone. In some cases due to movement of the work zones, the iCones had to be placed closer to a town resulting in lower overall average speeds but that did not alter the data collection procedure. A research team of four members performed the experiment using two iCones, two video cameras and two camera drums along with a set of two portable traffic signals. Based on the results of the preliminary testing, the research team decided to orient the two iCones parallel to the adjacent traffic lane and collect data for both directions of traffic. One iCone each was used on either side of the work zone approximately 0.25 mile upstream from the location of the flagger station. Apart from testing its accuracy, a secondary objective of the tests was to evaluate the iCone's performance if vehicular queues at the flagger station were to extend beyond 0.25 mile. The data from the iCone were then compared to the video data to determine the percentage error and overall accuracy.

Figure 17. iCone test setup on US-56 near Burlingame, KS.

Figure 18. iCone test setup on K-31 near Melvern, KS.

Figure 19. iCone test setup on US-24 near Beloit, KS.

Figure 20. iCone test setup on US-50 near Newton, KS.

Results

Table 10. Results from Data Reduction for Field Tests at Locations 7, 8, 9 and 10

Date	iCone		Video Count			Error	iCone ID	Avg. Speed
	Site	Reads	coming	going	Total			
8/5/2014[1]	Burlingame	209	93	92	185	12.97%	1275	42.75
8/6/2014[2]	Scranton	573	191	181	372	54.03%	1274	37.91
8/7/2014[3]	Scranton	1103	413	262	675	63.41%	1274	30.85
8/12/2014[4]	Melvern	100	27	23	50	100.00%	1275	43.97
8/12/2014[5]	Melvern	425	79	162	241	76.35%	1274	30.75
8/13/2014[6]	Melvern	943	215	214	429	119.81%	1274	27.10
8/13/2014[7]	Melvern	174	70	62	132	31.82%	1275	42.76
8/14/2014[8]	Melvern	229	115	84	199	15.08%	1275	43.96
8/19/2014[9]	Beloit	1135	519	527	1046	8.51%	1275	24.14
8/20/2014[10]	Beloit	1302	354	290	644	102.17%	1274	43.66
8/20/2014[11]	Beloit	1139	484	598	1082	5.27%	1275	25.10
8/21/2014[12]	Beloit	1713	547	517	1064	61.00%	1274	45.38
8/21/2014[13]	Beloit	1059	397	415	812	30.42%	1275	43.79
8/26/2014[14]	Newton	**1511**	759	784	**1543**	-2.07%	1275	54.11
		1511	759	784	1543	99.08%		54.11
8/27/2014[15]	Newton	**3567**	2037	2091	**4128**	-13.59%	1274	47.19
		3567	2037	2091	4128	75.11%		47.19
8/27/2014[16]	Newton	**2620**	1361	1279	**2640**	-0.76%	1275	52.92
		2620	1361	1279	2640	92.51%		52.92

[1] the iCone was deployed on the edge of a two-way, two-lane, level rural highway.
[2] the iCone was deployed on a slight vertical curve on a two-way, two-lane rural road.
[3] the iCone was deployed on a horizontal curve on a two-way, two-lane road in Scranton, KS.
[4] the iCone was deployed on a sharp vertical curve on a two-way, two-lane rural highway.
[5] the iCone was deployed inside the city near an intersection on a two-way, two-lane road.
[6] the iCone was deployed inside the city near an intersection on a two-way, two-lane road.
[7] the iCone was deployed on a sharp vertical curve on a two-way, two-lane rural highway.
[8] the iCone was deployed in a side ditch on a two-lane road with no shoulders.
[9] the iCone was deployed inside the city near an intersection on a two-way, two-lane road.
[10] the iCone was deployed on a two-lane level road on the edge of a six feet wide shoulder.
[11] the iCone was deployed inside the city near an intersection on a two-way, two-lane road.
[12] the iCone was deployed on two-lane level road on the six feet wide paved shoulder.
[13] the iCone was deployed on a vertical curve on a two-lane road.
[14] the iCone was deployed on two-lane level road on the six feet wide paved shoulder.
[15] the iCone was deployed on the shoulder of a four-lane road with a wide median.
[16] the iCone was deployed inside the city on the shoulder of a two-lane road.

The KU research team believed that all the above-mentioned geometric and topographical factors resulted in inaccurate results at all the test locations.

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

The iCone collected speed and count data for vehicles within its range (approximately 250 to 300 feet) and aggregated the data over any user-desired time period: the KU research team used a one minute interval for the purpose of the study.

The KU research team did not extensively test the iCone for the accuracy of its speed data. From the only test that was conducted for collection of speed data, the team found that there was a difference of 1 mph between the means of the speeds for data from the iCone and the pneumatic road tubes. Keeping in mind that the iCone recorded average speeds of the vehicles over a user-defined time period, the KU research team recommends the iCone to be used when KDOT desires to monitor the average speeds (for e.g. monitoring average speeds on a bridge or in a work zone). It would be noteworthy to mention that the iCone recorded a count of the vehicles that were traveling in a particular speed range at a location. KDOT might find this information useful to determine whether a large percentage of vehicles were actually traveling at higher speeds or whether the data were skewed due to the presence of a couple of outliers.

The iCone could find applicability as a speed monitoring device near a work zone or residential areas if used in conjunction with a dynamic changeable message sign indicating the prevailing speeds. If higher average speeds were observed, the continuous monitoring of the roadway speeds would assist the contractors or the city in determining subsequent speed control measures that need to be adopted.

The research team also recommends the iCone to be used in conjunction with police enforcement for monitoring and controlling vehicular speeds. If multiple iCone units were positioned on different streets, only a single police officer could effectively keep a track of speeds that were recorded at the different locations. The researchers believed that such a practice would reduce the load on the police officers for continuous driving and monitoring speed violations in the neighborhoods, and they would be able to be optimally position to reduce speeds.

The iCone was inaccurate when collecting the vehicular count data and showed variations in the percentage errors at every test location. The preliminary tests and the four field tests at locations 7, 8, 9 and 10 differed in the extent of data that were collected. During the preliminary tests on an average data were collected for one to two hours (generally the peak hour). On the contrary, data were collected for more than six to seven hours a day for the field tests at the last four locations. The research team believed that the increase in the overall percentage error was a function of the increased sample size. In conclusion, the KU research team would not recommend KDOT to use the iCone for collecting count data for longer periods.

Also, the results from Table 10 suggested that the best location to use the iCone would be a two-way, two-lane level highway with clear sight distances. Any other location with complex geometrics would result in inaccurate data collection and shewed results.

The researchers observed that it was difficult to orient the iCone in any particular manner to collect specific data. For example: if data for only the nearest lane were desired, one cannot guarantee that orienting the iCone at a particular angle would collect only these data. Also, the data sheets available from the website do not distinguish data for different lanes. After several tests it was observed that the parallel orientation yielded the best results and would be recommended when using the device.

Finally, based on the extensive data collected it would be safe to assume that the iCone collected data with more precision for all the vehicles in the nearby lane than vehicles in the other lanes.

4.1 Future Plans

In future, the researcher team desires to test the device on high speed sections and freeways to recommend better procedures for using the device when speeds exceed 65 mph.

Finally, the team plans to evaluate the device by comparing the data collected with other traffic data collection devices such as; JAMAR handheld data counter, LIDAR guns, Autoscope system with camera trailer, etc. The evaluation will focus on three characteristics namely; speed, volume, and drivers' response towards these devices when driving.

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