ACCURACY OF TRAFFIC SPEED AND VOLUME DATA DETECTED USING RADAR TECHNOLOGY

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ABSTRACT

Selecting an appropriate device for collecting accurate traffic data without creating any negative influence on traffic flow can be challenging for a traffic engineer. Understanding the tradeoffs of different data collection methods is a priority in order to conduct a successful data collection effort. This study explored the differences between three non-intrusive ITS sensors using radar technology: iCone, Radar Recorder, and Wavetronix SmartSensor HD (WSSHD) to collect a specific traffic parameter in comparison to the pneumatic road tubes (PRTs). This study compared 408 hours of sensor data along a rural two-lane road with a posted speed limit of 55 mph and quantified the differences in accuracy of the devices used for collecting speed and volume traffic data. The results showed that the error in detected speeds and volumes for iCone and Radar Recorder in comparison with PRTs were 1.5 percent and 1.4 percent, respectively, and 2.1 percent for the WSSHD. The error in detected volumes for the iCone and Radar Recorder in comparison with the PRTs were 8.6 percent and 7.8 percent, respectively, while for the WSSHD there was no difference from the PRTs. Based on the results, to collect traffic volume data for each traffic lane separately, the WSSHD is recommended. When collecting individual vehicle data is required, the Radar Recorder is recommended. As long as individual vehicle data are not required, the iCone could be a convenient option especially for short-duration data collection and more specifically at work zones where detector placement may be a challenge.

Keywords: Pneumatic Road Tubes, iCone, Radar Recorder, Wavetronix SmartSensor HD, ITS, In-roadway sensors, Over-roadway sensors, work zone.
BACKGROUND

Intelligent Transportation Systems (ITS) are traffic systems, which contain the integrated application of communications, control, and information-processing technologies to the transportation system to improve safety, reduce travel time, save money, and reduce negative environmental impacts (1). The quality of the operational data collected by any ITS device for use in decision-making can have impacts on the usefulness of the results and any error in the data collection can result in non-optimal decisions by highway agencies that use the data (2).

Based on their installation locations ITS infrastructure technologies are classified to roadway technologies and in-vehicle technologies, whereupon the currently available roadway ITS technologies are classified according to their locality to in-roadway sensor technologies and over-roadway sensor technologies (3). In-roadway sensors involve many sensors such as pneumatic road tubes, inductive loop detectors, magnetic sensors, and piezoelectric sensors, while the best example of over-roadway sensors are video image processors (VIP), microwave radars, infrared sensors, ultrasonic sensors, and passive acoustic sensors.

In work zones, the capacity of uninterrupted flow facilities can be reduced even when lanes are not closed. Therefore, The additional presence of ITS can be noticed and have a further detrimental impact in work zones. Creating a smart work zone through deploying different intelligent transportation technologies in construction zones has an important role in increasing safety and providing motorists with significant information regarding delays and travel times. In addition to collecting sufficient historic and real-time traffic data, which can be use in future design and construction projects. The accuracy and reliability of the data depends on the number and placement of the monitoring devices on a roadway segment, while its effectiveness is based on providing web-based reporting system, which allows monitoring construction activities and quick assessments of work zone performance, thus evaluating and responding to the situations on the site (4).

The most challenging task in the field of ITS is increasing the accuracy of data created by sensors. Therefore, the competing goals of the data users’ desire to get an accurate detector within budget constraints and manufactures’ competition to produce the least error at the lowest cost propelled the demand to evaluate detectors continuously (5).

To take into consideration the importance of getting accurate data, quantifying the differences in accuracy of the devices used for collecting speed and volume traffic data was the primary objective of this study. This study was initiated to evaluate three non-intrusive ITS sensors: iCone, Radar Recorder, and Wavetronix SmartSensor HD (WSSHD) in collecting traffic speed and volume in comparison to the PRTs.

LITERATURE REVIEW

In 2006, Klein, et al. presented an inclusive reference guide to support the practicing traffic engineers, planners, or technicians in selecting, planning, installing, and maintaining traffic sensors and classified traffic detectors in two families based on their locations along the road segments: in-roadway sensors, and over-roadway sensors (6). Several important studies evaluated new over-roadway detectors against the popular and proven in-roadway devices such as loop detectors and PRTs.

Three studies revealed that the iCone was more accurate in detecting traffic speed for the nearest lanes than the farthest lanes because some traffic is visually blocked, reducing the radar’s
ability to detect the farthest lanes’ traffic (7-9). The error in detecting traffic speed for the farthest lanes was 15 mph more than the nearby lanes from the iCone (7). The average differences in detected speeds by dual-loop detectors at a three-lane roadway in one direction was three mph (five percent error) lower than speeds detected by the iCones, while the difference in detected speeds from the loop detectors at the closest lane to the iCone was two mph (four percent error) (8). The speeds detected by the iCone were not sensitive to its position and orientation, and the iCones were inaccurate in detecting traffic volume (9).

The iCone speed and count data sufficiently matched when compared with those data from PRTs on a one-lane ramp and on two-lane undivided highways (10). The difference of the speeds measured on the similar section of ramp and highways by the iCone system in comparison to the Advanced Traveler Information System (ATIS) was less than 10 mph (11). These contradictory results about the accuracy of the iCone indicated a need for more testing to verify its accuracy. Therefore, in 2015, Mohammed recommended that the best location to use the iCone for collecting vehicular count data would be a two-way, two-lane level road with clear sight distances and the best orientation of its detection direction was parallel to the adjacent traffic lanes (12).

Marti et al. indicated that the Radar Recorder sensor was most accurate in traffic volume detection by one percent error and WSSHD was the most accurate in classification capability in comparison to other eight traffic detectors versus Automatic Traffic Recorder (ATR). In addition, the Radar Recorder and WSSHD were the most accurate sensors for speed detecting with a 1.2 percent error (13). Bellucci and Cipriani indicated that devices adopting multiple technologies, generally, and double technology systems, specifically, had better accuracies in traffic counting and reliability than devices using a single technology (14).

According to Gates et al., the five common portable speed measurement detectors performed equally well for the 35-mph trails, while Lidar and radar were the most accurate devices for the 55-mph trails (15). Jasrotia established the effects of tested devices on the driver response and found that vehicle speeds were reduced when the Lidar gun or Autoscope with trailer were visible on the roadside, while increased speeds were observed when the Smart Sensor was installed (16).

According to Fitzsimmons et al., PRTs were found to be accurate in capturing vehicle lateral position at vehicle speed ranging from 19 to 51 mph for both day and night (17). Yu et al. indicated that the accuracy of tested sensors were effected by different influence factors such as weather, illumination, traffic congestion, location of sensors from detection area, and crown slope of pavement. The traffic classification capability of Autoscope and Infrared Traffic Logger (TIRTL) was adequate at ideal conditions, but SmartSensor HD was inadequate (18). The SmartSensor HD performance in volume detection was found to have an error range from -10.4 percent to 14.8 percent and overestimated the speed by 7.5 percent. The volume detected by TIRTL was undercounted about 3.3 to 6.1 percent depending on the slope of the pavement, while the error in volume detected by Autoscope was less than four percent (19). The traffic detectors with microwave radar technologies provided 90 percent accuracy in volume and 75 percent in classification detection on eight lanes of traffic under optimal conditions (20).
SITE SELECTION AND DATA COLLECTION

To evaluate the performance of the selected devices, the collection of field data was conducted on a one-half mile of two-way, two-lane level road with a clear sight distances on US 24/40, close to the Lawrence Municipal Airport, between E 1500 Rd. and E 1600 Rd, northeast of Lawrence, Kansas as shown in Figure 1. The Annual Average Daily Traffic (AADT) recorded in 2014 for that road segment was 6,580 Vehicle per day (21). The speed and volume of traffic data were collected with PRTs, iCone, Radar Recorder, and WSSHD devices on normal days for 408 hours over six weeks in March and April 2015, as shown in Figures 2-4. PRTs were used as a control device in this study and were always present throughout the data collection period, while the other devices were substituted after collecting sufficient data. A pair of PRTs was laid across the road at a distance of eight feet perpendicular to the direction of traffic and the iCone was deployed on the shoulder parallel to the adjacent traffic lane. The Radar Recorder was mounted to a nearby utility pole, while the WSSHD was installed on a level and hard surface by 25 ft offset from the first detection lane and 26 ft above the ground level, as recommended by the manufacturer.

DATA REDUCTION

In order to evaluate the accuracy of each test device against the control device in collecting traffic data, the data collected by the control device (PRTs) were prepared for statistical comparison and analysis with the test devices. All devices created data files in Microsoft Excel format containing different traffic parameters, but all parameters were deleted except the parameters of interest (time, date, speed, and volume). Because the PRTs and the Radar Recorder collected individual traffic data for each vehicle, and the iCone and WSSHD collected data for one-minute intervals, the entire data were classified to five-minute intervals of unified data to make proper comparisons between systems.

DATA ANALYSIS

The primary goal of the data analysis was to compare the accuracy of the iCone, Radar Recorder, and WSSHD devices against PRTs in detecting traffic speed and volume. The test hypothesis used for comparing the accuracy of the tested devices was divided to two stages: the difference in average speed and volume between the test and control systems were different, whereas the null hypothesis was that there was no differences.

\[
H_0: \Delta \mu_i = \Delta \mu_j = \Delta \mu_k
\]

\[
H_a: \text{At least one of them not equal}
\]

Where: \( \Delta \mu = (\text{average of mean speed and volume of PRTs} - \text{average of mean speed and volume of a device}) \);

\( i = \text{iCone}; \)

\( j = \text{Radar Recorder}; \) and

\( k = \text{WSSHD}. \)
Figure 1. Study location on US 24/40, near the Lawrence Municipal Airport.
Figure 2. iCone sensor installed by the roadside.

Figure 3. Mounted Radar Recorder.
If in the first stage of the analysis, it was found that the null hypothesis was rejected, then in the second stage of the analysis, the objective was to determine which one (or more) of the devices different from the PRTs. The null and alternative hypotheses for the second stage were:

\[ H_0: \mu = \mu_i \]
\[ H_a: \mu \neq \mu_i \]

\[ H_0: \mu = \mu_j \]
\[ H_a: \mu \neq \mu_j \]

\[ H_0: \mu = \mu_k \]
\[ H_a: \mu \neq \mu_k \]

Where: \( \mu \) = average of mean speed and volume of PRTs;
\( i = i\text{Cone}; \)
\( j = \text{Radar Recorder}; \) and
\( k = \text{WSSHD}. \)

In the first stage, The F-test was computed to determine if the average speed for each interval measured by the PRTs minus the average speed for each interval measured by the
individual data collection device was significantly different for all respective data collection devices. In the second stage, paired t-tests were computed to determine if the average of mean speed recorder by the PRTs and each tested device was significantly different for each interval. Significant differences were indicated by an asterisk in Table 1. As shown, the differences between the average of mean speed recorded by the PRTs and the average of mean speed recorded by iCone, Radar Recorder, and WSSHD were significantly different at the 0.05 level of significance. The errors in detecting speeds by the iCone, Radar Recorder, and WSSHD in comparison to the speeds were detected by PRTs were 1.5, 1.4, and 2.1 percent, respectively.

### TABLE 1 Paired T-Test for Average Speed of PRTs with Other Devices

<table>
<thead>
<tr>
<th>Tested Devices</th>
<th>Mean</th>
<th>Difference (mph)</th>
<th>Error (%)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRTs</td>
<td>57.10</td>
<td>0.86*</td>
<td>1.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>iCone</td>
<td>56.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRTs</td>
<td>57.35</td>
<td>0.81*</td>
<td>1.4</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Radar Recorder</td>
<td>56.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRTs</td>
<td>50.45</td>
<td>-1.07*</td>
<td>2.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>WSSHD</td>
<td>51.52</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The detected average of the mean volume was computed for five-minute volume intervals. In the first stage, the average volume for each interval was measured against the PRTs minus the average volume for each interval measured by the individual data collection device. It was found that significant differences existed at the 0.05 level of significance for all respective data collection device when the F-test was applied.

At the second stage, paired t-tests were computed to determine if the averages of the mean volumes recorded by the PRTs and each tested device was significantly different for each interval. As shown in the Table 2, significant differences were indicated by an asterisk. The error in detected traffic volumes by the iCone and Radar Recorder were 8.6 percent and 7.8 percent, respectively, while detected traffic volumes by the WSSHD was not significantly different in comparison to the volumes were detected by PRTs for each interval.

### FINDINGS AND RECOMMENDATIONS

Through the preceding analysis and the results from the comparison of each of the three devices with the PRTs to evaluate their accuracy in detecting traffic speed, and volume, these findings were concluded:

1. Statistical analyses were performed to verify whether the tested devices detected the same traffic speed and volumes as the control device. The results clarified that of the three devices, only the WSSHD produced similar results in traffic volume detection and the
Table 2: Paired T-Tests for Average Volumes of PRTs with Other Devices

<table>
<thead>
<tr>
<th>Tested Devices</th>
<th>Mean</th>
<th>Difference (mph)</th>
<th>Error (%)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRTs</td>
<td>26.01</td>
<td>-2.22*</td>
<td>8.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>iCone</td>
<td>28.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRTs</td>
<td>23.86</td>
<td>-1.85*</td>
<td>7.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Radar Recorder</td>
<td>25.71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRTs</td>
<td>24.8</td>
<td>-0.06</td>
<td>0</td>
<td>0.711</td>
</tr>
<tr>
<td>WSSHD</td>
<td>24.87</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

difference of the average volume detected was 0.061 vehicles per each five-minute interval. The error in detecting volume was zero percent in comparison to the volumes detected by PRTs.

- The error in detected speeds for the iCone and Radar Recorder in comparison with the PRTs were 1.5 percent and 1.4 percent, respectively. Both devices detected the traffic speeds less than what the control device detected by 0.9 mph per interval.
- The error in detected speeds for the WSSHD in comparison with PRTs was 2.1 percent.
- The error in detected volumes for the iCone and Radar Recorder in comparison with the PRTs were 8.6 percent and 7.8 percent, respectively. Both devices detected traffic volumes greater than what the control device detected by 1.8 vehicles per interval.
- The difference in detected volumes for the WSSHD in comparison with PRTs was zero percent. This device was considered as the most accurate device in collecting traffic volume among the tested devices through this study.
- For collecting traffic volume data only for each of adjacent traffic lanes, and when individual vehicle data are not required, the WSSHD is recommended. Although this detector requires several workers and a more time for installation, monitoring the traffic conditions and downloading data online could save time and provide safety as it is set up farther from the lanes of traffic.
- When collecting individual vehicle data are required, the Radar Recorder is recommended for traffic data collection. The Radar Recorder requires at least one person present frequently on site with a laptop to extract data and check the batteries or recharge them. For studies where huge amounts of data are required, this can be a difficult process. It should also be considered that collecting data with the presence of the data collector could influence the driver behavior.
- As long as individual vehicle data are not required, the iCone could be a convenient option especially for short-term data collection and more specifically at work zone. The iCone is easy to install and remove. Its shape makes it suitable for work zones and its online database provides safety and saves a lot of time in traffic monitoring and extracting data.
ACKNOWLEDGMENTS

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