MIDWEST SMART WORK ZONE DEPLOYMENT INITIATIVE

MwSWZDI

FHWA POOLED FUND STUDY

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Radar Speed Display

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Supplemental Notes

Abstract

The MwSWZDI has evaluated radar actuated speed displays in several contexts. One of the most significant criticisms of previous evaluations has been that data were only collected for a relatively short time period (e.g., one week or less). Popular thought is that the displays are effective for only a few days, after which the novelty effect dissipates and drivers begin to ignore the device. This evaluation was conducted on a two-lane rural commuter route just west of Lawrence, Kansas. Data were collected for approximately one hour each work day for approximately 8 weeks. The speed display was present for five weeks, with one and a half weeks of before data and one and a half weeks of after data. The data showed statistically significant reductions in mean speed, 85^{th} percentile speed, and percent speeding. Mean and 85^{th} percentile speed reductions were both about 5 mph. Percent speeding dropped from about 80% (baseline) to about 40% when the display was present. The percent of drivers traveling at least 5 mph over the speed limit dropped from about 30% to less than 5%. The reductions were consistent for the entire deployment, demonstrating that the speed display's effectiveness was not due to its novelty.

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Project Year 2002 Evaluations

Long Term Effects of

Radar-Activated Speed Displays

Evaluation Performed by
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Long Term Effects of Radar-Activated Speed Displays

INTRODUCTION

Radar-Activated Speed Displays, such as those shown in Figure 1, are not a new concept, but the associated technologies and the understanding of their effective use have grown considerably over the past few years. As Bloch (1998) pointed out, although speed displays were introduced in the late 1980's and have become a widely accepted tool for speed control, little objective study of their effectiveness occurred during their first decade of use. Bloch's study found speed displays to reduce mean speeds by 5.8 mph at the sign, and by about half as much 0.2 mi downstream of the sign. He also found that there was a small (1.7 mph) residual reduction in speeds a week after their removal. Carlson, et al (2000), found similar reductions downstream of a display deployed at a lane drop prior to a temporary work zone, but smaller reductions—around 2 mph—at the display itself.

Figure 1. Trailer mount[1] (right) and vehicle/pole mount (left)

[1] Trailer mounted unit appears less bright than it actually is due to the angle of view.

The Midwest Smart Work Zone Deployment Initiative (MwSWZDI) has conducted several studies of speed displays, beginning in the summer of 1999, when displays were tested in Iowa, Kansas, and Nebraska. Meyer (2000) deployed a display within a work zone and measured speeds at the display and at a point approximately half a mile downstream. Mean speeds were reduced by 2.8 mph at the display and 0.8 mph 0.5 mi downstream of the display. The percent of motorists traveling above the posted speed dropped from 67% to 36%. McCoy and Pesti (2000) in their evaluation in Nebraska also found the display to result in a modest reduction in mean speeds and a substantial reduction in percent speeding. In a test of another brand of speed display conducted in Iowa in the same year by Maze, et al (2000), no effects were observed. The conclusion was that the font size was too small to be effective in an environment where freeway speeds are typical.

A survey of state transportation agencies by Kamyab, et al, (2001) cited mixed opinions regarding the effectiveness of speed displays as a speed control tool in work zones, although most seemed to be without objective verification. The only state that provided quantitative details reported a speed reduction of 4-6 mph using the displays. The same year, a study in Texas observed up to 10 mph reductions in speed when a speed display was deployed at a work zone approach, compared to standard work zone traffic control alone. (Fontaine, 2001)

The most common criticism of speed displays—that they work only for short duration deployments (i.e., a few days)—has persisted for many years, even though it is largely based on anecdotal evidence and unsubstantiated by empirical study. The scopes of the aforementioned studies were limited by various factors, and as a result they could not address the longevity of the effectiveness of speed displays. The longest deployment among them was only a week.

To address this concern, a second test was conducted by Pesti and McCoy (2001). In this test, the display was deployed for 5 weeks, and the data showed that there was actually very little novelty effect. When the display was deployed, the mean speed immediately dropped by about 3 mph, and the reduction persisted for the duration of the 5-week deployment. When the display was removed, a residual speed reduction of 1.5 mph was observed, suggesting that the displays had a lasting effect on driver behavior. Another test of speed displays by Pesti and McCoy (2002), this time on freeway entrance ramps, found speed reductions of 3-6 mph the first week the displays were on site, and no statistically significant reduction during the second week of deployment.

To further investigate the validity of the common perception that speed displays are effective for only short-term deployments, the MwSWZDI funded another Kansas study of a speed display, designed specifically to examine the novelty element of the display's effectiveness. This report details the methodology of the study and the results of the data collection and analysis, and presents recommendations regarding the use of speed displays.

TECHNOLOGY DESCRIPTION

The speed display used in this study comprised a Stalker radar speed sensor, a backlit display, and a strobe flash, all contained in a trailer mount. The unit tested is available in many configurations, including two mounting options. It can be integrated with a trailer, including a solar panel and batteries, shown on the right in Figure 1, or contained in a unit that can be mounted on a pole or a vehicle (using a trailer hitch adapter), shown on the left in Figure 1. The trailer-mounted unit was used in this study.

Inside the unit is a control panel on which the strobe flash can be turned on and off, and a threshold speed set for strobe activation, as shown in Figure 2. The system controller monitors the speeds observed by the radar sensor, and when the observed speed exceeds the threshold, the controller makes the display flash the speed and turns on the flashing strobe light.

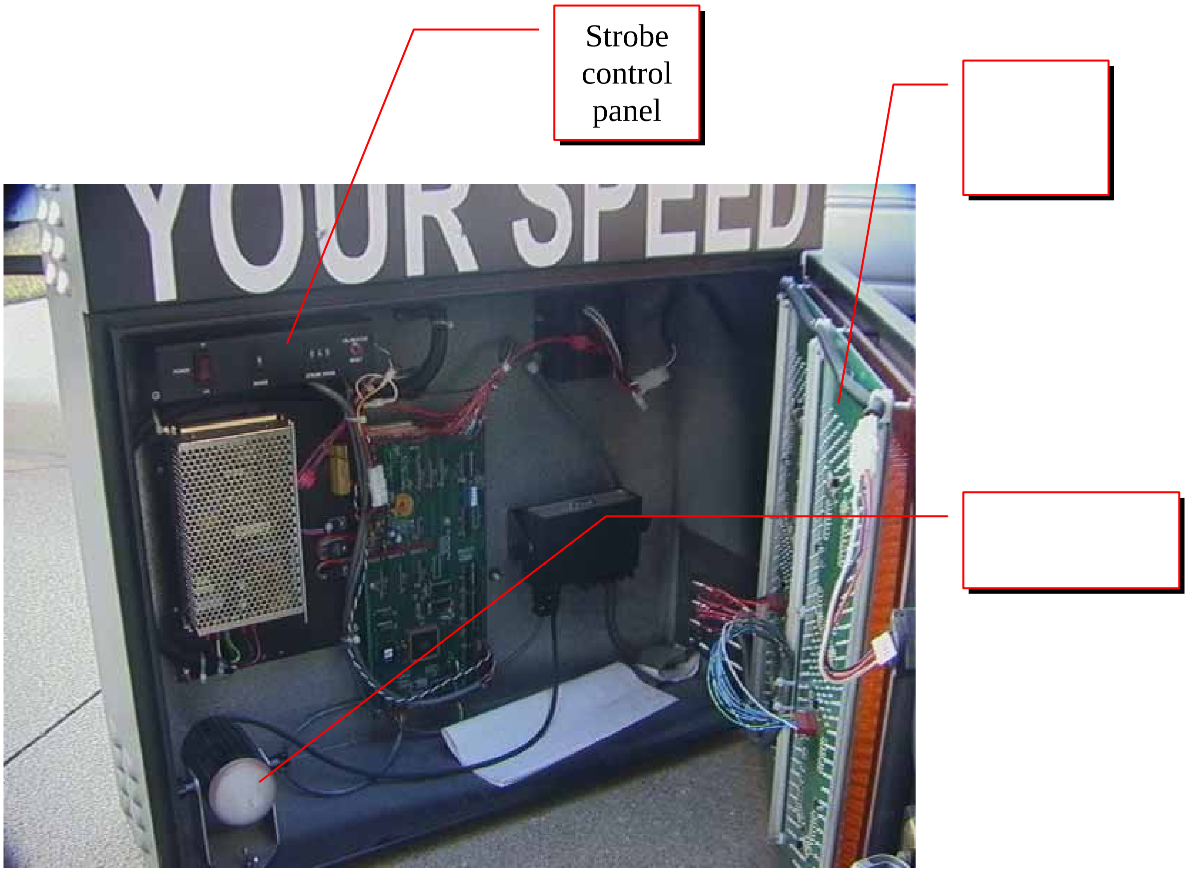

Figure 2. Inside of vehicle/pole mountable unit.

Typically, a speed limit sign is mounted above the display, but in this case, the limit was posted just a few feet downstream of the display, as shown in Figure 3, so no speed limit sign was mounted to the unit itself. The strobe flash was set to activate when a vehicle's speed exceeded 68 mph.[2] A maximum speed could also be set for the display, discouraging drivers from competing to post higher speeds on the display. The device is camera-ready to allow photo enforcement, although no camera was used in the evaluation (Photo enforcement is at this time precluded by Kansas state statute. In order for a citation to be issued, an offense must be witnessed by the issuing law enforcement officer).

[2] Typically, the threshold would be set to 5 to 10 mph above the posted speed. During the baseline data collection the range of speeds observed indicated that the effect of the strobe could be better observed if the threshold were set lower than 5 mph over the posted speed.

Figure 3. Speed Display, Speed Limit Sign, and Observation Location

The Evaluation Team comprised the following members.

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Speed Measurement Laboratories provided the display. The University of Kansas performed the data collection and analysis. The Kansas Department of Transportation served as liaison with local transportation officials and law enforcement.

GOALS

The goals of this study were the following.

1. Determine the effect on speeds attributable to the presence of the speed display.
2. Determine the effect on speeds attributable to the use of the strobe flash, relative to the speed display without the strobe.
3. Assess the degree to which the effectiveness of the device is due to its novelty (i.e., the degree to which the speed reductions diminish over time).
4. Examine the relationship between the effectiveness of the display and the use of radar detectors among the driving population.

5. Examine the residual effect of the display on driver behavior.

STUDY SITE

The study site was a segment of Kansas Route 10 (K10), west of Lawrence, Kansas, immediately north of the US40 interchange. The segment was a rural 2-lane highway with an AADT of 8,830 vpd (5% trucks) and a posted speed of 65 mph.

Data was collected for approximately one hour each weekday during the study period. Traffic characteristics for the study period are shown in Table 1.

Table 1. Daily Traffic Characteristics for Study Period.

	NB Hourly Volume (vph)	Percent Heavy Vehicles
Min	163	0.9%
Max	370	5.8%
Avg	**279**	**3.0%**

Figure 4 shows the study site from the perspective of the observer (facing South). The device is in the center of the image, approximately 900 ft from the observer. On the far left is an unpaved access road. Next to the access road, running directly in front of the observer, is a walk/bike path. US40 is the overpass at the horizon, approximately 3600 ft from the observer.

Figure 4. Observation Perspective of Study Site.

DATA COLLECTION

Data collection occurred between July 16 and September 6, 2002. The trailer was deployed at the same location each weekday during the study period, with the exception of August 6, when equipment failure prevented deployment. On each day of data collection, the trailer was deployed during the morning peak period only and stored off site during the remainder of the day. For each day, data was collected for approximately one hour beginning between 6:30 AM and 7:30 AM.

Data was collected for northbound traffic only. The data items that were recorded are listed in Table 2. Data logging was accomplished via one of two means, depending on whether data was being collected by one or two researchers. When two researchers were present, one measured the speed and called out the data values, and the second researcher entered them directly into a laptop computer using a custom logging utility. When data was being collected by only one researcher, a tape-recorded data log was created, which was later transcribed into the computer.

Table 2. Data Items and Collection Means.

Data Item	Units	Collection Means
Observation Time	time of day	Computer system clock/wristwatch
Vehicle Speed	mph	Kustom Signals ProLaser III Laser Speed Gun
Vehicle Range	ft	Kustom Signals ProLaser III Laser Speed Gun
Vehicle Classification	Passenger car/truck	Manual observation
Use of Radar Detector	true/false	Spectre Radar Detector Detector[3]

In addition to the primary data listed in Table 2, supporting data was collected to post-process the speed data for improved accuracy. As can be seen in Figure 4, the study segment was a curve section. Consequently, the appropriate speed correction for observation angle depended on the location of the vehicle along the curve at the instant of observation. To maximize the accuracy of the data, a correction factor lookup table was developed such that the range of the vehicle at the time of observation could be used to enter the table and extract the appropriate correction factor.

To create the correction factor lookup table, a GPS receiver was used to mark the observation point. Then the receiver was used to record the travel path for subject vehicles by logging GPS data while traveling the segment. For each GPS point on the travel path, the observation angle was approximated as the angle formed by the line of view to the previous point and the chord connecting the points immediately before and after the subject point, shown as *Angle B* in Figure 5. For each data point, the correction factor used was interpolated from the table based on the range. Data points defining the path were taken at a rate of one per second, and the data was collected at a speed to yield approximately 70 ft between data points. Consequently, the error introduced by using the line of sight to the previous data point in the

[3] Radar Detector Detector was provided by McCoy's LawLine, Chanute, Kansas.

calculation of the incident angle is negligible. The GPS data points collected are shown in Figure 6, with key locations indicated.

Vehicles entering the highway from US40 were noted and omitted from analysis. Vehicles whose speed was likely affected by entering traffic were also omitted from analysis. Speeds greater than 100 mph or less than 20 mph were assumed to be data entry errors and were removed from the data set during post processing.

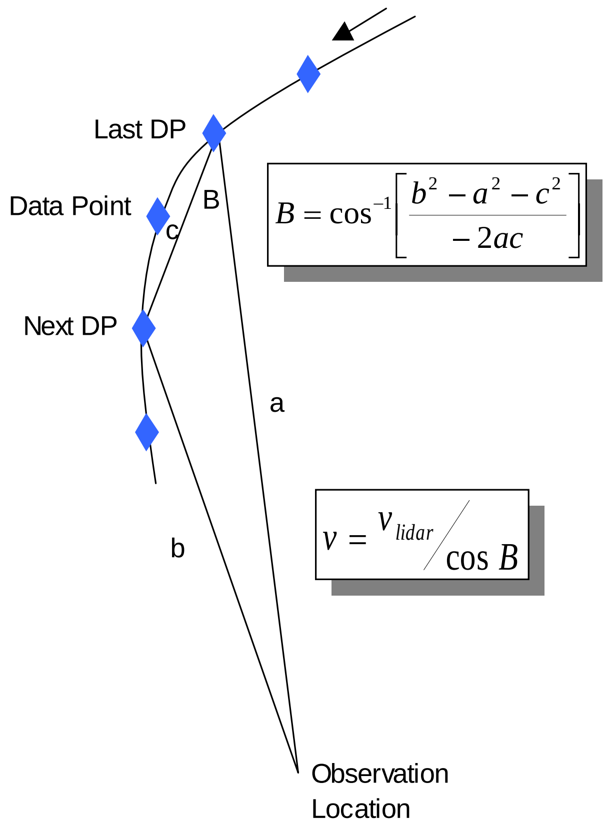


Figure 5. Approximation of Observation Angle.

During data collection, observers were precluded from measuring speeds on a portion of the segment near the display because the speed limit sign posted about 100 ft downstream from the display blocked the observers' line of sight. As a result, some speeds were measured upstream of the display and some were measured downstream of the display. Most measurements were taken when the vehicles were either about 100 ft upstream of the sign or about 400 ft downstream of the sign.

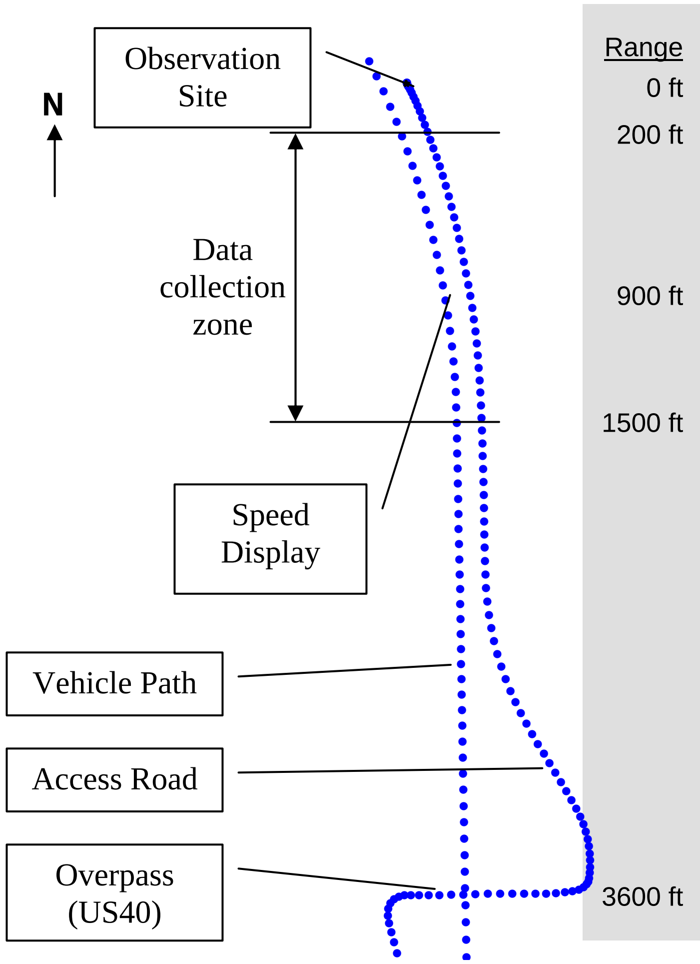


Figure 6. Plan view of study site. (not to scale)

Scatter plots and speed distributions from three sample days from each of the four phases of the test (baseline, with strobe, without strobe, residual) are given in Appendix A.

DATA ANALYSIS

Speeds were observed for all vehicles (i.e., both passenger cars and trucks). Effects of platoons were removed by eliminating all vehicles with headways of 5 seconds or less. The location of the study and the time of data collection were selected to ensure a high percentage of commuters (i.e., repeat traffic) so as to best evaluate the effects of the display when encountered repeatedly by the same drivers.

Range

Records with a range greater than 1500 ft were omitted from the analysis. This limit was imposed to ensure that drivers had enough time to be picked up by the radar, see the display, and respond. Ranges less than 200 ft were omitted from analysis because beyond that point the cosine correction (*cos B*) decreased to less than 0.9, and the risk of compromising data accuracy grew proportionally. Some speeds were measured upstream of the display and some were measured downstream of the display. For each day of data, Pearson's correlation coefficient, r, was calculated to determine if there were a correlation between the speed of a vehicle and the range to the vehicle at the time of measurement. For all days, the values of r were in the range of

$$-0.206 \le r \le 0.126$$

with an average value of –0.054. These values suggest that speeds did not vary with the location of the vehicle.

Scatter plots for speed vs. range for a typical baseline day and a typical day during deployment are shown in Figure 7 and Figure 8, respectively. It can be seen from the plots that if there is any relationship between logged speeds and ranges, the difference between the extremes is not discernable to the naked eye and is likely of little practical significance, even if it is statistically significant.

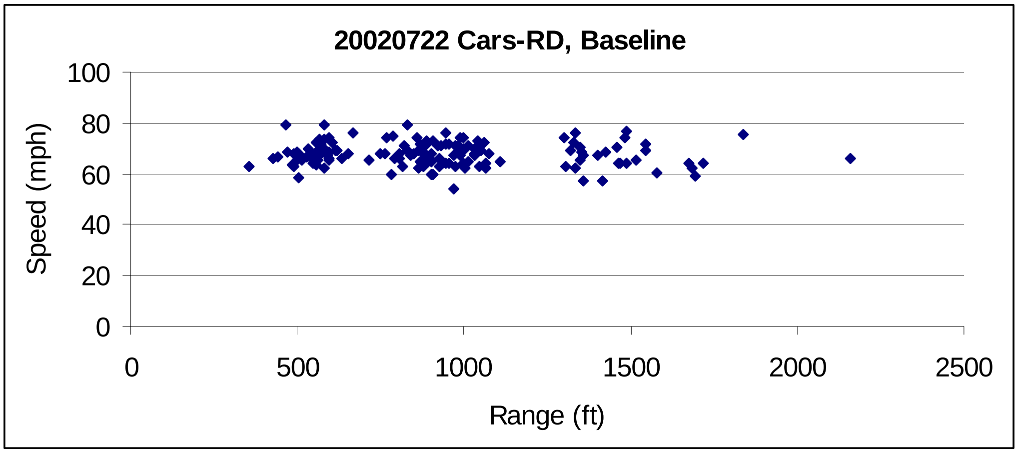


Figure 7. Speeds vs. Range for July 22, Cars -RD, Baseline.

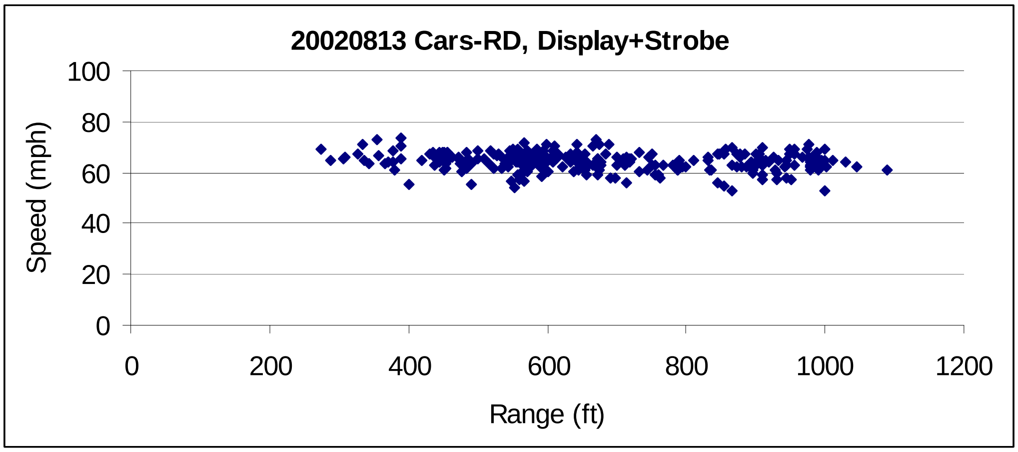


Figure 8. Speeds vs. Range for August 13, Cars -RD, Display +Strobe.

Figure 9 shows a frequency distribution of range values for a typical day, August 22. Distributions varied among days, but the double peaked distribution shown in the figure occurred in most of the data sets. A wider variation occurs in the baseline data. This was necessary to identify any anomalies prior to deciding the location for the display. None were found, so the display was located so as to be close to the speed limit sign, to be well downstream of the merge of US40 traffic, and to allow ample room to maneuver the towing vehicle.

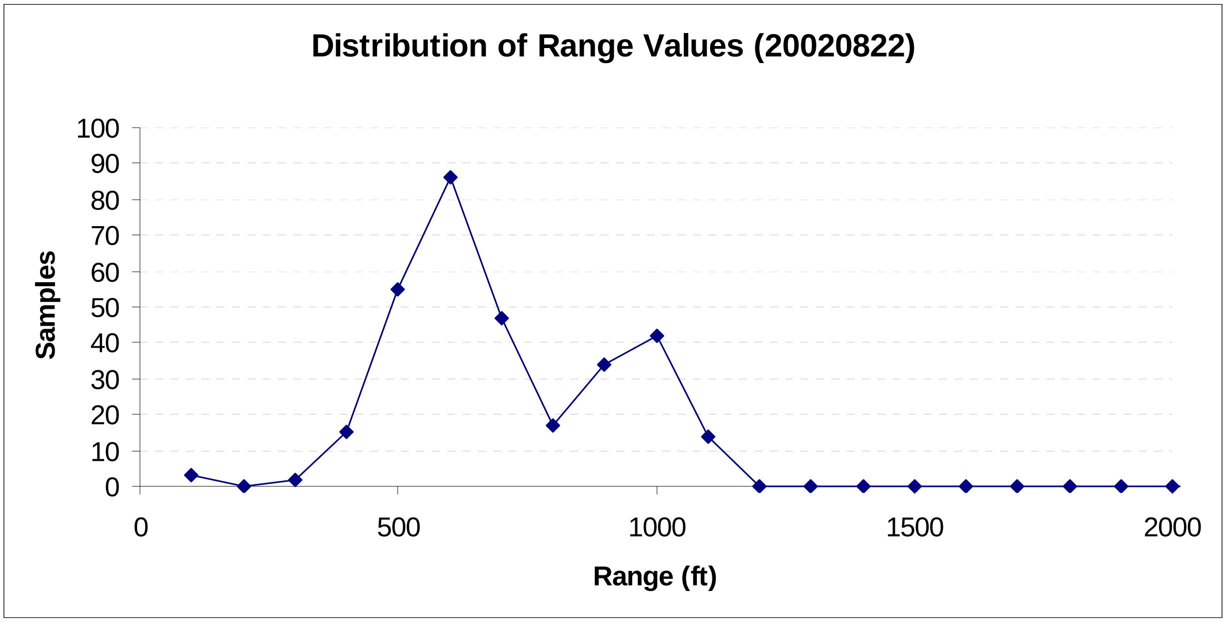


Figure 9. Typical Frequency Distribution of Range Values.

There are two possible concerns with regard to the range of vehicles at the time the speed was captured. First, if typical speeds vary by range and the proportion of upstream measurements versus downstream measurements is different for treatment data than for baseline data, the statistics would be artificially skewed. For example, if grade or entering traffic caused the majority of vehicles to accelerate over the study segment, speeds measured at closer ranges would tend to be higher than speeds measured at farther ranges. Suppose that during baseline data collection most of the readings were taken at closer ranges, where speeds tend to be higher, and during deployment data collection, most of the readings were taken at farther ranges, where speeds are typically lower. The data would show a reduction in mean speed when the display was deployed compared to baseline conditions. The reduction, however, would actually reflect the location where the data was collected rather than the effects of the display.

The second concern is that mean speed varies with range only for the treatment data. Suppose that during baseline data collection, speeds are uniform along the length of the segment. Further suppose that when the display is deployed, it has a real effect on speeds, causing a small reduction in the mean. If a portion of the speeds were taken far enough upstream of the display—prior to drivers having opportunity to see their speed and respond—those measurements would not reflect the effects of the display. As a result, the effects shown in the data taken further downstream would be at least partially masked by the inclusion of data from upstream of the affected segment. Any effects of the display would be artificially reduced and perhaps yielded undetectable.

To address both concerns, two subsets of data were drawn from each day's log, an upstream subset and a downstream subset. The upstream subset contained speeds recorded at a range of 1000 ft to 1500 ft. The downstream subset contained speeds recorded at a range of 200 ft to 600 ft. The daily means for each subset were calculated, and the average of the daily means for the upstream subsets was compared with the average of the daily means for the downstream subsets. The comparison statistics for baseline data is shown in Table 3 and for treatment data (display +strobe) in Table 4. In both cases, the difference between the upstream and downstream means was about half a mile per hour. In both cases, the p-value is greater than 0.05, meaning the differences are not statistically significant. Similarly, the differences in the daily standard deviations for the subsets was not statistically significant between the upstream and downstream subsets, for both baseline and treatment data.

Table 3. Comparison of baseline means for vehicles at different distances.

t-Test: Paired Two Sample for Means

	1000-1500	***200-600***
Mean	**67.56 mph**	**68.14 mph**
Variance	0.31	0.38
Observations	6	6
Pearson Correlation	-0.89	
Hypothesized Mean Difference	0 mph	
Df	5	
t Stat	-1.250	
P(T<=t) two-tail	**0.266**	
t Critical two-tail	2.571	

Table 4. Comparison of treatment means for vehicles at different distances.

t-Test: Paired Two Sample for Means

	1000-1500 ft	***200-600 ft***
Mean	**64.14 mph**	**64.68 mph**
Variance	1.45	1.78
Observations	15	15
Pearson Correlation	0.55	
Hypothesized Mean Difference	0 mph	
df	14	
t Stat	-1.748	
P(T<=t) two-tail	**0.102**	
t Critical two-tail	2.145	

Effect of Radar Detectors

A common perception is that speed displays are effective only because the radar speed sensor triggers radar detectors, and not because of the display itself. A previous study by Meyer (2000) funded by the MwSWZDI examined the effects of a radar drone and found that there was no effect on speeds attributable to the radar signal alone. However, other studies have found otherwise, so during the data collection for this study, a *radar detector detector* was used to monitor vehicles for the presence of active radar detectors. Using this information, vehicles with active radar detectors could be compared to those without detectors to determine whether the effectiveness of the speed display is due to the radar signal alone, or if the display of the speed affects driver speed choice.

Time of Day

Pearson correlation coefficient, *r*, was calculated for several parameters to determine if the start time of data collection affected the characteristics of the data collected. The results showed that no significant correlation existed between the data collection start time and the data collected. The coefficient values are shown in Table 5.

Table 5. Pearson Correlation between start time and various parameters.

Parameter	***Pearson,r***
Start Time	1.00
NB volume	0.35
Percent trucks	-0.16
Daily sample size	0.29
Percent PC using radar detectors	-0.19
Mean Speed	0.16

Notes: passenger cars –radar detector +display +strobe

Study Goals

Each of the goals of this study was pursued by applying a Student's *t*-test to appropriate data. Variances were assumed to be unknown. Table 6 lists the goals of the study and the comparison performed that is most closely associated with that goal. Unless stated otherwise, comparisons were of passenger cars not operating radar detectors.

Table 6. Study goals and associated comparisons.

Goal	Comparison
1. Determine the effects on speeds attributable to the **presence of the speed display**.	Daily speed characteristics with and without speed display (+strobe)
2. Determine the effect on speeds attributable to the **use of the strobe flash**, relative to the speed display without the strobe.	Daily speed characteristics of display +strobe with display -strobe
3. Assess the degree to which the effectiveness of the device is due to its **novelty** (i.e., the degree to which the speed reductions diminish over time).	Daily speed characteristics from the first week the display is active with the last week display is active (+strobe)
4. Examine the relationship between the effectiveness of the display and the **use of radar detectors** among the driving population.	Daily speed characteristics during deployment of passenger cars using radar detectors with passenger cars not using radar detectors
5. Examine the **residual effect** of the display on driver behavior.	Daily speed characteristics from the first week after the display is removed with baseline data

RESULTS

Traffic was filtered by two characteristics: vehicle classification (passenger car vs. truck) and presence of an active radar detector. A summary of these two parameters is shown in Table 7. Three percent of the traffic were trucks, on average. An average of 5% of the vehicles were operating radar detectors.[4]

Table 7. Radar detector characteristics by day.

	NB Hourly Volume (vpd)	Percent Heavy Vehicles	Percent Using Radar Detector
Min Day	163	0.9%	0.4%
Max Day	370	5.8%	11.5%
Avg Day	**279**	**3.0%**	**5.0%**

Figure 10 shows a temporal profile of speed characteristics throughout the study for passenger cars without radar detectors. It is evident from the graph that when the speed display was deployed, mean speeds and 85th percentile speeds both decreased. It appears that the standard deviations also decreased, implying more uniform speeds, although this change is less obvious. No data was collected on August 6 due to equipment failure. On August 15 (Thursday) the trailer was deployed but the strobe light was turned off. The following day the strobe was active, and then turned off for the remainder of the deployment.

Figure 10. Temporal profile of daily speed characteristics.

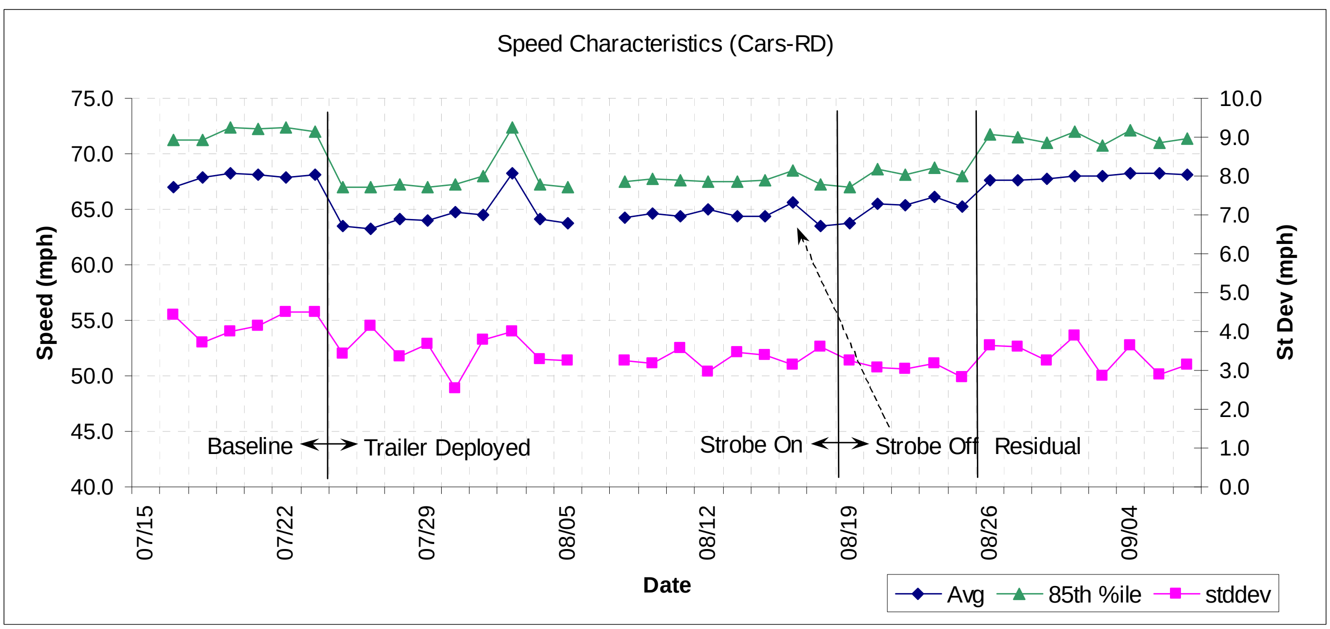
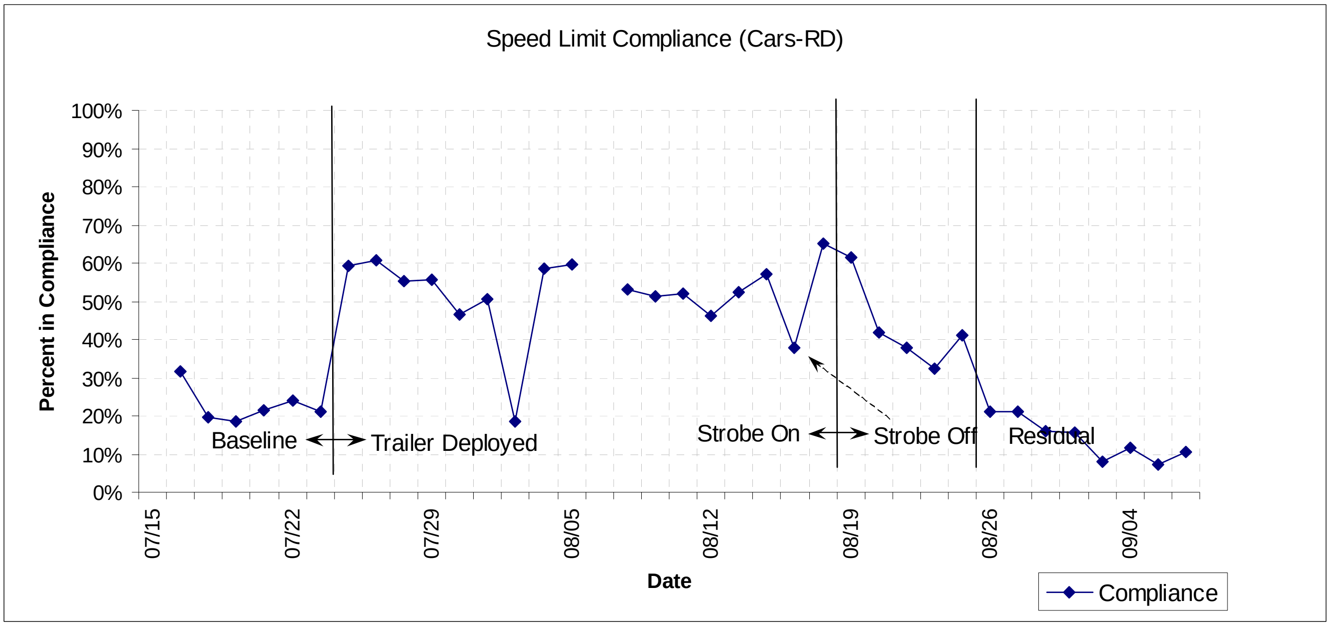


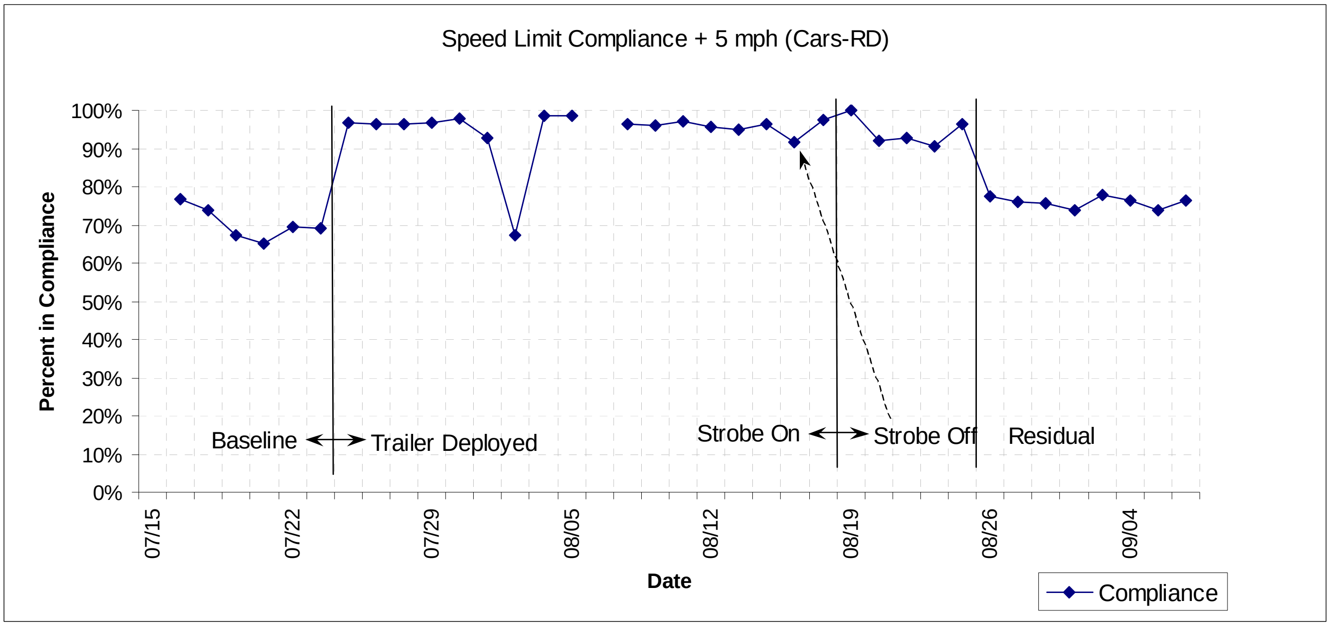
Figure 11 shows the daily percentage of vehicles that were traveling at or below the posted speed limit of 65 mph. Compliance during the baseline period was around 20% for all but one day. When the display was deployed, typical values for compliance were around 50%. Figure 12 shows the daily percentage of vehicles traveling no more than 5 mph over the posted speed (i.e., speed <= 70 mph). The percentage change is similar to that shown in Figure 11, but the consistency across days makes the effects more pronounced. In Figure 11, compliance during the residual period was lower than baseline values, suggesting that the variation in speeds was greater than during the baseline period, which is not evident from the standard deviations shown in Figure 10. However, when the posted speed + 5 mph is used for the threshold as in Figure 12, the percentages in the residual period are similar to those of the baseline period.

Figure 11. Percent of vehicles complying with 65 mph posted speed limit.



[4] When a detector was observed in a platoon, it was attributed to the lead vehicle.

Figure 12. Percentage of vehicles traveling 70 mph or less.



Note: Posted Speed Limit was 65 mph.

In the data shown in Figure 10, Figure 11, and Figure 12, the value for August 1, a Thursday, stands out as a possible outlier. Mean, 85th percentile speed, and both compliance measures returned to baseline levels on that day, moving back to the expected trend the following day. The change is pronounced, but no satisfactory explanation could be confirmed. The trailer was deployed that day, and researchers confirmed its proper operation. One possible explanation proposed was that if law enforcement were active upstream of the test site, drivers may have increased their speed once past the threat of being ticketed. Local and state law enforcement agencies were contacted, and no officers were posted near that segment on that day.

Even though no adequate explanation could be identified, the data appears to be an obvious outlier, showing the effect of some unidentified factor. Grubb's test for outlier identification was applied to the value, yielding a very high probability that it was indeed an outlier. Table 8 shows the relevant values. The p-value indicates the likelihood that the disparity between this value and the mean is due only to random variations. The probability is very small, or, in other words, the probability that some unaccounted-for factor is affecting this data point and not the others is very high, suggesting that it does not belong in the same data set (i.e., should be omitted). The values associated with this day were removed from the data set for subsequent analyses.

Table 8. Grubb's Test for outliers applied to August 1 mean speed.

Grubb's Outlier Test	
Z	3.4
Zcrit	2.6
T	8.5
p(z<=zcrit)	7.2E-07

Presence of the Speed Display

Data from the baseline period was compared with the data collected while the display was deployed and the strobe was active. Table 9 shows a summary of the comparisons of several parameters. Data was summarized for each day of data collection, yielding a single value for each of the parameters listed across the top of the table (e.g., the daily mean, standard deviation, etc.). All differences were statistically significant at the 95% confidence level. The mean speed decreased by 3.7 mph. During the first week of deployment, the mean speed was 0.5 mph below the overall mean, raising the possibility that the data in Table 9 depicts a conservative view of the device's effectiveness. There are several measures of speed uniformity, all of which showed changes toward greater uniformity. The compliance measures show the most dramatic difference, with increases of approximately 30%. These statistics confirm other studies, which have found speed displays to reduce mean speeds and increase speed uniformity.

Table 9. Comparison of daily characteristics with and without display.

	Cars-RD	Daily Statistical Measures of Effectiveness							
		Mean	**Standard Deviation**	**Confidence Interval**	**10-mph Pace**	**Pct in Pace**	**85th %ile**	**Compliance**	**Compliance +5**
Baseline	count	6	6	6	6	6	6	6	6
	stdev	0.466	0.324	0.102	0.516	0.030	0.502	0.048	0.042
	mean	**67.9**	**4.2**	**0.6**	**67.3**	**85%**	**71.9**	**23%**	**70%**
Display +strobe	count	15	15	15	15	15	15	15	15
	stdev	0.473	0.368	0.074	0.756	0.031	0.297	0.053	0.015
	mean	**64.2**	**3.4**	**0.4**	**64.0**	**90%**	**67.4**	**55%**	**96%**
	change	**-3.7**	**-0.8**	**-0.2**	**-3.3**	**6%**	**-4.5**	**32%**	**26%**
	p(T<=t)	0.000	0.000	0.006	0.000	0.004	0.000	0.000	0.000

Notes: All units are mph except Pct in Pace and Compliance, which are percentages.
Shaded values are statistically significant changes (t-test, α=.05).

Use of the Strobe Flash

Given that many brands of speed display do not include the strobe light feature, this study was designed to examine the incremental effectiveness that can be attributed to the strobe. Six of the last seven days of deployment, the strobe light was turned off. Table 10 shows comparison statistics of the days when the strobe was active with the days when it was not. The average daily mean speed was 1.1 mph higher when the strobe was not active. The measures of speed uniformity did not all agree. Compliance and 85th percentile speed both changed in the direction indicating greater uniformity when the strobe was on, but standard deviation and percent in pace changed in the direction indicating the opposite. All changes were relatively small and of debatable practical significance, though they were statistically significant.

Table 10. Comparison of daily characteristics with and without strobe light.

	Cars-RD	Daily Statistical Measures of Effectiveness							
		Mean	Standard Deviation	Confidence Interval	10-mph Pace	Pct in Pace	85th %ile	Compliance	Compliance +5
Display -strobe	count	6	6	6	6	6	6	6	6
	stdev	0.824	0.153	0.058	0.816	0.018	0.631	0.100	0.036
	mean	**65.3**	**3.1**	**0.4**	**65.3**	**94%**	**68.2**	**42%**	**94%**
Display +strobe	count	15	15	15	15	15	15	15	15
	stdev	0.473	0.368	0.074	0.756	0.031	0.297	0.053	0.015
	mean	**64.2**	**3.4**	**0.4**	**64.0**	**90%**	**67.4**	**55%**	**96%**
	change	**-1.1**	**0.3**	**0.0**	**-1.3**	**-3%**	**-0.8**	**13%**	**3%**
	p(T<=t)	0.023	0.014	0.396	0.007	0.006	0.023	0.025	0.144

Notes: All units are mph except Pct in Pace and Compliance, which are percentages.
Shaded values are statistically significant changes (t-test, α=.05).

Novelty Effects

The primary impetus for conducting this study was to examine the degree to which the speed reduction effects of speed displays are due to the novelty of the device to drivers in a particular context. In this study, the device was deployed for approximately 5 weeks. During the last week and a half the strobe was turned off, so the first week of deployment was compared with the last week when the strobe was active. The display was deployed on a Wednesday, so the first week comprised 3 days of observation. Similarly, the last week included 4 days of observation (i.e., with the strobe turned on). Table 11 summarizes the results. All parameters showed small changes and none of the changes were statistically significant. The comparison was performed a second time using the first and last 5 days of data. The second set of comparisons yielded similar results. One parameter, 85th percentile speed, did show a change that was statistically significant, but the change was only 0.4 mph. So, if that is an indication of a real novelty effect, its magnitude is so small as to make the change negligible.

Table 11. Comparison of daily characteristics during first and last weeks with display.

	Cars-RD	Daily Statistical Measures of Effectiveness							
		Mean	Standard Deviation	Confidence Interval	10-mph Pace	Pct in Pace	85th %ile	Compliance	Compliance +5
First Week+disp	count	3	3	3	3	3	3	3	3
	stdev	0.435	0.440	0.072	1.000	0.030	0.172	0.028	0.003
	mean	**63.7**	**3.6**	**0.5**	**63.0**	**88%**	**67.1**	**58%**	**96%**
Last Week+disp	count	4	4	4	4	4	4	4	4
	stdev	0.613	0.282	0.033	0.500	0.024	0.169	0.079	0.010
	mean	**64.3**	**3.4**	**0.4**	**64.3**	**91%**	**67.5**	**55%**	**96%**
	change	**0.6**	**-0.3**	**-0.1**	**1.3**	**3%**	**0.4**	**-3%**	**0%**
	p(T<=t)	0.169	0.392	0.097	0.141	0.298	0.052	0.489	0.551

Notes: All units are mph except Pct in Pace and Compliance, which are percentages.
Shaded values are statistically significant changes (t-test, α=.05).

Radar Detectors

It has been postulated that the source of the effectiveness of radar-activated speed displays lies in the activation of radar detectors, causing the operators to slow. This would suggest that a much less expensive and far easier to deploy radar drone could accomplish the same effect on traffic. Previous studies are mixed in their conclusions about the effectiveness of radar drones, while most (though not all) studies of speed displays have found them to effectively reduce speeds. In this study, by using a radar detector detector, vehicles operating radar detectors could be identified in the data log. For both the baseline period and for the period when the display was deployed with the strobe light activated, speeds of vehicles with radar detectors were compared with speeds of vehicles without radar detectors. A paired t-Test was used, pairing the mean speed of passenger cars with detectors and the mean speed of cars without detectors on the same day. The comparison details are shown in Table 12. The use of radar detectors did not have a statistically significant effect on speeds, either before or during the deployment. These results would suggest that the effectiveness of the device is not dependant upon the use of radar detectors among the driving population. It would also support the claim of some research that radar drones are ineffective when used for speed reduction.

Table 12. Effect of radar detector usage in passenger cars.

t-Test: Paired Two Sample for Means				
	Baseline		**With Display**	
	-RD	***+RD***	***-RD***	***+RD***
Mean	67.9	67.8	64.2	64.7
Variance	0.2	2.7	0.2	1.5
Observations	6	6	14	14
Pearson Correlation	0.38		0.01	
Hypothesized Mean Difference	0		0	
df	5		13	
t Stat	0.078		-1.415	
P(T<=t) two-tail	**0.941**		**0.181**	
t Critical two-tail	2.571		2.160	

Residual Effects

Some studies have observed that speeds following the deployment of a speed display were lower than the baseline data collected prior to the deployment. This residual effect was observed by Pesti and McCoy (2001) to be more than half of the 2.2 mph reduction observed when the display was deployed. Following the removal of the trailer in this study, data was collected for an additional 8 workdays. Statistically significant changes were observed, particularly in the uniformity measures, although all changes were small. The comparisons suggest that there may be a residual effect, particularly in the uniformity measures, although this study found it to be too small to be of practical significance. Table 13 shows the comparison details.

Table 13. Comparison of daily characteristics without display after test with before test.

Cars-RD	Daily Statistical Measures of Effectiveness	Mean	Standard Deviation	Confidence Interval	10-mph Pace	Pct in Pace	85th %ile	Compliance	Compliance +5
Baseline	count	6	6	6	6	6	6	6	6
	stdev	0.466	0.324	0.102	0.516	0.030	0.502	0.048	0.042
	mean	**67.9**	**4.2**	**0.6**	**67.3**	**85%**	**71.9**	**23%**	**70%**
Residual	count	8	8	8	8	8	8	8	8
	stdev	0.223	0.384	0.066	0.535	0.036	0.492	0.055	0.015
	mean	**68.0**	**3.4**	**0.4**	**68.0**	**91%**	**71.4**	**14%**	**76%**
	change	**0.1**	**-0.8**	**-0.2**	**0.7**	**6%**	**-0.5**	**-9%**	**6%**
	p(T<=t)	0.723	0.001	0.006	0.038	0.006	0.097	0.008	0.022

Notes: All units are mph except Pct in Pace and Compliance, which are percentages.
Shaded values are statistically significant changes (t-test, α=.05).

Effects on Trucks

For all effects, the differences in mean values observed for trucks were similar to those observed for passenger cars. However, many of the differences that were statistically significant for cars were not so for trucks, probably because of the smaller sample sizes for trucks (about 5% that of cars). Figure 13 shows the daily sample size for trucks with the daily means for both cars and trucks (right axis). It is evident that the means for trucks follow similar patterns to those of cars, although there is more random fluctuation. The sample sizes are all less than or equal to 15 for trucks, while the smallest daily sample for cars was 155. Nonetheless, some of the effects of the display on trucks could be seen in the statistical comparisons. Table 14 shows the comparisons of data from the baseline period with data from the deployment period (with strobe). All statistically significant effects were slightly larger than the analogous values for passenger cars. With respect to the incremental effect of the strobe, only the differences in mean and 85th percentile speeds were statistically significant, but those values were nearly twice their analogous values for passenger cars. The comparison statistics related to use of the strobe are given in Table 15. All differences for residual speed reductions and for novelty effects were not statistically significant for trucks. Only 2 trucks were observed to be operating radar detectors during the entire study, so no statistical analysis of that data would be meaningful.

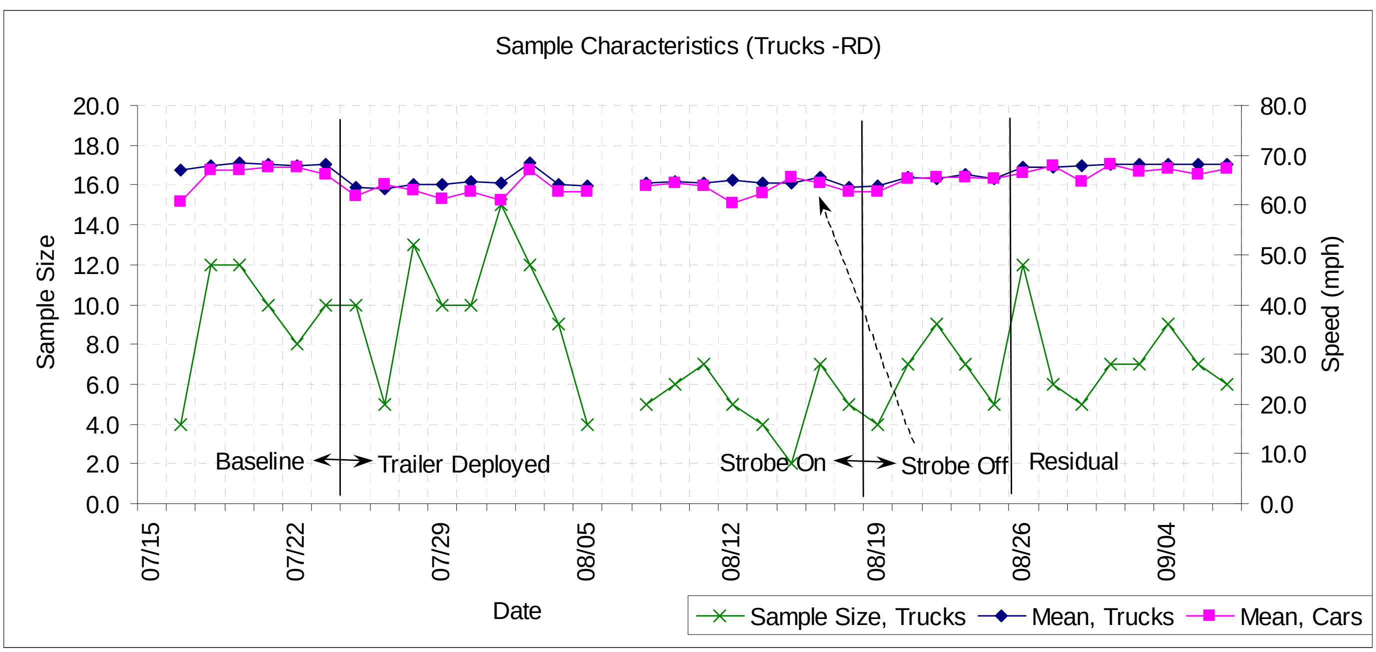


Figure 13. Sample Characteristics for Trucks -RD.

Table 14. Comparison of Baseline with Display +Strobe, Trucks -RD.

HV-RD		Mean	Standard Deviation	Confidence Interval	10-mph Pace	Pct in Pace	85th %ile	Compliance	Compliance +5
Baseline	count	6	6	6	6	6	6	6	6
	stdev	1.177	1.022	3.910	1.329	0.049	1.381	0.084	0.168
	mean	**66.6**	**3.5**	**3.9**	**65.2**	**97%**	**69.5**	**30%**	**86%**
Display +strobe	count	15	15	15	15	15	15	15	15
	stdev	1.399	1.640	1.625	0.799	0.101	0.863	0.214	0.000
	mean	**62.8**	**3.4**	**3.7**	**61.3**	**95%**	**65.7**	**64%**	**100%**
	change	**-3.8**	**-0.1**	**-0.2**	**-3.9**	**-2%**	**-3.8**	**34%**	**14%**
	p(T<=t)	0.000	0.888	0.888	0.000	0.565	0.000	0.000	0.092

Daily Statistical Measures of Effectiveness

Table 15. Comparison of display with and without strobe, Trucks -RD.

HV-RD		Mean	Standard Deviation	Confidence Interval	10-mph Pace	Pct in Pace	85th %ile	Compliance	Compliance +5
Display -strobe	count	6	6	6	6	6	6	6	6
	stdev	1.146	1.048	1.694	1.941	0.074	1.290	0.117	0.097
	mean	**64.8**	**3.2**	**3.4**	**62.8**	**95%**	**67.2**	**51%**	**92%**
Display +strobe	count	15	15	15	15	15	15	15	15
	stdev	1.399	1.640	1.625	0.799	0.101	0.863	0.214	0.000
	mean	**62.8**	**3.4**	**3.7**	**61.3**	**95%**	**65.7**	**64%**	**100%**
	change	**-2.0**	**0.3**	**0.3**	**-1.6**	**0%**	**-1.5**	**13%**	**8%**
	p(T<=t)	0.007	0.662	0.693	0.104	0.931	0.034	0.090	0.086

Daily Statistical Measures of Effectiveness

CONCLUSIONS

The speed display was deployed on a rural two-lane segment with a posted speed of 65 mph. Data was collected during the morning peak period on weekdays only, for 6 days prior to deployment, about 5 weeks with the display in place, and for 8 days after the deployment. The results of the data analysis show that the display caused both a reduction in mean speed and an increase in speed uniformity. The reduction in mean speeds was 3.7 mph, and the percentage of vehicles complying with the posted speed increased by 30%.

A comparison of the data collected while the display was operating with the strobe light turned on and data collected while the strobe was turned off indicated that the strobe was responsible for approximately 30% of the display's effectiveness. A 3.7 mph reduction in mean speeds was observed when the display was deployed (with strobe active), and a 1.1 mph increase in mean speeds was observed when the strobe was turned off.

No statistically significant novelty effect could be identified. The display was deployed for more than three weeks with no significant change in the speed reductions or uniformity increases realized.

It was found that the use of radar detectors was not related to the effectiveness of the display. Similar speed characteristics were observed in vehicles with and without active radar detectors.

Small residual effects were observed in the uniformity parameters, but not in mean speeds. The magnitude of these effects was too small to be of practical significance.

Effects observed among trucks were similar to and in some cases greater than those observed for passenger cars. Many effects were not statistically significant because of the small sample sizes, but the display clearly appears to be effective for trucks as well as cars.

Overall, the display does appear to be effective at reducing speeds and increasing speed uniformity and posted speed compliance, and its effectiveness does not quickly dissipate, as is commonly perceived to be the case. A display with a strobe light is substantially more effective than a display without a strobe light.

RECOMMENDATIONS

Based on the data collected and the analysis conducted during this study, the radar-activated speed display is highly recommended as an effective tool for reducing speeds and increasing both speed uniformity and compliance with posted speed. The use of a unit with a strobe light is recommended. It is further recommended that the use not be limited to short-term deployments. While more study is needed before conclusions can be drawn about long-term installations (e.g., several months), middle-term deployments can be expected to maintain their effectiveness for at least several weeks.

While there may be residual effects, they are likely to be very small, and it is not recommended that they be included in a cost-effectiveness assessment.

It is noted that among the literature, the observed effectiveness of speed displays varies considerably. It is recommended that further research be conducted to identify the contextual factors contributing to the differences between study results. A better understanding of these factors would help to maximize the cost-effectiveness of using displays as a speed management tool by identifying contexts in which their effectiveness is nominal. Potential factors include traffic mix, posted speed, roadway environment (e.g., classification), and strobe activation threshold.

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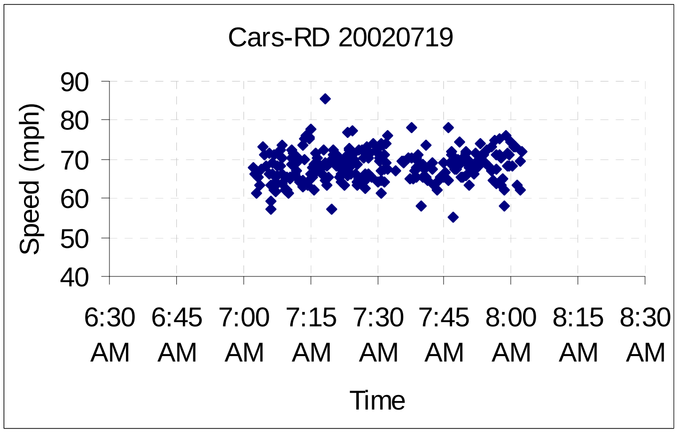
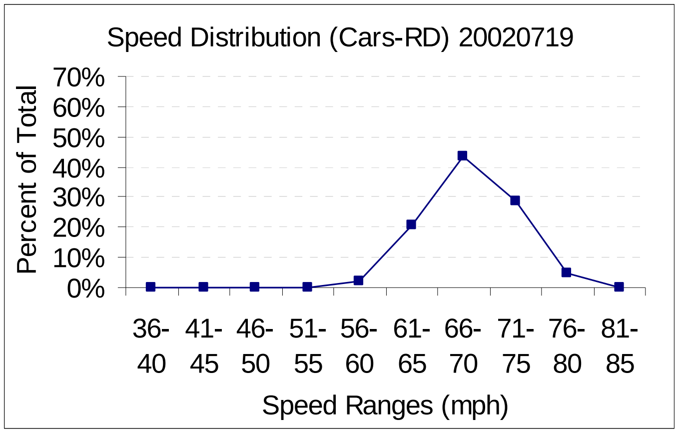
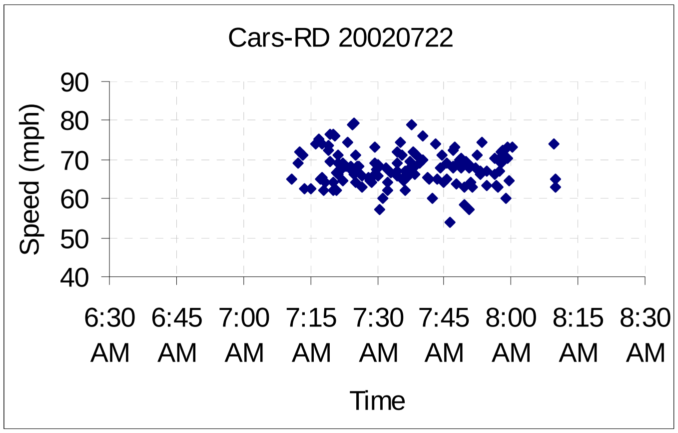
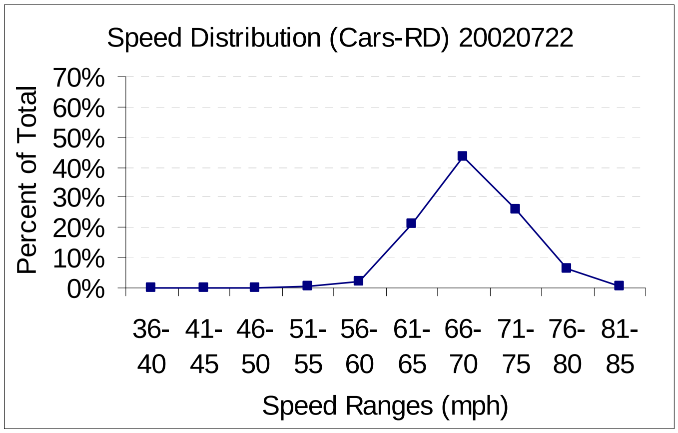
APPENDIX A: SCATTER PLOTS AND SPEED DISTRIBUTIONS

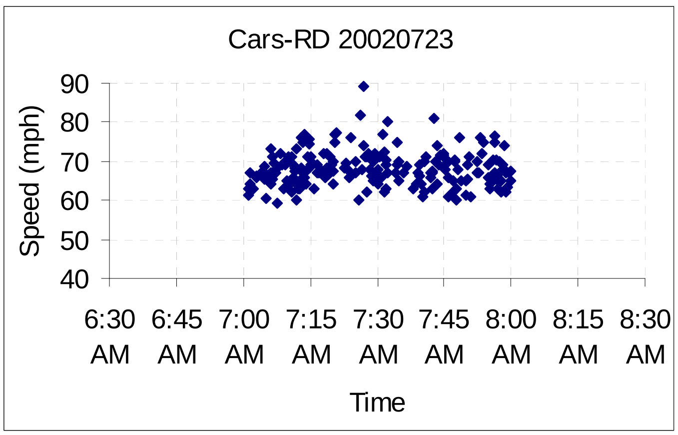
Baseline Data

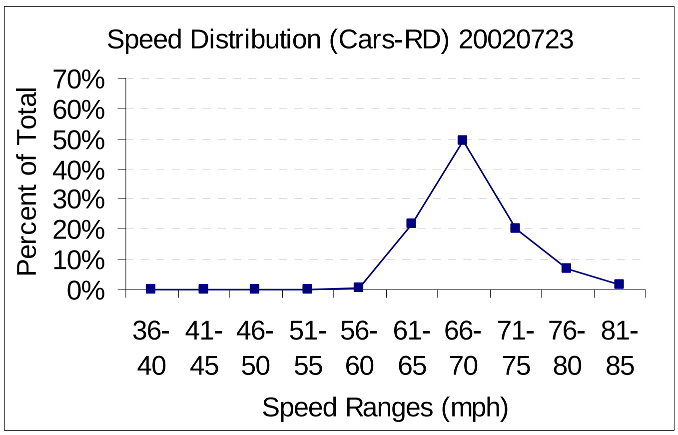




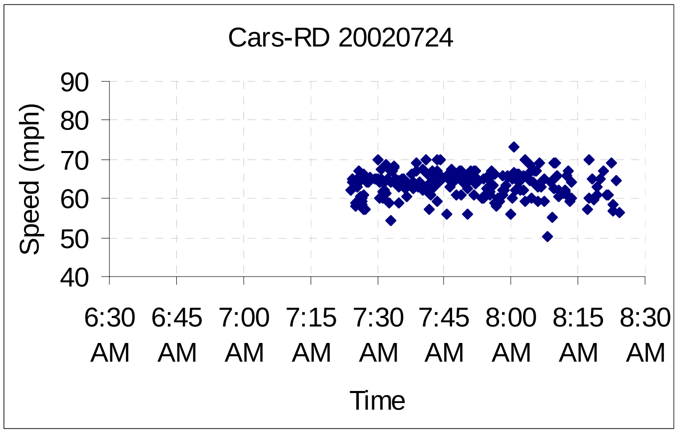


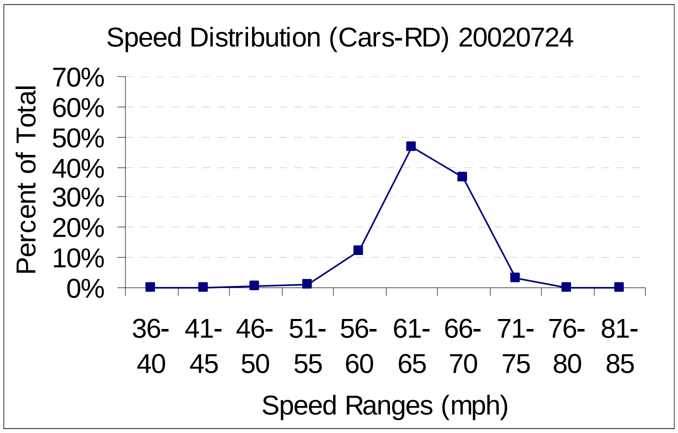


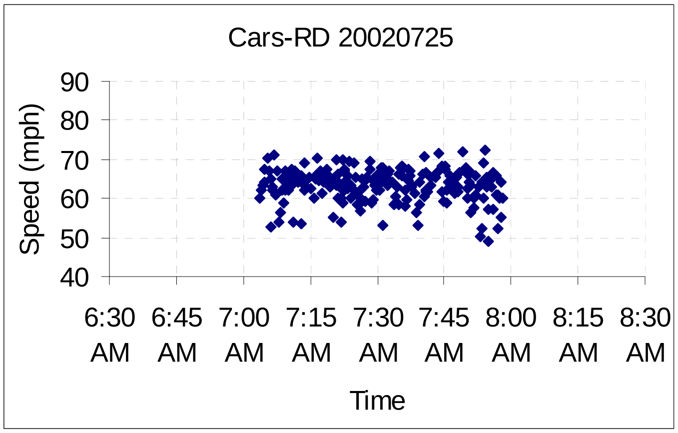


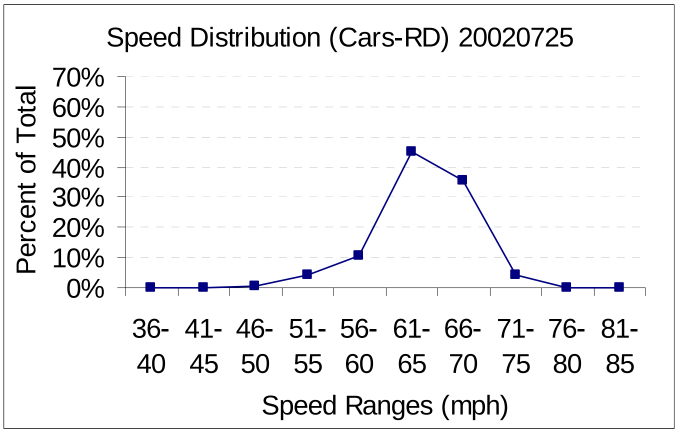


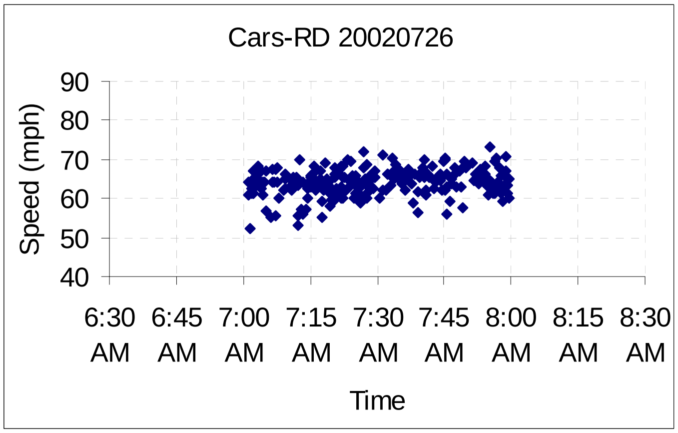
First Week With Display +Strobe

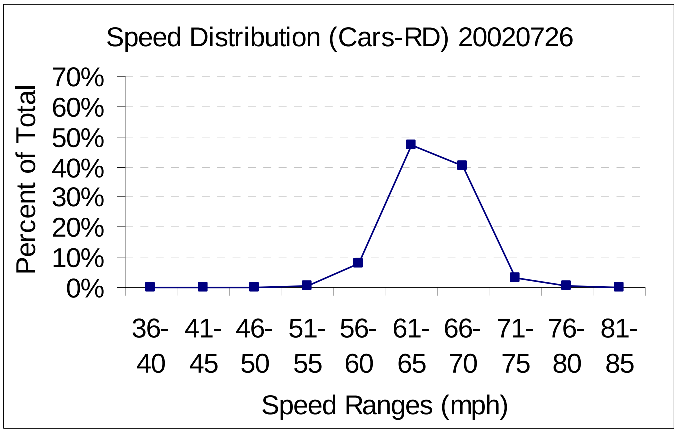




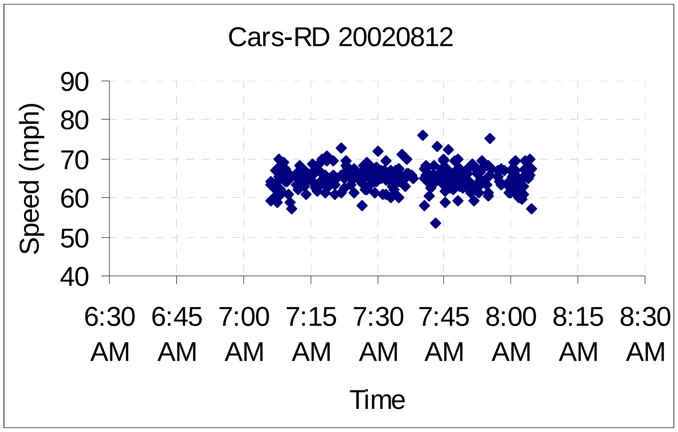


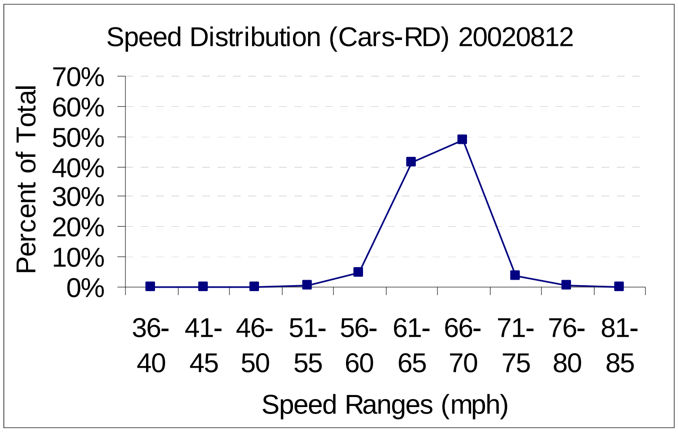


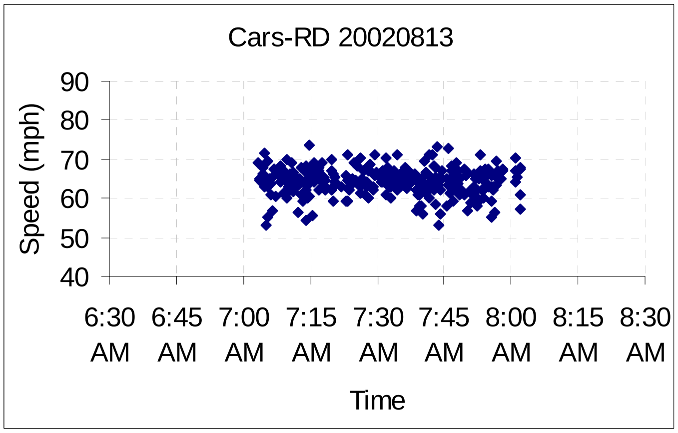


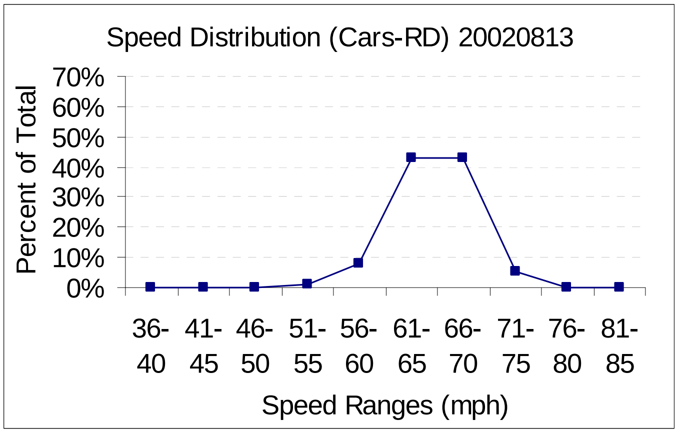


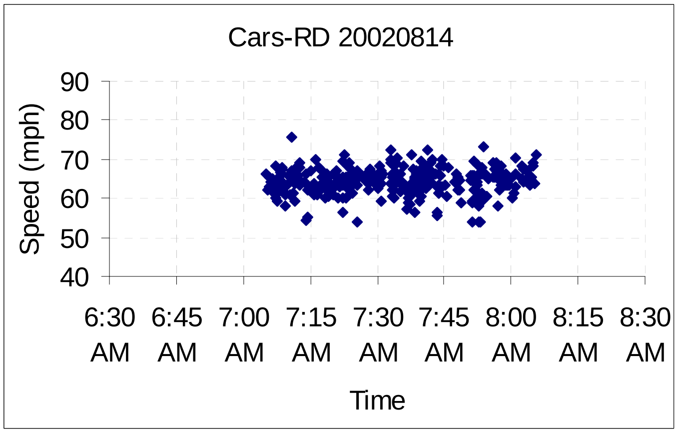
Last Week With Display +Strobe

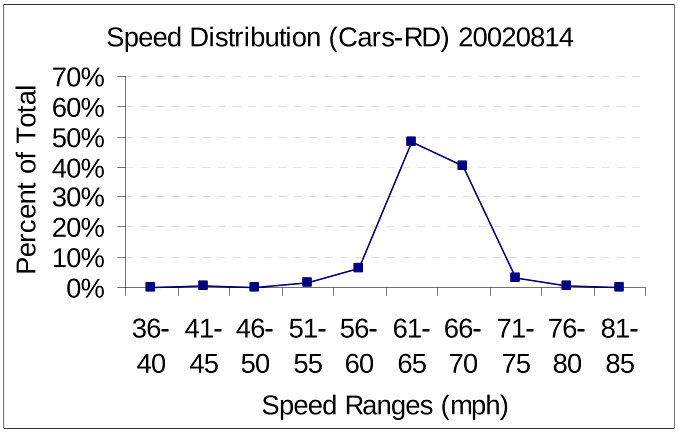




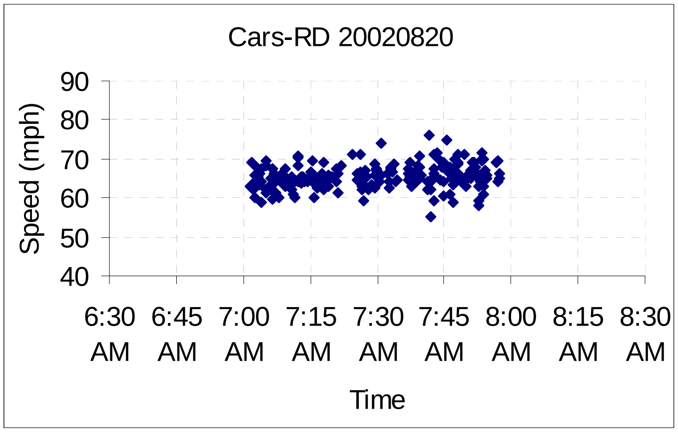


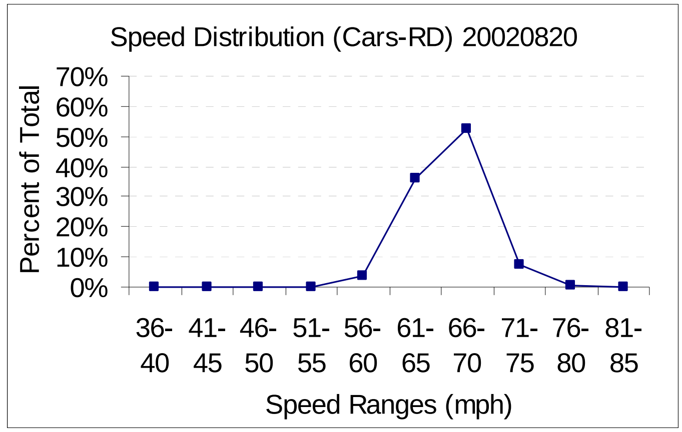


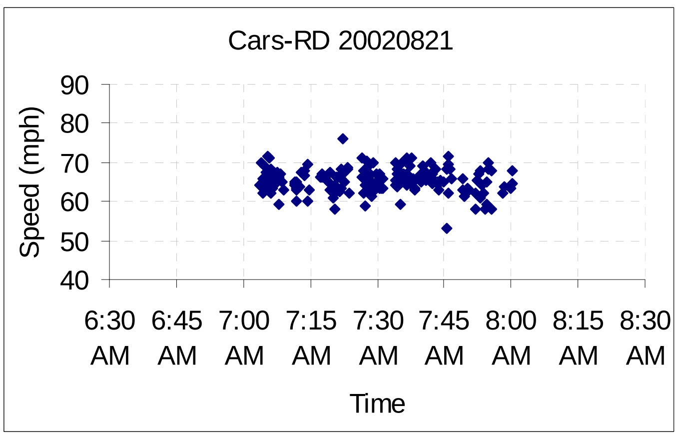


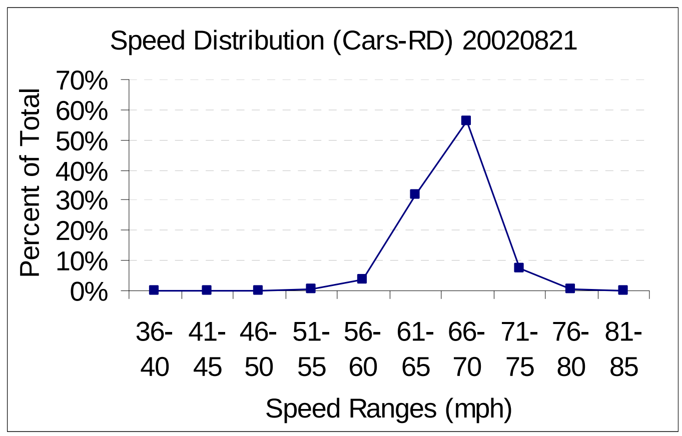


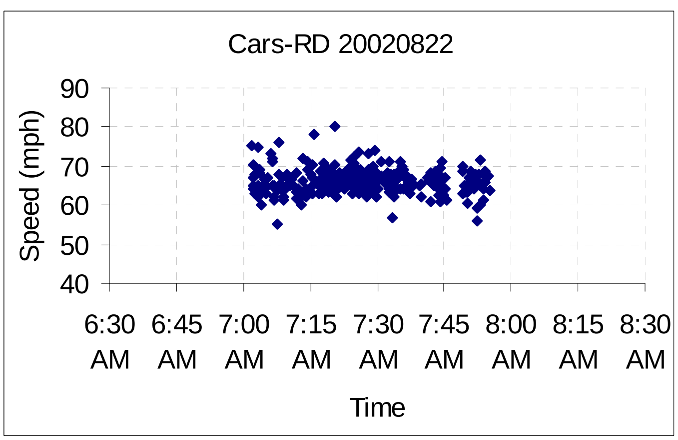
Display –Strobe

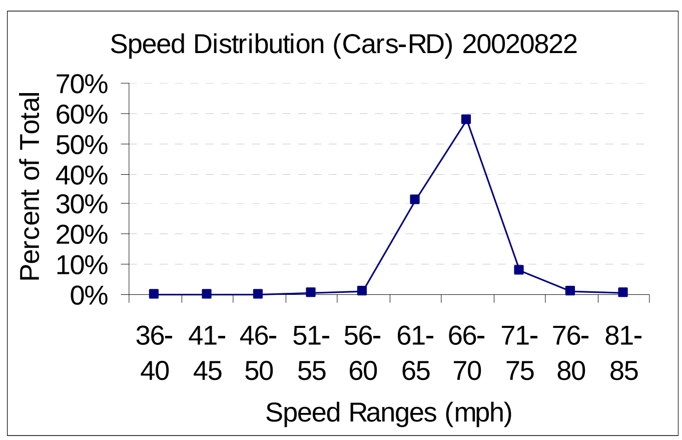












Residual Period