Smart Work Zone Deployment Initiative Wisconsin Evaluations
Summer 2001
Mobile/Stationary Speed Boards (You/Me Boards)

Wisconsin Evaluation

Thomas Notbohm, P.E.
Wisconsin Department of Transportation
Thomas.Notbohm@dot.state.wi.us

Alex Drakopoulos, Associate Professor
Department of Civil & Environmental Engineering
Marquette University, Milwaukee, Wisconsin
Alexander.Drakopoulos@Marquette.Edu
http://www.eng.mu.edu/~drakopoa/

Georgia Vergou, Graduate Student
Department of Civil & Environmental Engineering
Marquette University, Milwaukee, Wisconsin
georgia.vergou@marquette.edu

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ABSTRACT

The present report is an evaluation of the Mobile/Stationary Speed Boards (You/Me Boards), a portable system measuring the speed of the maintenance vehicle on which the device is mounted and the speed of a vehicle approaching the maintenance vehicle. These speeds are displayed in large-format digital displays, visible to approaching drivers from a distance of over 640 feet. Approaching drivers are expected to reduce their speed, once they are informed about the speed differential between the two vehicles.

A maintenance vehicle equipped with the display was parked on the right shoulder of a two-lane highway with a speed limit of 55 mph. Approaching vehicle speeds were monitored at a distance of approximately 330 feet from the display. Average approaching passenger car speed was 53.64 mph, and the 85^{th} percentile speed was 58.00 mph when the display was visible, 3 mph and 4 mph lower than the respective speeds when the display was not visible to approaching drivers.

Displayed speeds were found to be accurate, compared to the speeds measured by laser gun. A special brace was easily constructed to mount the device on a maintenance vehicle. The device performed reliably throughout the evaluation period.

An experienced painting crew member felt that drivers were driving slower, more carefully and that traffic was calmer in the presence of the display during centerline painting operations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX

+

APPENDIX (CONTINUED)

APPENDIX (CONTINUED)

Page

Smart Work Zone Deployment Initiative Wisconsin Evaluations
Summer 2001
Mobile/Stationary Speed Boards (You/Me Boards)

TECHNOLOGY

The evaluated technology consists of two, two-digit digital displays, mounted side by side on the back of a maintenance vehicle. The left display (see Figure 1) indicates the speed of oncoming vehicles, and the right display indicates the speed of the vehicle on which the display is mounted. The words "ME" (in white letters) and "YOU" (in yellow letters) identify which speed is measured by each display.

The system uses a link to the gearbox odometer connection to record the maintenance vehicle's speed, and a radar mounted on the display face[1] to record the speeds of approaching traffic. Special software/hardware eliminates displaying the speeds of traffic moving away from the maintenance vehicle. A white strobe light, mounted on the display face[2] can be set to flash at a predetermined speed (the speed limit, for example).

Figure 1. Approaching Traffic ("YOU") Speed Display

[1] The radar is placed behind the round white element at the lower left corner in Figure 1.

[2] The strobe light is the oval white element on the left side of Figure 1.

The objective of the technology is to inform oncoming drivers about their own speed and the speed of the maintenance vehicle and thus provide them the opportunity to adjust their speed to a safe level, by the time they are abreast with the maintenance vehicle. Improved safety in the vicinity of the maintenance vehicle is anticipated, if the display is effective.

The objectives of the present evaluation were to assess the ease of installation and removal, device reliability, device accuracy and visibility, and a measurement of display speed impacts within the work zone. A safety assessment was not included within the scope of the evaluation.

The technology vendor is Carl Fors, President, Speed Measurement Laboratories Inc., 2300 Harvest Glen, Fort Worth, Texas 76108. Mobile phone 817 291 2396, 817 560 9318, FAX 817 244 7630. Web site www.speedlabs.com, E-mail speedy3@speedlabs.com.

STUDY SITES

For the purposes of the present evaluation, it was desired to identify a work zone(s) involving maintenance vehicles moving at low speeds (or stopped), adjacent to traffic moving at high speeds. Centerline marking painting operations provided a good candidate work zone, fitting the desired criteria.

The Wisconsin DOT coordinator, the system vendor, the system evaluators and Wisconsin DOT District 1 maintenance and sign shop personnel worked over three days to address the needs of this evaluation. On the first day the team discussed data collection details and decided how the display would be supported on a WisDOT vehicle. A preliminary data collection effort was performed, in order to address potential problems. On the second day the display was mounted on a WisDOT vehicle and the formal data collection effort began. During the third day, additional data was collected before the data collection effort was concluded.

Data collection took place between June 4 and June 6, 2001, as the maintenance vehicle convoy painted centerline markings on rural two-lane highways.

On June 4, the preliminary data collection effort took place on US Route 151 between Mineral Point, and Platteville, ending at the intersection with State Trunk Highway 80/81 (see Appendix, Maps 1, 2 and 3). The data collection starting point was approximately 45 miles from the WisDOT District 1 sign shop in Madison. The traveled route was approximately 20 miles long. Data collection started at approximately 10:10 am and ended at 3:33 pm. Figure 2 displays a typical view of the part of Route 151 traveled on that day.

On June 5, data was collected on State Trunk Highway 19, approximately 1.8 miles west of Interstate 90/94, and 7.5 miles from the WisDOT District 1 sign shop (see Appendix, Map 4). Data collection started at 10:07 am and concluded at 12:10 pm.

On June 6 data collection took place over 17 miles of roadway, starting from a location approximately 65 miles from the WisDOT District 1 sign shop (see Appendix, Map 2). The effort was divided into three parts:

1. US Route 151, from the intersection with State Trunk Highway 80/81 in Platteville, to Church Road, south of Platteville. Data was collected between 11:06 am and 12:02 pm.
2. US Route 151 approximately 2,000 feet North of Church Road, recording traffic speeds in the direction toward Platteville (north/east-bound) between 12:15 pm and 12:51 pm.
3. US Route 151 between Church Road and Dickeyville, and US Route 61/ State Trunk Highway 35 from Dickeyville, to Tennyson between 1:00 pm and 3:29 pm.

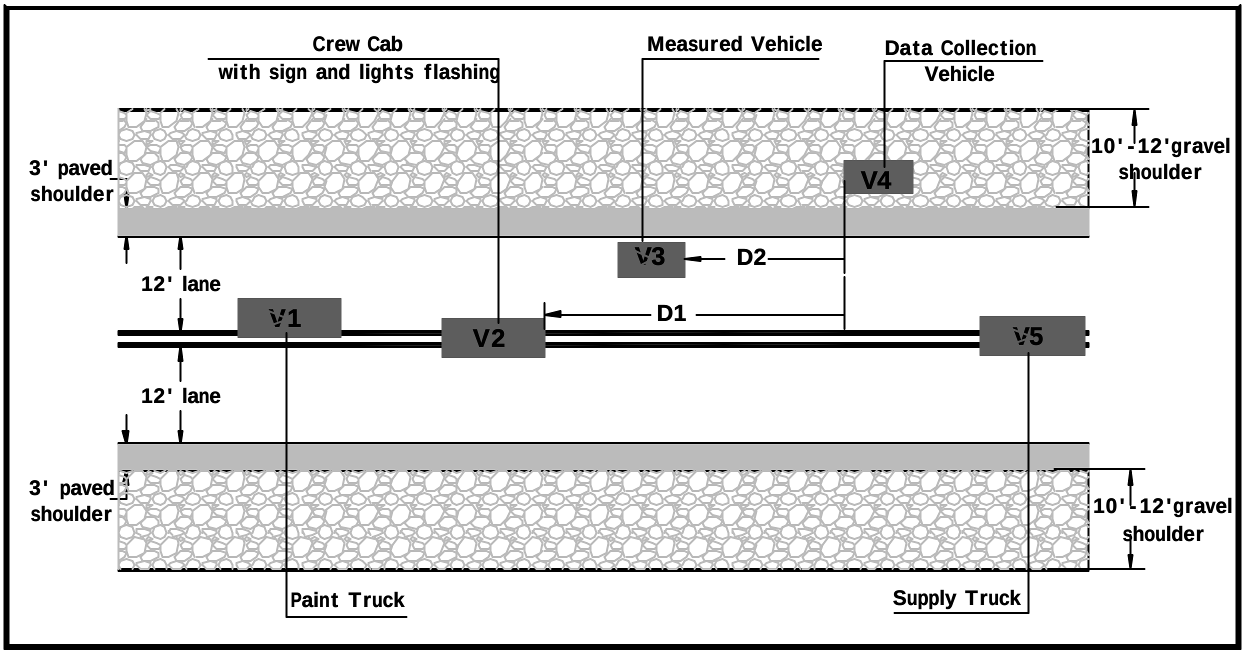
More details about the data collection efforts on each of the above-listed locations are presented later in the report.

Figure 2. Typical Data Collection Site

DATA COLLECTION

The evaluated display was mounted on a crew cab truck that was part of a three-maintenance vehicle pavement marking convoy. The data collection effort concentrated on measuring the speeds of vehicles approaching the evaluated display, and the distances of these vehicles from the display at the instant each speed measurement was recorded. Two typical vehicle arrangements were used during data collection. A mobile arrangement is shown in Figure 3. This arrangement was used for data collected as the maintenance vehicle convoy painted centerline markings on rural two-lane highways.

Figure 3. Mobile Vehicle Arrangement



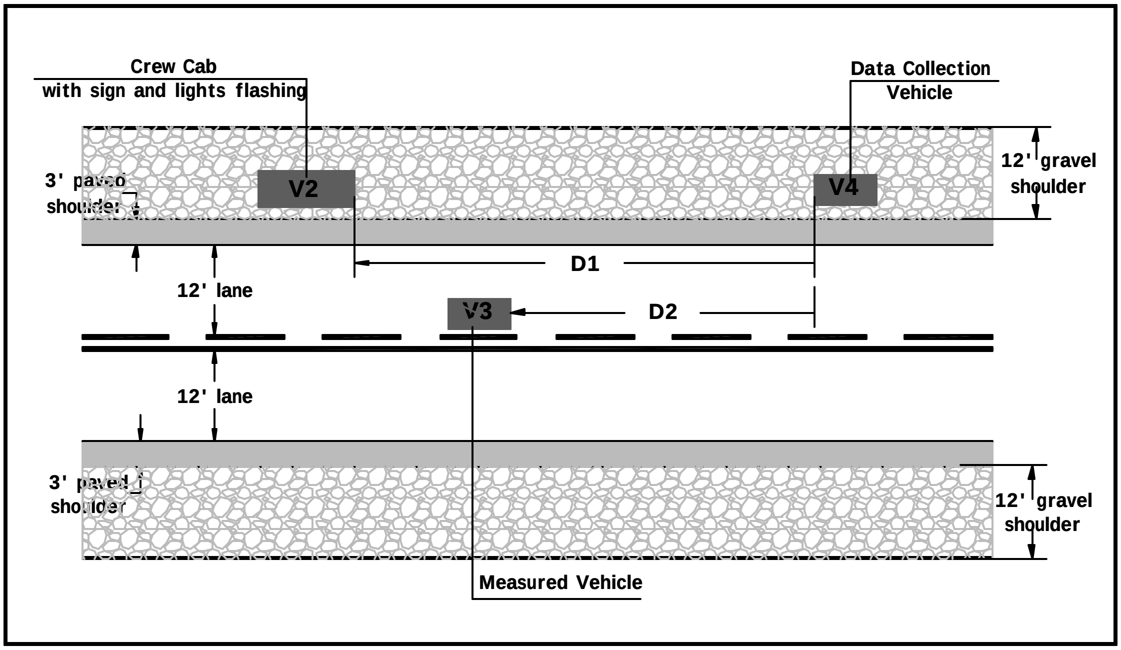
The maintenance vehicle convoy moved from right-to-left in Figure 3. Vehicle V1 (see Figure 4) was painting centerline markings, positioned to the right of, and adjacent to the roadway centerline, vehicle V2 followed, straddling the centerline. Vehicle 4 carried the data recorders, driving on the right shoulder, and V5 followed, straddling the centerline.

Figure 4. Clockwise From Top Left: V1 & V2; V4 for June 4 and 5; V4 for June 6; V

Vehicles V1, V2 and V5 carried arrow boards, flashing an arrow pointing to the right. Displays mounted on the vehicles are visible in Figure 4. A sign with the word “Pass” and an arrow pointing to the right is partially visible on the back of V1. V5 carried a sign identical to the one mounted on the back of V2; the crash cushion was in the horizontal position during painting operations.

An alternate vehicle arrangement was used to collect data with V2 and V4 parked on the right shoulder. This stationary vehicle arrangement is illustrated in Figure 5.

Figure 5. Stationary Vehicle Arrangement



Data Collection Method.
The front seat passenger of V4 aimed a laser gun toward V2 to get a reading for distance D1 (the distance between V4 and V2), and the distance was recorded in a field data collection sheet. When the mobile vehicle arrangement was used, the driver of V4 attempted to maintain a constant D1, for as long as possible. Because the line of sight between V4 and V2 changed as the convoy moved during the painting operation, depending on roadway geometry, a new D1 measurement was taken when necessary. After a D1 measurement was recorded, the speeds of free-flowing vehicles V3 approaching V2 in the direction the convoy was moving were measured through the laser gun, and recorded on the field data collection sheet, together with distance D2 (the distance between V3 and V4). (Distances D1 and D2 were later used to calculate the distance between V3 and V2, the distance that an approaching vehicle was from the evaluated display when its speed was recorded).

The data collection method was the same, regardless of which vehicle arrangement was used. When vehicles V2 and V4 were stationary (see Figure 5), only one D1 measurement was necessary.

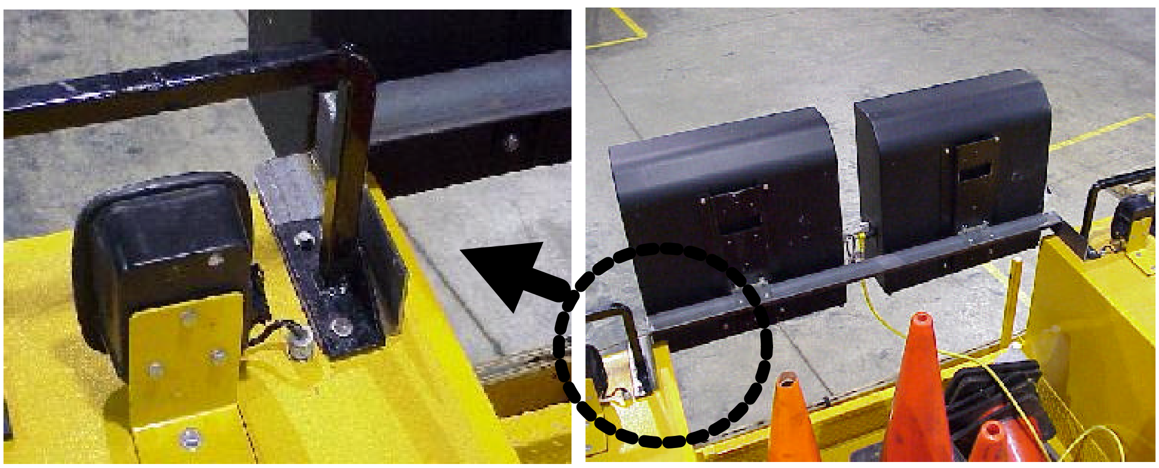
Only passenger car speeds were recorded, because trucks drove at very low speeds when they were between V5 and V1, had significant difficulty passing the convoy vehicles, and had to use the gravel shoulders during the passing maneuver. An effort was made to avoid recording in segments with a significant grade (the terrain was gentle-rolling, overall).

The front seat V4 passenger would read the laser gun speed and distance indications aloud and the passenger behind him would record this information on data collection sheets. Another recorder in the back seat collected directional traffic volume information and summarized it in 15-minute intervals. Separate counts were kept for passenger cars and trucks. Volume counts were collected as evidence that the two-lane segments on which data was collected remained uncongested (that is, that speeds were not affected by congested traffic conditions) during data recording periods.

Data was collected in a similar manner when the display was visible and when the display was not visible to approaching drivers. The effect of the evaluated display on vehicular speeds would be measured by comparing speeds collected under these two conditions.

The evaluated display was mounted on V2 with a custom-made simple support on June 5. Support details are shown in Figure 6.

Figure 6. Custom-made Display Support Details



June 4 Data Collection .

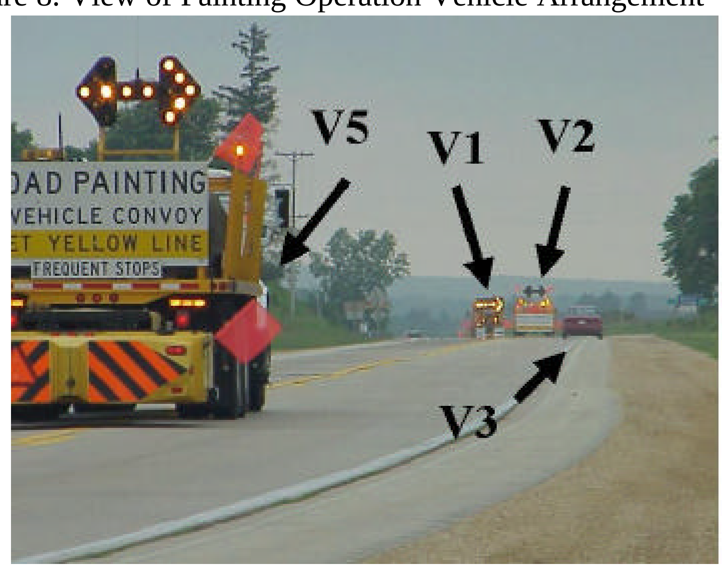
On June 4 the vendor, the evaluation team, the WisDOT coordinator and the WisDOT District 1 maintenance shop and painting crews met at 6:45 am to discuss details about vehicle convoy arrangement, and field-test the proposed data collection method. One important issue was also how the evaluated display would be mounted on V2. The maintenance shop crew took measurements and started working on the display mounting supports. The vehicle convoy drove to the painting operation starting point, once it was clear that the light rain that was falling that morning would dissipate and pavement conditions would be appropriate for painting operations. The evaluated display was not mounted on V2 during this day (see Figure 7).

Figure 7. Vehicle V2 Without Evaluated Display-June 4, 2001.

Data collection started on Route 151 at Mineral Point, at 10:10 am. The mobile vehicle arrangement (shown in Figure 3) was used, after briefly experimenting with an arrangement in which V4 trailed V5. That arrangement was abandoned, because the line of sight between V4 and V2 was often obstructed by roadway geometry or traffic located between V5 and V2. The painting operation moved at approximately 8-10 mph and stopped when it was necessary to replenish painting supplies.

The mobile operation stopped at 12:35 pm for lunch break, during which the stationary vehicle arrangement was used to collect data. The mobile vehicle arrangement was resumed at 1:43 pm and data collection ended for the day at 3:33 pm. A typical view of the painting operation vehicle arrangement is shown in Figure 8.

Figure 8. View of Painting Operation Vehicle Arrangement



Laser gun information was automatically stored in an electronic file during the entire data collection effort. Speed and distance information was not recorded manually that day. Directional passenger car and traffic volume counts were collected manually and summarized in quarter-hour intervals. It was originally anticipated that the electronic file collecting laser gun measurements would provide speed and distance measurements for each vehicle for which data was collected. It was later realized that only speed summary statistics were available through the software. Thus, the decision was made to record individual speed and distance measurements manually during the formal data collection effort. It was also decided not to collect truck speeds, because trucks were moving at very low speeds due to the difficulty in passing the maintenance vehicle convoy.

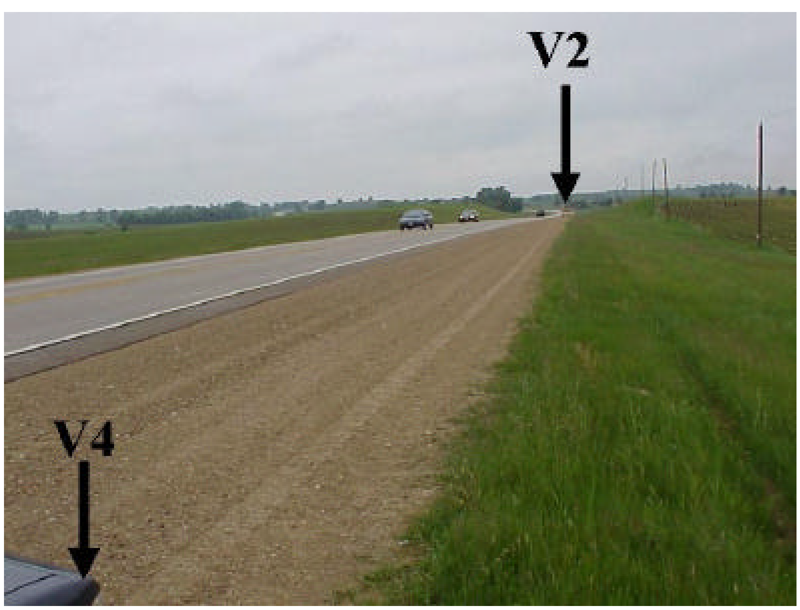
Conclusions at the end of the day were that the chosen evaluation conditions were appropriate:

- Maintenance vehicle speeds were substantially lower than average traffic speeds (thus a device that had the potential to induce drivers to lower their speeds would be beneficial).
- Evaluation sites were appropriate, because traffic volumes were light- no congestion was present that would reduce vehicular speeds.
- Despite the low traffic volumes, it was possible to collect a large enough sample of vehicular speeds from free-flowing passenger cars during a work day.
- Mobile and stationary vehicle arrangements had been tested and found to be workable.

June 5 Data Collection.

The stationary vehicle arrangement was used for data collection on that date. Data recording took place on a tangent, level section of State Trunk Highway 19, west of the I-90/94 freeway. Figure 9 presents the recording location. The distance D1 between V4 and V2 (identified by arrows in Figure 9) was 865 feet. The two-lane study segment had twelve-foot travel lanes, three-foot paved shoulders, and 12-foot gravel shoulders.

Figure 9. Data Recording on State Trunk Highway 19, June 5, 2001



The display was covered with a tarp. The arrow board flashed a straight line ("shoulder closed" indication), and the yellow strobe lights were operational.   Speed and distance measurements were collected between 10:07 am, and 10:57 am. Subsequently, the display was uncovered, and the strobe light mounted on the surface of the "YOU" display was set to flash when approaching traffic exceeded the speed limit of 55 mph. The collection effort resumed at 11:18 am and continued until 12:10 pm. A total of 150 observations were collected when the display was covered, and 149 observations were collected when the display was visible.

June 6 Data Collection.

Three separate data collection efforts took place that day. The mobile vehicle arrangement was used for data collection between 11:06 am and 12:02 pm. The stationary vehicle arrangement was used between 12:15 pm and 12:51 pm. The distance between the data collection vehicle (V4) and the crew cab (V2) was 1250 feet. Ten-foot shoulders were present at the data collection site. The mobile vehicle arrangement was used once again between 1:00 pm and 3:29 pm. A variety of adverse conditions resulted in collecting very few observations during that day: the terrain had steeper grades and fewer tangents, thus no data was collected for many segments; traffic volumes were lighter on the traveled sections; because of the terrain, and generally narrower soft shoulders trucks had particular difficulty passing the maintenance vehicles, thus long queues were present behind the crew cab most of the time, and very few free-flow vehicles were present; extra delays were caused by unusual technical problems (a sticking paint gun and a flat tire). Pictures of typical traffic problems during that day can be seen in Figure 10.

In addition, data collection took place further from the maintenance shop, thus the part of the day that could be used for data collection was shorter. The most productive part of the survey was the one using the stationary vehicle arrangement, because vehicle V2 was parked on the shoulder, not obstructing traffic in the moving lane, allowing for many free-flow vehicle observations within a relatively short period of time. The evaluated display was visible throughout the day.

The sample sizes of useable observations collected during the periods starting at 11:06 am, 12:15 pm and 12:57 pm were 6, 38 and 20, respectively.

Figure 10. Typical Problems Encountered During Data Collection, June 6, 2001

DATA ANALYSIS

General Observations About the Display.

During the course of data collection, the "YOU" board displayed identical speeds to those acquired through the laser gun; speeds were +/-1 mph on rare occasions. Two evaluators assessed the display readability distance at 640 and 770 feet, respectively. (Displayed indications were read through binoculars when distance between the data collection vehicle and the crew cab [D1 in Figures 3 and 5] was longer than the display readability distance.)

Mounting the display on the back of the crew cab was done with relative ease. The mounting bracket was manufactured in-house with minimal labor and materials, and was affixed to the crew cab using already existing accessory mounts.

It was noted that the "ME" display was dark when the maintenance vehicle was stationary (see Figure 11, right side).

An experienced painting crew member commented that he felt that drivers were driving slower, more carefully and that traffic was calmer when the display was visible during mobile data collection efforts.

Data Set Description.

Data collected in the field were coded into Excel spreadsheets and analyzed using the SPSS statistical package. The stationary vehicle arrangement was used on June 5, 2001, when two data sets were collected: **data set A** represented conditions when the display was not visible by drivers (Figure 11, left side), and **data set B** represented conditions when the display was visible to the drivers(Figure 11, right side).

Figure 11. June 5, 2001 Data Collection: Left-Display Covered With Yellow Tarp; Right-Display Visible

Three data sets were collected on June, 2001; the display was visible for the entire data collection effort on that day: **data set C** represented conditions under the mobile vehicle arrangement, **data set D** was collected using the stationary vehicle arrangement, and the mobile vehicle arrangement was used again for **data set E**. Table 1 is a summary of data set attributes.

Table 1. Data Set Attribute Summary

Data Set	Vehicle Arrangement	Display	Date	Time	N of Data Points
A	Stationary	Not Visible	6/5/2001	10:07am-10:57am	150
B	Stationary	Visible	6/5/2001	11:18am-12:09pm	149
C	Mobile	Visible	6/6/2001	11:06am-1:58am	6
D	Stationary	Visible	6/6/2001	12:15pm–12:51pm	38
E	Mobile	Visible	6/6/2001	12:57pm–3:29pm	20

Note: Data sets are listed in the order in which data was collected in the field.

Analysis Objective.

The thrust of the analysis is a comparison between approaching vehicle speeds when the display was visible and when the display was not visible to approaching drivers. The display was visible during both time periods for which the mobile vehicle arrangement was used, thus no comparison can be performed for this vehicle arrangement with a condition when the display was not visible. Statistics for data collected with the mobile vehicle arrangement are presented as information of general interest, however this data could not be used in assessing the effect of the evaluated display on approaching vehicle speeds.

Analysis Organization.

General statistics are presented in the Appendix for each data set identified in Table 1, for vehicle V3 speed and distance from the display (this distance was calculated by subtracting D2 from D1—see definitions in Figures 3 and 5 A description of information presented for data set A is provided here in order to familiarize the reader with the contents of the Appendix. Identical information is provided in the Appendix for the other four data sets listed in Table 1. Identical ranges have been used for the horizontal and vertical axes of Appendix figures, so comparisons between data sets can be made with ease.

Typical statistics (e.g., mean, median, minimum, maximum, percentiles) are provided for vehicle V3 speed in Table A1. The same information is provided in the form of a histogram in Figure A1. The speed limit for each location is shown on the histogram with a dotted vertical line, and also indicated in bold type numbers. The outline of a normal distribution has been fitted over the actual speed distribution. A scattergram of speed versus distance is presented in Figure A2, with a linear regression line fitted to the data; linear regression model details are provided, following the figure.

Pages A25 and A26 summarize speed and distance statistics, respectively, about all five sets examined together.

RESULTS

Speed-Distance Relationship-Data Set A.

One important issue that needs to be addressed before investigating the speed effects of the evaluated display, is whether the distance from the display at which speed measurements were taken was correlated with speeds: if, for example, speeds measured closer to the display were lower, a speed analysis would have to account for the distance at which speed measurements were taken. The following paragraphs address the relationship between observed speeds and the distances at which these speeds were recorded.

The average distance between the observed vehicle (V3) and the evaluated display (mounted on the crew cab, V2) was 332 feet-see Table A2 p. A6. Approximately 50% of the observations were between 294 and 372 feet (based on the percentile information presented on the table). The relationship between distance from the display and approaching vehicle (V3) speed is presented in graphical form in Figure A2, p. A8, where a linear regression equation was fitted to the data.

The regression line has a negative slope, which is counter-intuitive, since speed would normally be expected to decrease as vehicle V3 approaches the stationary vehicle V2. However, the relationship between speed and distance is very weak, with an $R^2 = 0.01512$, thus the data cannot be interpreted to suggest a linear relationship between distance and speed (a linear equation using distance to estimate vehicular speed would explain 1.5% of the variation in measured speeds. In addition to the linear form, quadratic, cubic, compound, inverse logarithmic, inverse, power, logistic and exponential forms were investigated, but are not presented here. None produced a model with a good fit to the data).

Thus, the distance at which measurements were taken did not have a noticeable effect on vehicular speeds for this data set (any speed changes must have occurred further from the evaluated display than the distance at which speed information was captured). This conclusion was based on a large number of observations (n = 150) and thus can be trusted to be valid.

The particular linear regression model presented here was shown (based on the R^2 value), not to provide a useable relationship between speed and distance, however, a brief model presentation is provided here to inform the reader about the use of regression information available in the Appendix. Based on information on p. A8, the calibrated form of a regression model for data set A, using distance from the display (independent variable) to estimate approaching vehicle (V3) speed (dependent variable), is given in Equation (1):

Speed = 60.43 – 0.0115 (*Distance from Sign*)   Equation (1)

It should be kept in mind that this model was calibrated for distances ranging between 115 and 458 feet from the display. The model should not be considered to be valid outside these limits.

Speed-Distance Relationship Data Sets B, C, D and E.
The best-fitting regression model among the ones fitted to data sets B, C, D and E, is the one for model C, with an $R^2 = 0.571$. This R-square value is still quite low (the model explains 57.1 % of the variation in the speed data), but what is most important about that model, is that it is based on very few observations (n = 6) and cannot be relied upon to provide a valid relationship between speed and distance.

None of the regression models fitted to the analyzed data sets provided evidence of a linear relationship between speeds and the distances at which these speeds were measured during field data collection. Thus, inclusion of distance information in the analysis of speed data is not necessary. It appears that any speed changes must have occurred at longer distances from the display than the distances at which speeds were recorded.

Speed Statistics.

A summary of speed statistics for all data sets is presented in Figure A11, p. A25. Speeds for data sets A, B, and D, taken when maintenance vehicles were stationary, were within similar ranges (averages between 51 and 57 mph). Speeds for data sets C and E, taken when maintenance vehicles were moving near the roadway centerline, were much lower (averages 38 and 40 mph, respectively). This was expected, because a substantial part of the available travel lane was blocked under the mobile vehicle arrangement, a situation that required drivers to slow down considerably more as they approached the display, than when they encountered a stationary maintenance vehicle on the right shoulder.

Table A1 (p. A5) in the Appendix indicates that the mean speed for data set A was 56.63 mph and the 85th percentile was 62 mph. Speed distribution generally followed a normal curve distribution (Figure A1 p.A7), with higher than expected (for a normal distribution) concentration of values around the mean (see bars protruding above the normal curve outline). The mean speed exceeded the speed limit of 55 mph by 1.63 mph.

Statistics for data set B (Table A3 and Figure A3) show a similarly-shaped distribution, translated horizontally 2.99 mph to the left (the mean was 53.64 mph, 1.36 mph below the speed limit). The 85th percentile speed was 58 mph, four miles per hour lower than when the display was not visible to drivers.

Data set D was collected under similar conditions as dataset B (stationary maintenance vehicle, visible display). The mean speed for this data set was 51.47 mph (2.17 mph lower than that for data set B). The 85th percentile speed was 0.85 mph lower than that for data set B. The 95% confidence intervals for the means of data sets B and D overlap (see Figure A11 and Table A11 p. A25). The difference in average speeds could be partially due to narrower shoulders present when data set D was collected. Because of the difference in average speeds between data sets B and D, it was decided not to merge information for the two sets.

Data sets A and B provided the most valuable information for analysis because: i) both data sets had large numbers of observations (n = 150 and n = 149, respectively); ii) speed data was collected under identical conditions: the same location, at nearly identical distances (332 feet for data set A and 326 feet for data set B, with nearly identical standard deviations—see Figure A12 and Table A12, p.A26). Thus conditions were identical, for all practical purposes, except for the effect of the measured variable, the presence or absence of the evaluated display. An independent samples T-test for equality of means was performed for data sets A and B. Average speeds were found to be 2.99 mph lower when the display was visible to drivers. The 95% confidence interval for this value was between 1.8 and 4.2 mph. Details about the t-test can be found in Table 2 below.

Table 2. Independent Samples T-test Comparison of Means Between Data Sets A and B.

			Measured Speed (mph)
Levene's Test for Equality of Variances	F		.172
	Sig.		.678
t-test for Equality of Means	t		5.025
	df		297
	Sig. (2-tailed)		.000
	Mean Difference		2.99
	Std. Error Difference		.595
	95% Confidence Interval of the Difference	Lower	1.818
		Upper	4.160

Data sets C and E will not be addressed any further, given: i) their small sample sizes; ii) the large V3 speed differences between the stationary and mobile maintenance vehicle arrangements (data cannot be merged with sets B and D, assuming they are indistinguishable); and, iii) the lack of similar data collected when the display was not visible to motorists. Information about data sets C and E in the Appendix is provided for the benefit of future research efforts.

Traffic Volumes.

Directional passenger car and truck traffic volumes, total bi-directional counts, and equivalent hourly flows during data collection hours are provided in the Appendix, summarized in quarter-hour intervals. Table A13 on page A27 presents data for June 5, and Tables A14 and A15 on p. A28 present data for June 6, 2001. The maximum counts were observed on June 5, between 10:30 and 10:45 am, when equivalent hourly flows of 592 passenger cars and 104 trucks were counted. If a passenger car equivalent of two cars for each truck is assumed (given the gentle terrain), the total bi-directional count of 696 vph would be equivalent to 800 pcph, which is substantially lower than the theoretical capacity of 2800 pcph (under ideal conditions) for a two-lane rural highway. Thus traffic on the roadway segments on which data collection took place was light during data collection hours.

DISCUSSION

Effects of the evaluated display on approaching vehicle speeds were found to be related to maintenance vehicle arrangement (mobile or stationary). The lower speeds present in data sets C and E were, in all likelihood, related to the fact that part of the traveled lane was blocked by maintenance vehicles under the mobile vehicle arrangement. If a passing lane was available for vehicles approaching a mobile maintenance vehicle arrangement, average speeds could have ranged somewhere between the higher speeds observed in data sets A, B and D (when approaching drivers had the entire width of their lane available), and the lower speeds observed in data sets C and E (when maintenance vehicles partially blocked the only available travel lane).

The evaluated display could have different speed effects, depending on maintenance vehicle arrangement and the availability or not of a completely unobstructed passing lane. Thus, it is important to mention the conditions under which speed effects were measured when these effects are reported.

CONCLUSIONS

The evaluated display was found to reduce average approaching vehicle speeds by 3 mph, and 85th percentile speeds by 4 mph, when the display was visible to drivers approaching a stationary display-bearing maintenance vehicle parked on the shoulder of a two-lane rural highway, compared to when the display was not visible to drivers approaching the same vehicle at the same location. The speed limit was 55 mph; average speed when the display was visible was 53.64 mph, and the 85th percentile speed was 58.00 mph. Only speeds of free-flow passenger cars were included in the analysis.

No relationship was identified between the speed of an approaching vehicle and the distance at which this speed was recorded--average distance at which speeds were recorded was 329 feet from the display. Given that display readability was conservatively assessed at 640 feet, drivers presumably adjusted their speeds before reaching the point at which speed measurements were taken.

During the course of data collection, the “YOU” board displayed identical speeds to those acquired through the laser gun; speeds were +/-1 mph on rare occasions.

Mounting the display on the back of the crew cab was done with relative ease. The mounting bracket was manufactured in-house by WisDOT employees with minimal labor and materials, and was affixed to the crew cab using already existing accessory mounts.

An experienced painting crew member commented that he felt that drivers were driving slower, more carefully and that traffic was calmer when the display was visible during the painting operation.

RECOMMENDATIONS

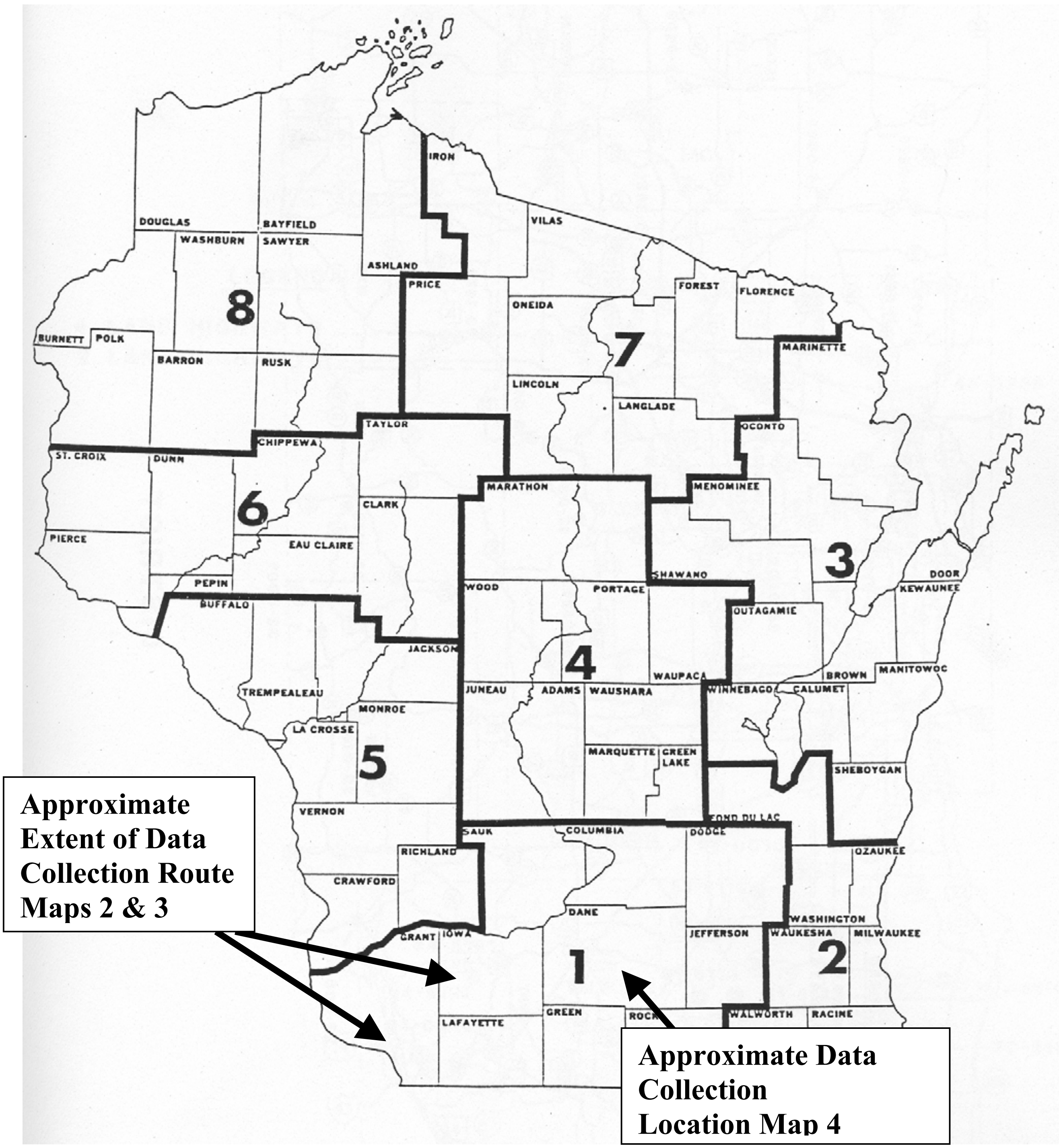
Based on the experience gained from the present evaluation, it is recommended to continue evaluating this display during different maintenance vehicle operations (for example, freeway lane closures, construction trucks entering/exiting work zone, snow plowing operations, etc.), in order to assess the situations in which use of the display is the most beneficial.

Replacing a blank display with an indication of zero miles per hour on the “ME” part of the evaluated display, when the maintenance vehicle is stationary, may enhance device effectiveness, since approaching drivers will be provided with both their own and the stationary vehicle’s speed.

ACKNOWLEDGMENTS
The author of this report wishes to acknowledge the valuable help of many Wisconsin DOT employees, without which this evaluation would have not been possible: Thomas Notbohm, P.E., who coordinated the effort between the Mid-America Transportation Center of the University of Nebraska, the Wisconsin DOT, and Marquette University--he also provided the evaluation sites and valuable input at every step of the project , including a comprehensive review of the present report; the centerline painting crew, Tim Stoikes, Charlie Barrett, Connie Campbell, Don Nihles and Jeff Holloway; Ned Schmitt, a pavement markings specialist who also drove V4, and Jim Emmons who installed the display on V2. Carl Fors, the system vendor helped tirelessly with solutions to multitudes of problems that would have been difficult to overcome without his help. The author is also greatly indebted to Georgia Vergou, a Marquette University Graduate Assistant who helped with data collection and the preparation of the present report.

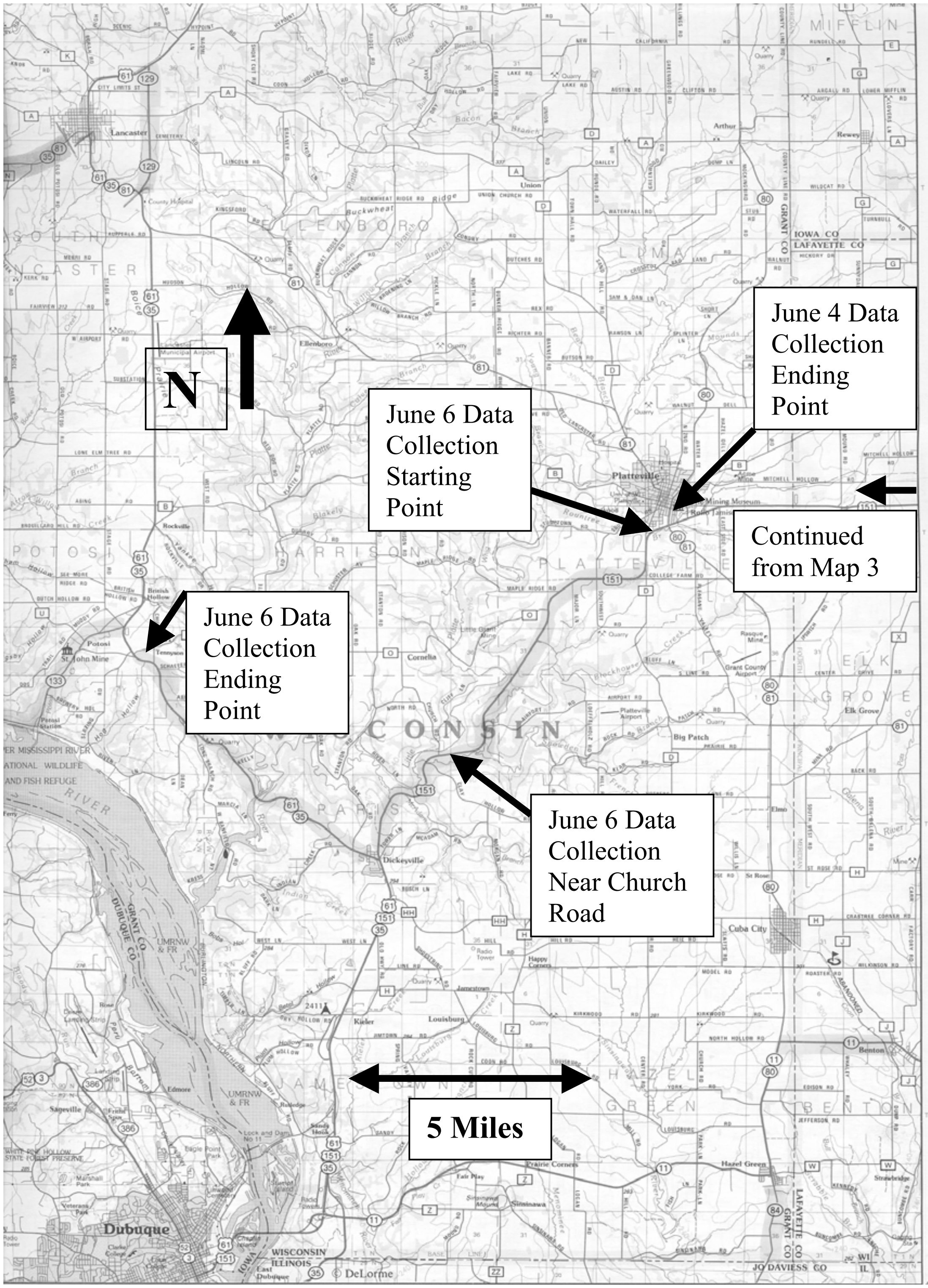
APPENDIX

Map 1. State of Wisconsin-Approximate Data Collection Locations

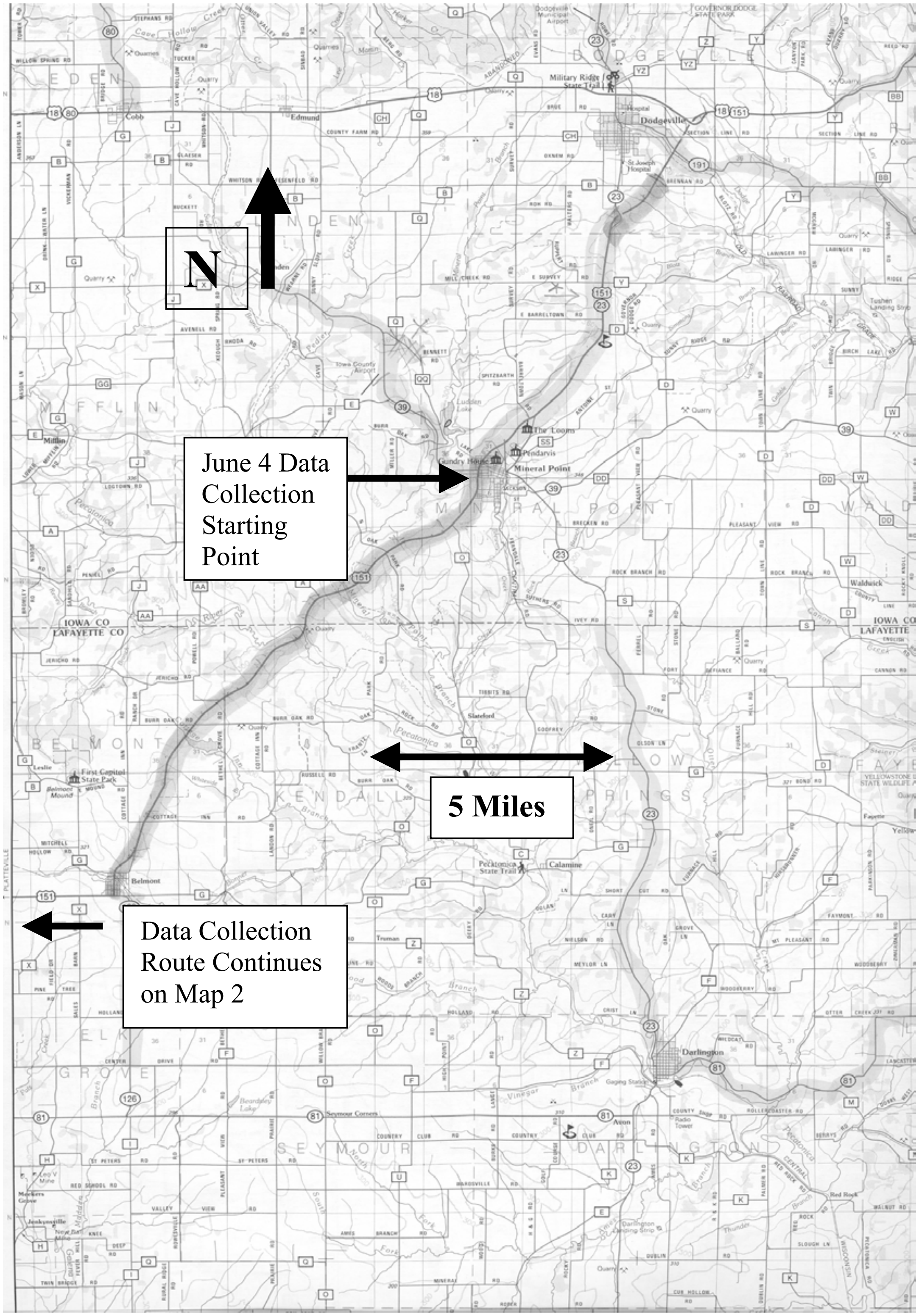


County names listed. Bold type numbers indicate Wisconsin DOT Districts.
Source: 1999 Wisconsin Vehicle Classification Data, March 2000, WisDOT.

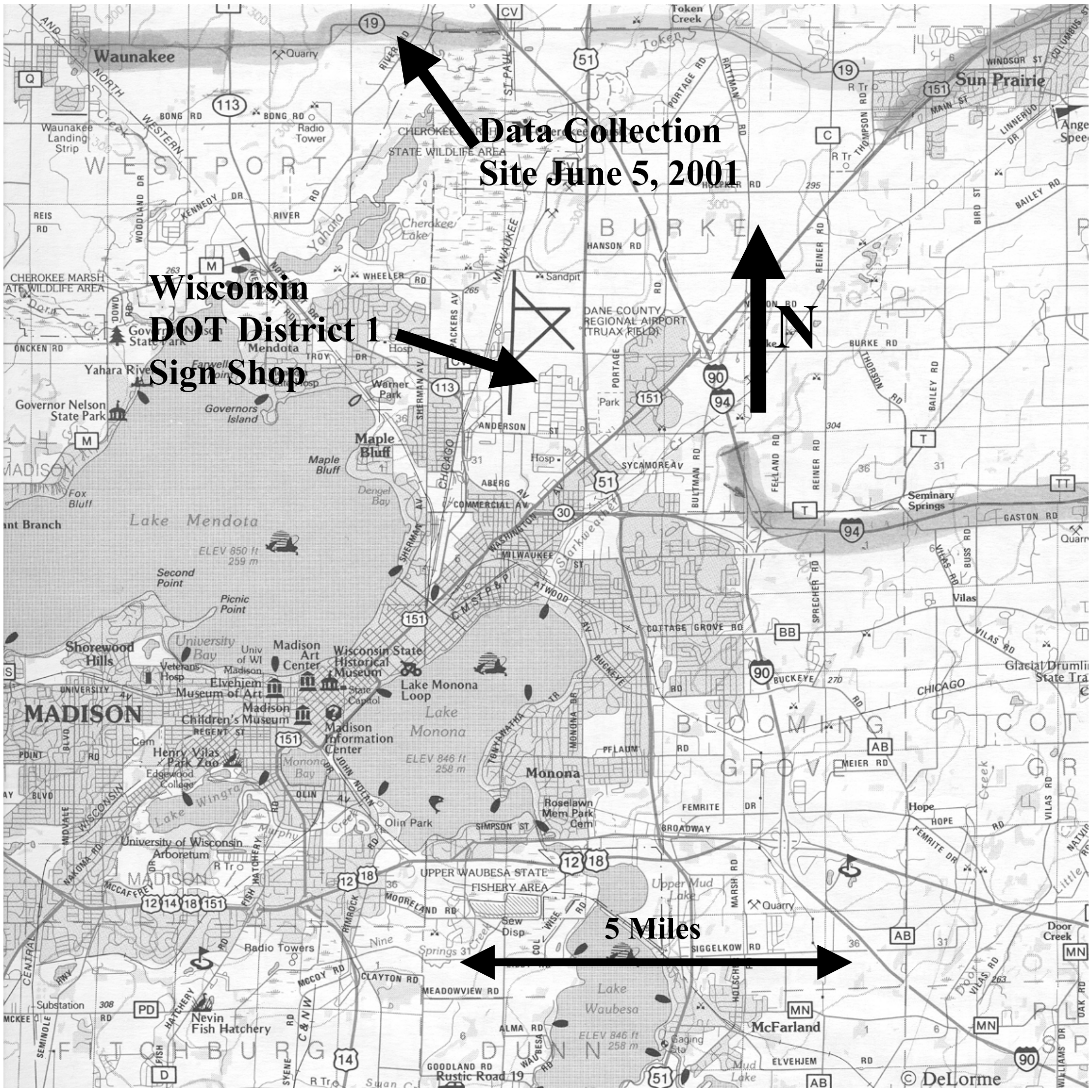
Map 2. Data Collection Efforts June 4 and June 6, 2001.



Map 3. Data Collection Efforts June 4, 2001.



Map 4. Data Collection Effort Location, June 5, 2001



Data Set A: Stationary Vehicle Arrangement. Display Not Visible.

Table A1. Measured V3 Speed Statistics

Variables

N	Valid	150
	Missing	0
Mean		56.63
Std. Error of Mean		.449
Median		57.00
Mode		57
Std. Deviation		5.499
Variance		30.236
Range		49
Minimum		19
Maximum		68
Percentiles	10	51.00
	20	52.20
	25	54.00
	30	55.00
	40	56.00
	50	57.00
	60	58.00
	70	59.00
	75	60.00
	80	61.00
	85	62.00
	90	62.00

Data Set A: Stationary Vehicle Arrangement. Display Not Visible.

Table A2. V3 Distance from Display Statistics

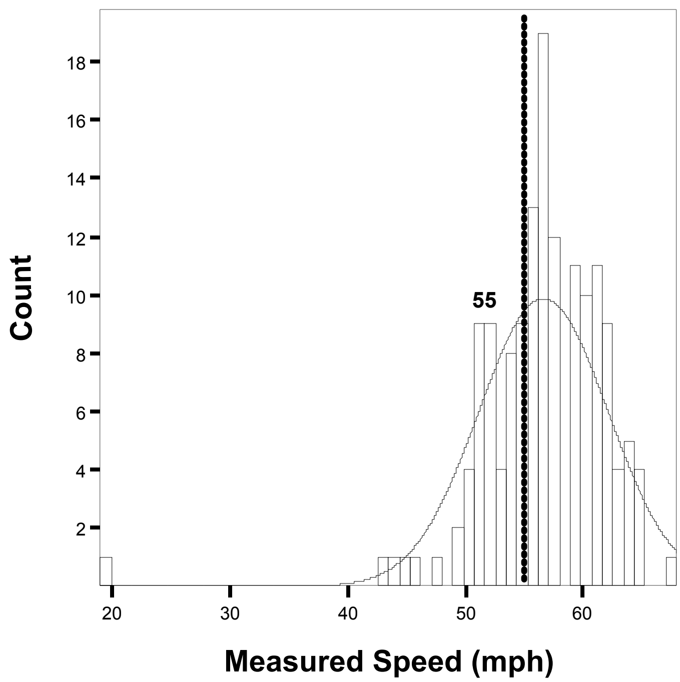
Variables

N	Valid	150
	Missing	0
Mean		332.07
Std. Error of Mean		4.817
Median		335.00
Mode		335[a]
Std. Deviation		58.992
Variance		3480.001
Range		343
Minimum		115
Maximum		458
Percentiles	10	260.30
	20	289.20
	25	294.50
	30	307.30
	40	320.40
	50	335.00
	60	350.00
	70	365.70
	75	372.25
	80	380.00
	85	397.35
	90	407.90

a. Multiple modes exist. The smallest value is shown

Data Set A: Stationary Vehicle Arrangement. Display Not Visible.

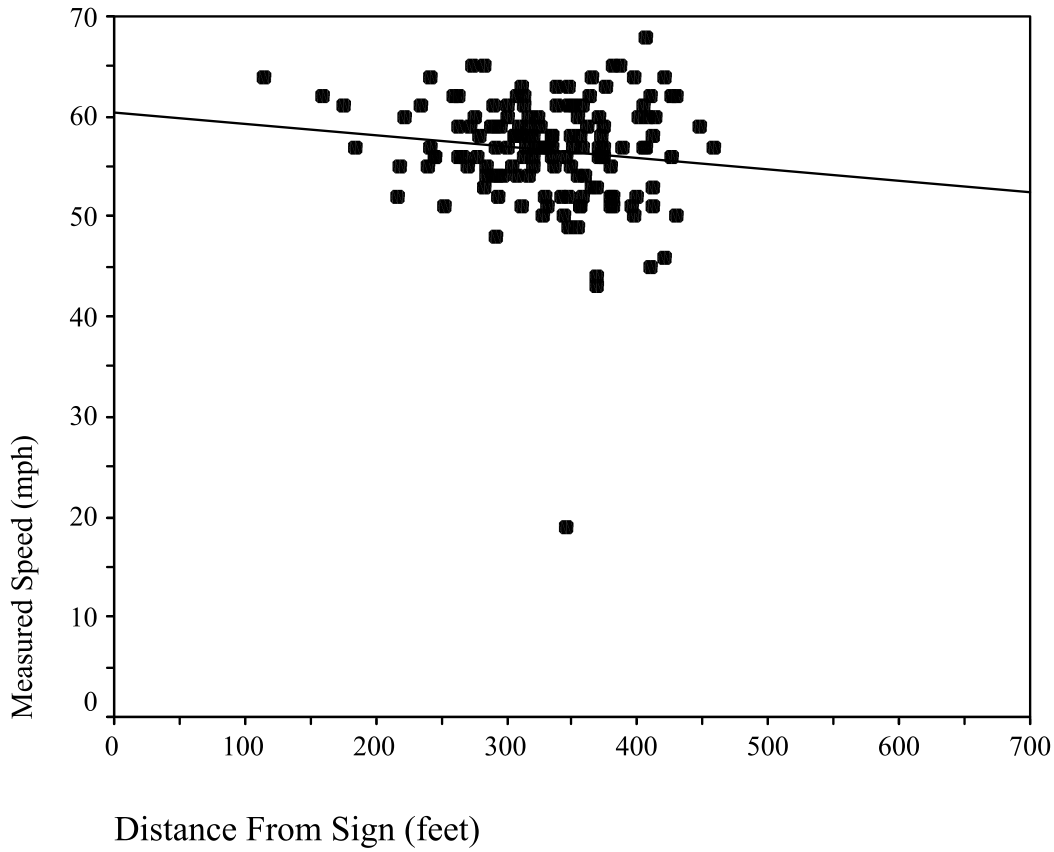
Figure A1. Measured V3 Speed Distribution



Thick dotted line indicates speed limit (55 mph).

Data Set A: Stationary Vehicle Arrangement. Display Not Visible.

Figure A2. Measured V3 Speed Distribution Versus Distance from Display




```
Multiple R           .12298
R Square             .01512
Adjusted R Square    .00847
Standard Error      5.47535

            Analysis of Variance:

                DF   Sum of Squares      Mean Square

Regression       1          68.1360        68.135954
Residuals      148        4436.9574        29.979442

F =       2.27276       Signif F =  .1338

-------------------- Variables in the Equation --------------------

Variable                     B        SE B       Beta         T  Sig T

DIST. FROM DISPLAY -.011463     .007604   -.122981    -1.508  .1338
(Constant)         60.433285    2.564280               23.567  .0000
```

Data Set B: Stationary Vehicle Arrangement. Display Visible.

Table A3. Measured V3 Speed Statistics

Variables

N	Valid	149
	Missing	0
Mean		53.64
Std. Error of Mean		.390
Median		54.00
Mode		53[a]
Std. Deviation		4.758
Variance		22.638
Range		26
Minimum		40
Maximum		66
Percentiles	10	47.00
	20	50.00
	25	51.00
	30	52.00
	40	53.00
	50	54.00
	60	55.00
	70	56.00
	75	57.00
	80	57.00
	85	58.00
	90	59.00

a. Multiple modes exist. The smallest value is shown

Data Set B: Stationary Vehicle Arrangement. Display Visible.

Table A4. V3 Distance from Display Statistics

Statistics

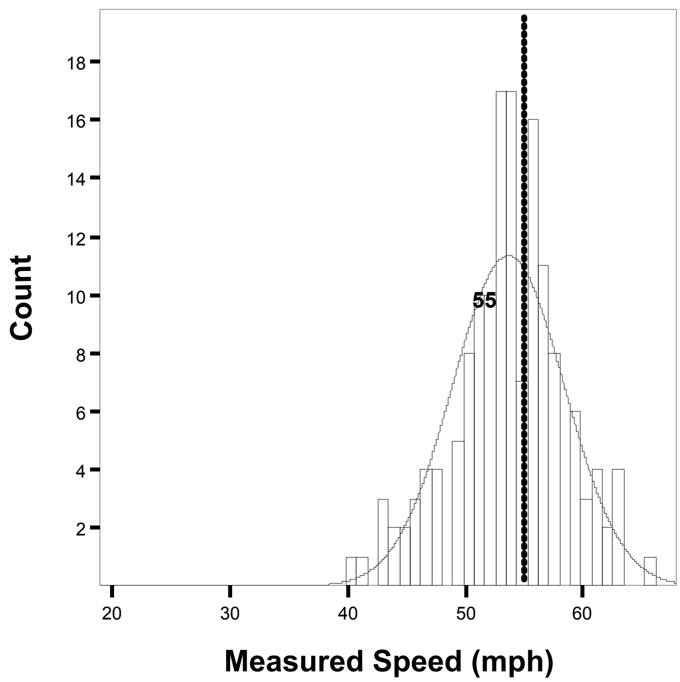
Variables

N	Valid	149
	Missing	0
Mean		325.65
Std. Error of Mean		4.997
Median		325.00
Mode		323[a]
Std. Deviation		60.991
Variance		3719.958
Range		434
Minimum		78
Maximum		512
Percentiles	10	256.00
	20	275.00
	25	294.00
	30	302.00
	40	313.00
	50	325.00
	60	341.00
	70	353.00
	75	364.00
	80	378.00
	85	389.00
	90	399.00

a. Multiple modes exist. The smallest value is shown

Data Set B: Stationary Vehicle Arrangement. Display Visible.

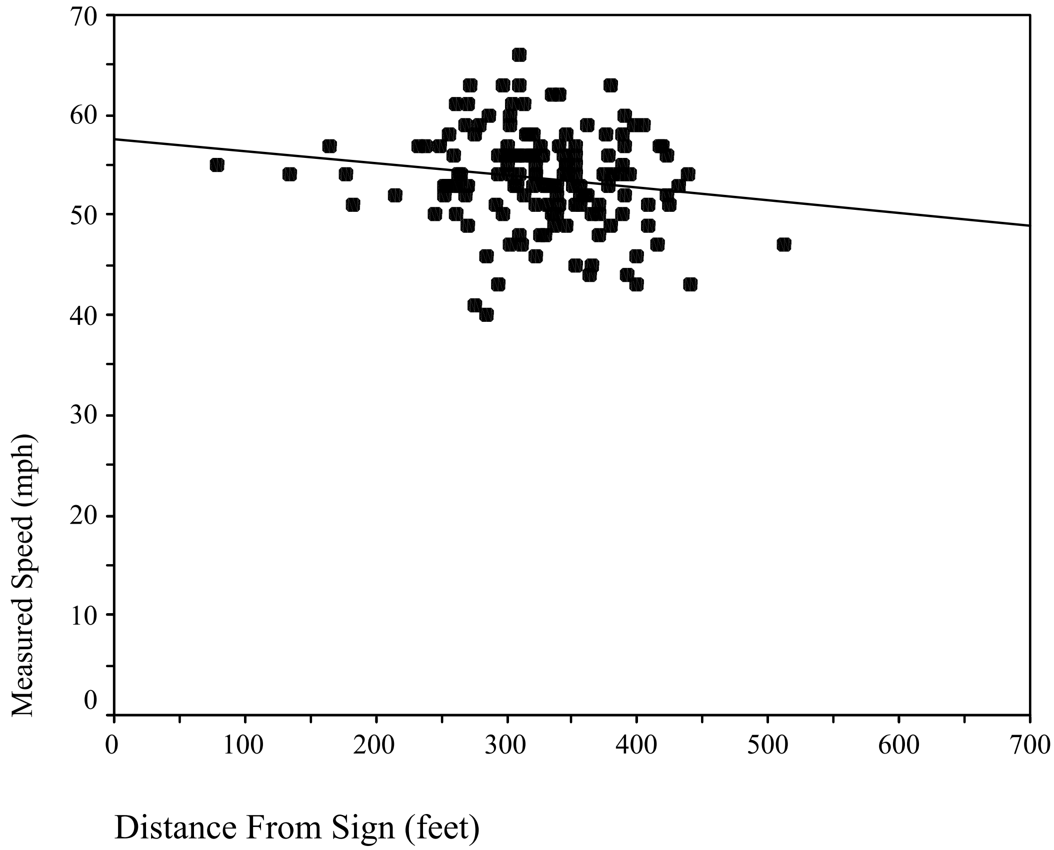
Figure A3. Measured V3 Speed Distribution



Thick dotted line indicates speed limit (55 mph).

Data Set B: Stationary Vehicle Arrangement. Display Visible.

Figure A4. Measured V3 Speed Distribution Versus Distance from Display




```
Multiple R           .15963
R Square             .02548
Adjusted R Square    .01885
Standard Error      4.71288

            Analysis of Variance:

                DF   Sum of Squares      Mean Square

Regression       1          85.3733        85.373337
Residuals      147        3265.0562        22.211267

F =       3.84370       Signif F =  .0518

-------------------- Variables in the Equation --------------------

Variable                    B         SE B       Beta         T  Sig T

DIST. FROM DISPLAY -.012453     .006352   -.159629    -1.961  .0518
(Constant)        57.692797    2.104148               27.419  .0000
```

Data Set C: Mobile Vehicle Arrangement. Display Visible.

Table A5. Measured V3 Speed Statistics

Statistics

Variables

N	Valid	6
	Missing	0
Mean		37.67
Std. Error of Mean		1.145
Median		37.00
Mode		37
Std. Deviation		2.805
Variance		7.867
Range		8
Minimum		35
Maximum		43
Percentiles	10	35.00
	20	35.40
	25	35.75
	30	36.10
	40	36.80
	50	37.00
	60	37.20
	70	37.90
	75	39.25
	80	41.00
	85	42.75
	90	43.00

Data Set C: Mobile Vehicle Arrangement. Display Visible.

Table A6. V3 Distance from Display Statistics

Statistics

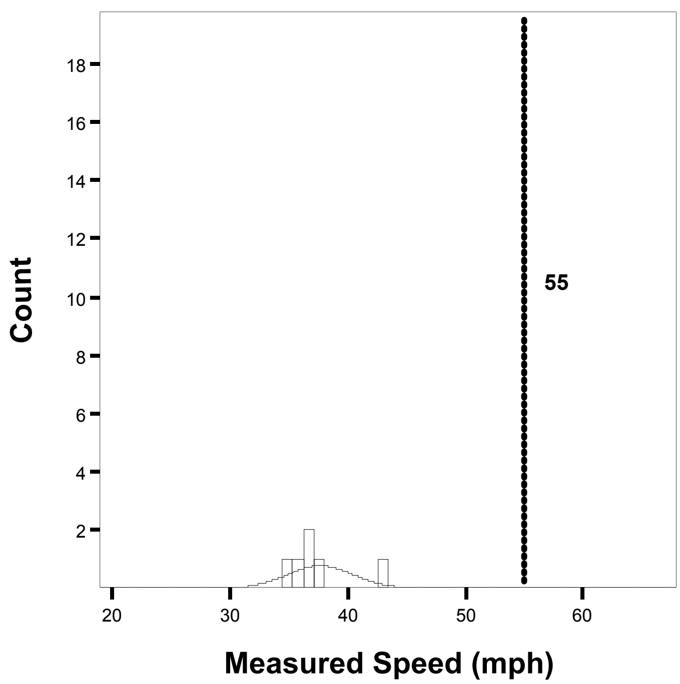
Variables

N	Valid	6
	Missing	0
Mean		326.83
Std. Error of Mean		30.653
Median		354.00
Mode		195[a]
Std. Deviation		75.085
Variance		5637.767
Range		214
Minimum		195
Maximum		409
Percentiles	10	195.00
	20	232.60
	25	265.50
	30	295.00
	40	337.00
	50	354.00
	60	359.20
	70	359.90
	75	372.25
	80	389.40
	85	406.55
	90	409.00

a. Multiple modes exist. The smallest value is shown

Data Set C: Mobile Vehicle Arrangement. Display Visible.

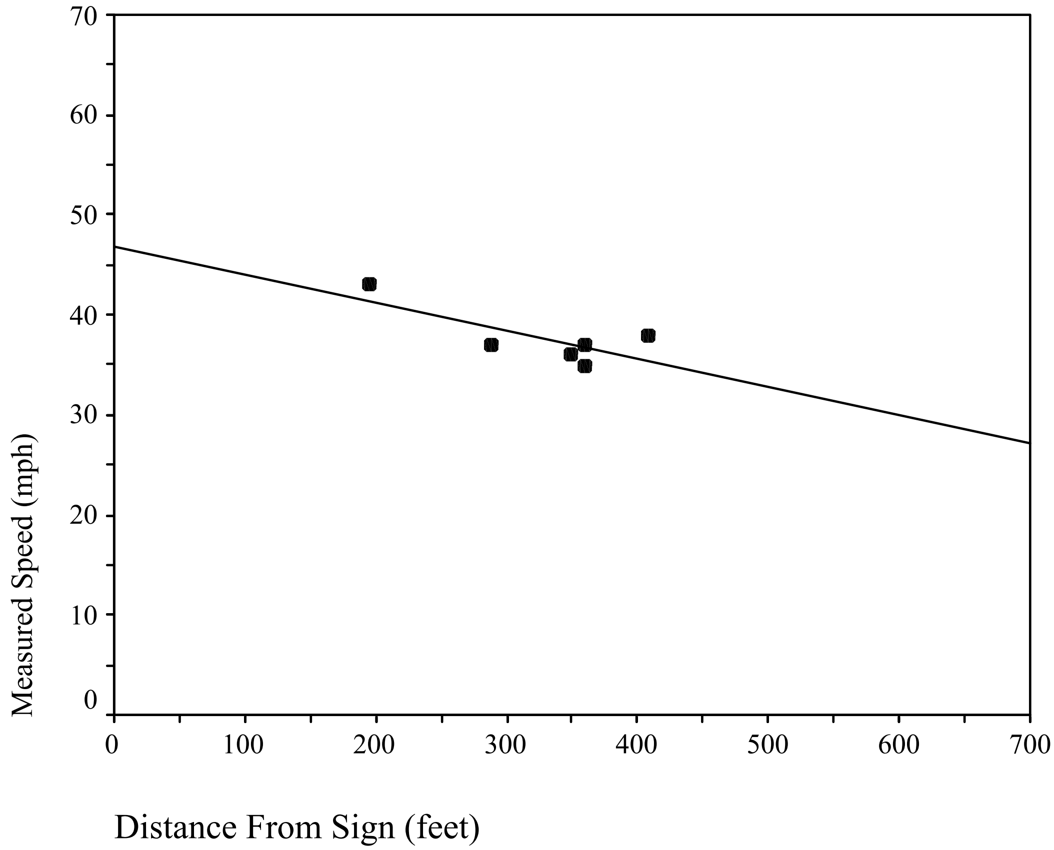
Figure A5. Measured V3 Speed Distribution



Thick dotted line indicates speed limit (55 mph).

Data Set C: Mobile Vehicle Arrangement. Display Visible.

Figure A6. Measured V3 Speed Distribution Versus Distance from Display




```
Multiple R           .75532
R Square             .57051
Adjusted R Square    .46313
Standard Error      2.05508

            Analysis of Variance:

              DF   Sum of Squares      Mean Square

Regression     1        22.439918        22.439918
Residuals      4        16.893415         4.223354

F =       5.31329       Signif F =  .0825

-------------------- Variables in the Equation --------------------

Variable                     B         SE B       Beta          T  Sig T

DIST. FROM DISPLAY -.028214     .012240   -.755319    -2.305  .0825
(Constant)        46.888100    4.087549               11.471  .0003
```

Data Set D: Stationary Vehicle Arrangement. Display Visible.

Table A7. Measured V3 Speed Statistics

Variables

N	Valid	38
	Missing	0
Mean		51.47
Std. Error of Mean		.923
Median		52.00
Mode		47[a]
Std. Deviation		5.689
Variance		32.364
Range		22
Minimum		38
Maximum		60
Percentiles	10	42.80
	20	47.00
	25	47.00
	30	49.40
	40	51.00
	50	52.00
	60	54.00
	70	55.30
	75	56.00
	80	57.00
	85	57.15
	90	58.10

a. Multiple modes exist. The smallest value is shown

Data Set D: Stationary Vehicle Arrangement. Display Visible.

Table A8. V3 Distance from Display Statistics

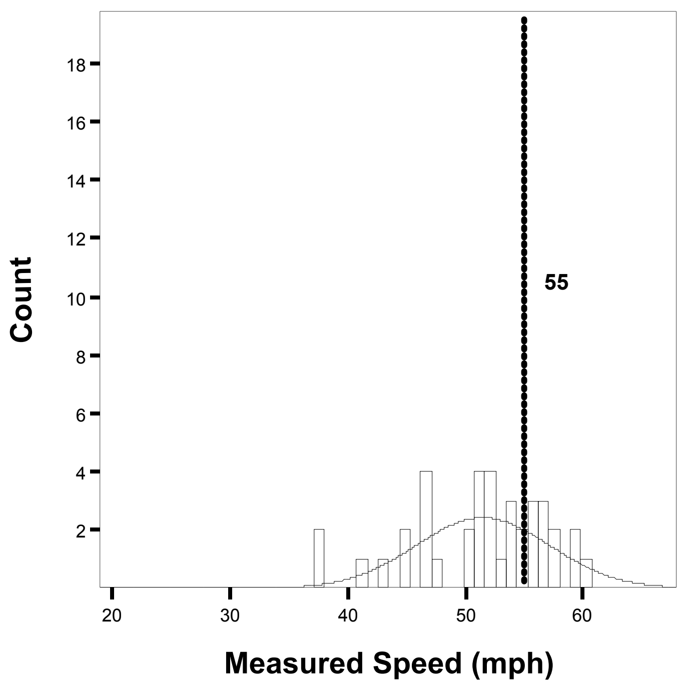
Variables

N	Valid	38
	Missing	0
Mean		448.79
Std. Error of Mean		19.941
Median		441.00
Mode		316[a]
Std. Deviation		122.925
Variance		15110.549
Range		489
Minimum		206
Maximum		695
Percentiles	10	286.10
	20	324.00
	25	364.50
	30	385.90
	40	425.00
	50	441.00
	60	473.00
	70	499.20
	75	535.50
	80	562.00
	85	603.45
	90	613.10

a. Multiple modes exist. The smallest value is shown

Data Set D: Stationary Vehicle Arrangement. Display Visible.

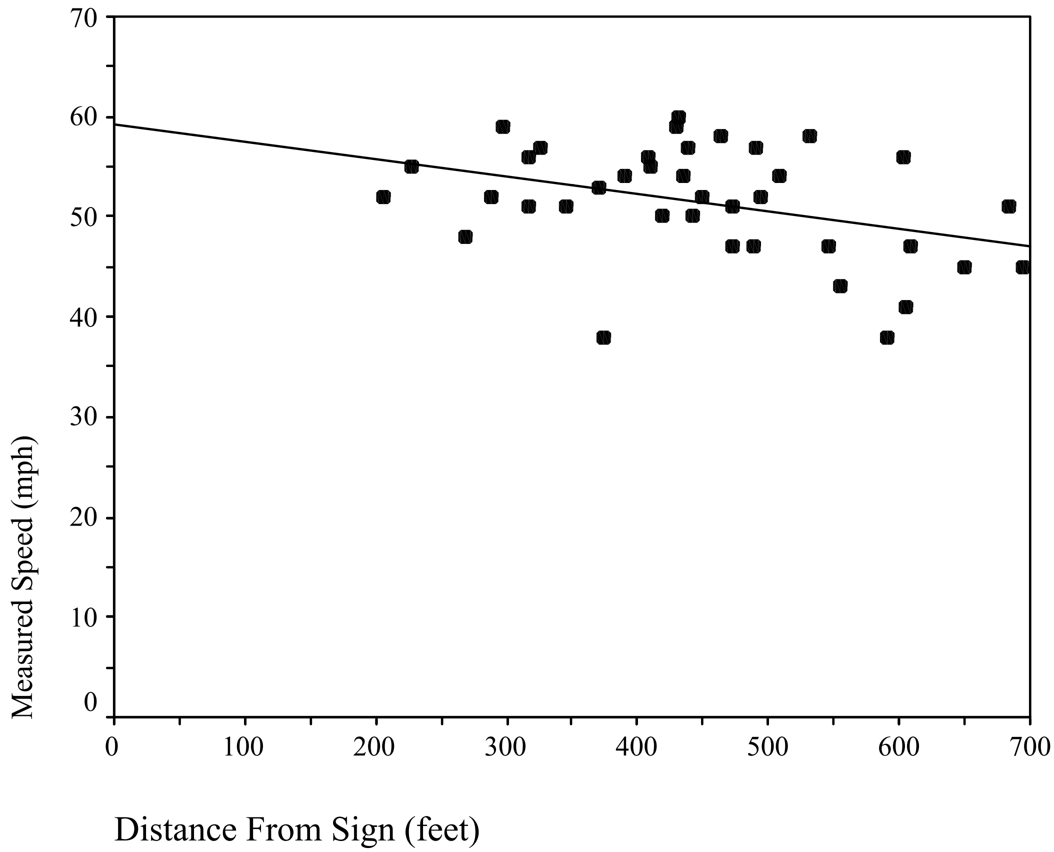
Figure A7. Measured V3 Speed Distribution



Thick dotted line indicates speed limit (55 mph).

Data Set D: Stationary Vehicle Arrangement. Display Visible.

Figure A8. Measured V3 Speed Distribution Versus Distance from Display




```
Multiple R           .37667
R Square             .14188
Adjusted R Square    .11804
Standard Error      5.34264

            Analysis of Variance:

               DF   Sum of Squares      Mean Square

Regression      1         169.8985        169.89852
Residuals      36        1027.5752         28.54375

F =       5.95221       Signif F =  .0198

-------------------- Variables in the Equation --------------------

Variable                    B         SE B       Beta         T  Sig T

DIST. FROM DISPLAY -.017432     .007145   -.376671    -2.440  .0198
(Constant)        59.297101    3.321750               17.851  .0000
```

Data Set E: Mobile Vehicle Arrangement. Display Visible.

Table A9. Measured V3 Speed Statistics

Variables

N	Valid	20
	Missing	0
Mean		40.10
Std. Error of Mean		1.183
Median		41.50
Mode		45
Std. Deviation		5.291
Variance		27.989
Range		20
Minimum		28
Maximum		48
Percentiles	10	31.40
	20	35.20
	25	36.00
	30	36.30
	40	39.80
	50	41.50
	60	42.60
	70	44.00
	75	44.75
	80	45.00
	85	45.00
	90	45.00

Data Set E: Mobile Vehicle Arrangement. Display Visible.

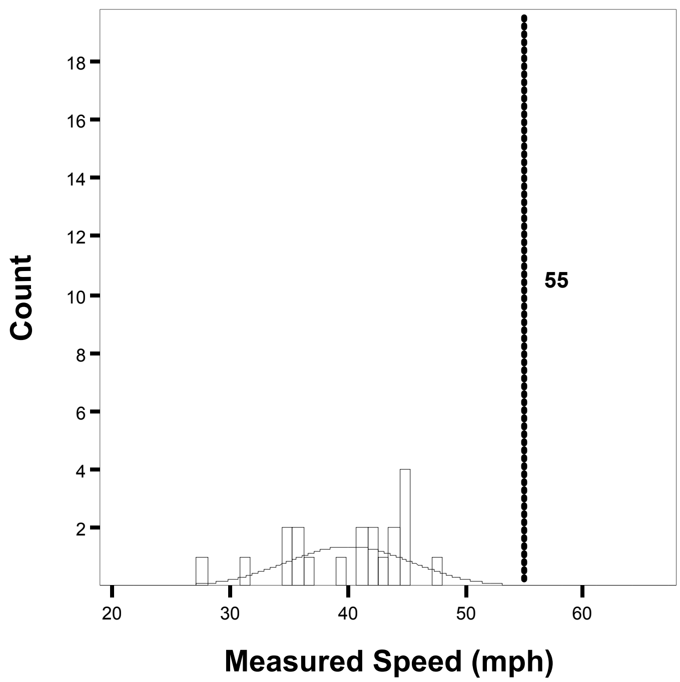
Table A10. V3 Distance from Display Statistics

Variables

N	Valid	20
	Missing	0
Mean		335.75
Std. Error of Mean		15.954
Median		333.50
Mode		266
Std. Deviation		71.349
Variance		5090.724
Range		264
Minimum		190
Maximum		454
Percentiles	10	255.10
	20	266.00
	25	269.25
	30	282.30
	40	315.60
	50	333.50
	60	355.00
	70	389.40
	75	403.50
	80	407.80
	85	414.80
	90	437.60

Data Set E: Mobile Vehicle Arrangement. Display Visible.

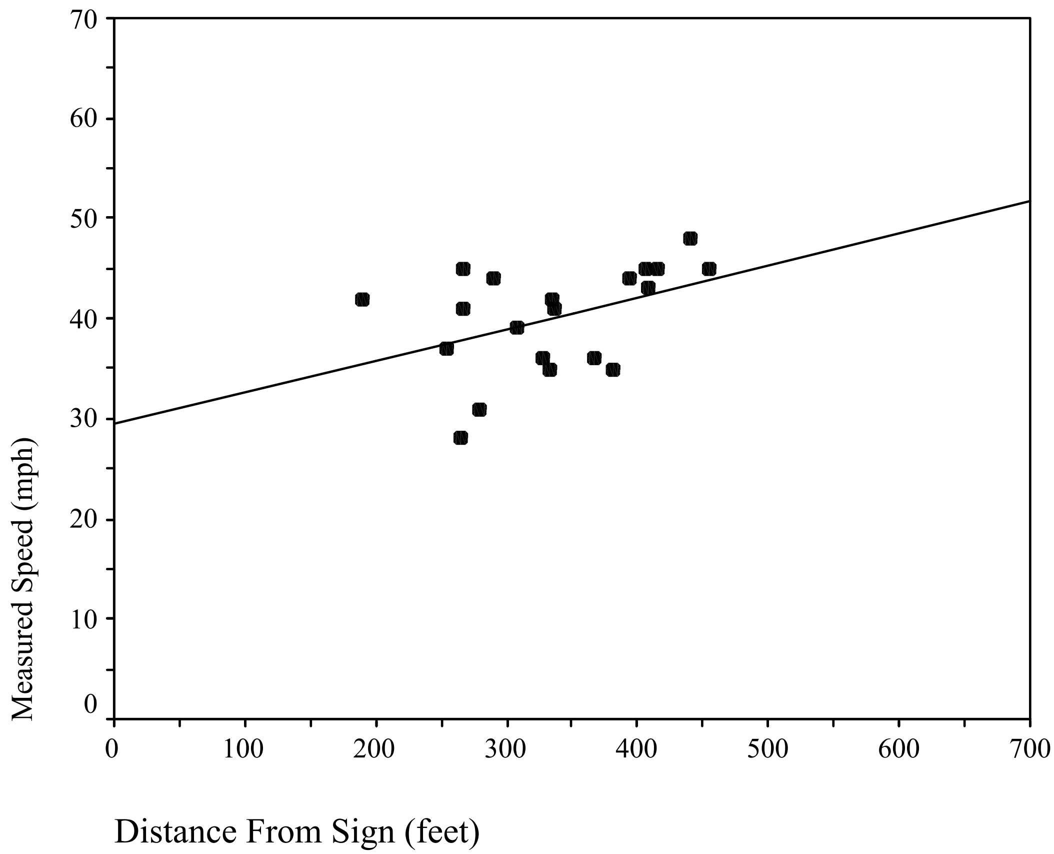
Figure A9. Measured V3 Speed Distribution



Thick dotted line indicates speed limit (55 mph).

Data Set E: Mobile Vehicle Arrangement. Display Visible.

Figure A10. Measured V3 Speed Distribution Versus Distance from Display



Multiple R	.42715
R Square	.18245
Adjusted R Square	.13704
Standard Error	4.91466

Analysis of Variance:

	DF	Sum of Squares	Mean Square
Regression	1	97.02924	97.029243
Residuals	18	434.77076	24.153931

F = 4.01712 Signif F = .0603

-------------------- Variables in the Equation --------------------

Variable	B	SE B	Beta	T	Sig T
DIST. FROM DISPLAY	.031673	.015803	.427147	2.004	.0603
(Constant)	29.465899	5.418324		5.438	.0000

Figure A11. V3 Speed--Statistics for All Data Sets

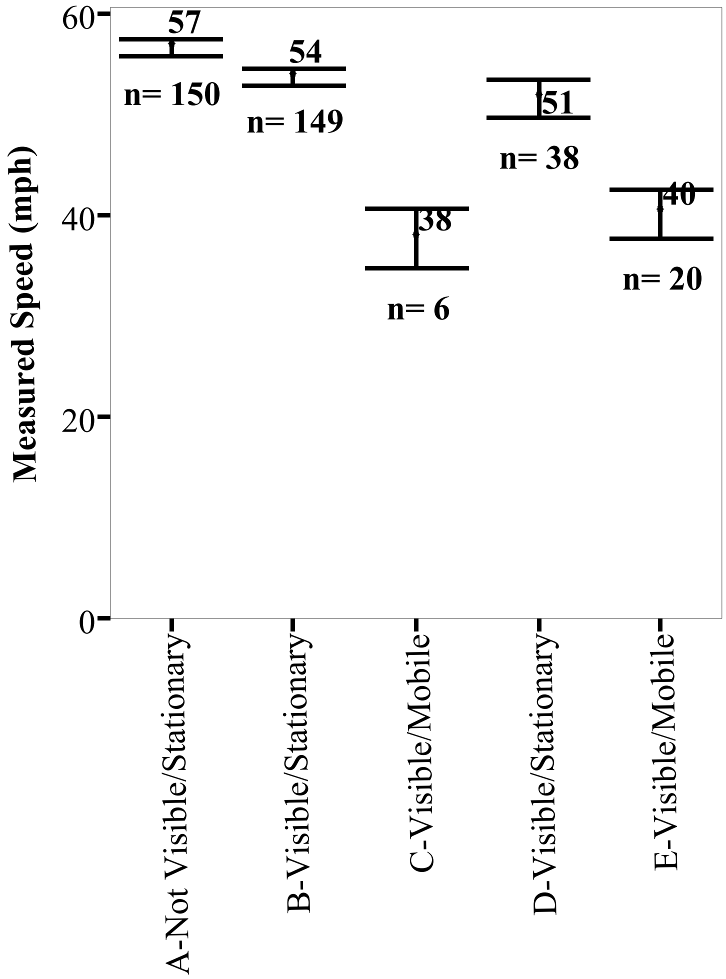


Table A11. Descriptive Statistics for Speed.

Dependent Variable

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
A-Not Visible/Stationary	150	56.63	5.499	.449	55.74	57.51	19	68
B-Visible/Stationary	149	53.64	4.758	.390	52.87	54.41	40	66
C-Visible/Mobile	6	37.67	2.805	1.145	34.72	40.61	35	43
D-Visible/Stationary	38	51.47	5.689	.923	49.60	53.34	38	60
E-Visible/Mobile	20	40.10	5.291	1.183	37.62	42.58	28	48
Total	363	53.64	6.718	.353	52.94	54.33	19	68

Figure A12. V3 Distance from Display--Statistics for All Data Sets

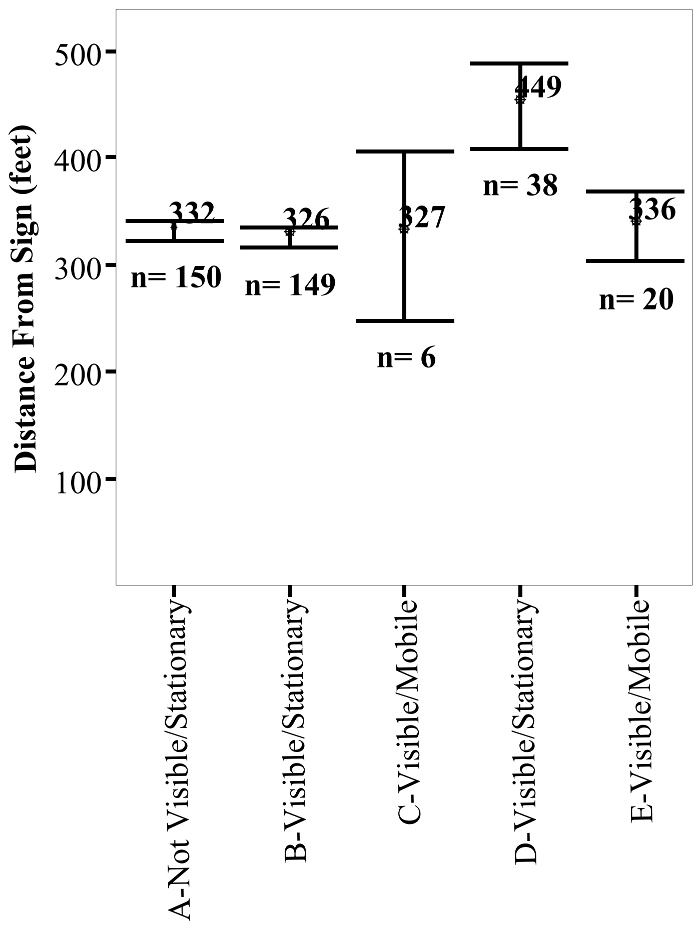


Table A12. Descriptive Statistics for Distance.

Dependent Variable

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
A-Not Visible/Stationary	150	332.07	58.992	4.817	322.56	341.59	115	458
B-Visible/Stationary	149	325.65	60.991	4.997	315.78	335.52	78	512
C-Visible/Mobile	6	326.83	75.085	30.653	248.04	405.63	195	409
D-Visible/Stationary	38	448.79	122.925	19.941	408.39	489.19	206	695
E-Visible/Mobile	20	335.75	71.349	15.954	302.36	369.14	190	454
Total	363	341.77	78.719	4.132	333.65	349.90	78	695

Table A13. Traffic Volumes on Wisconsin State Trunk Highway 19, 1.8 miles West of Interstate 90/94, During Data Collection.

Date: 6/5/01	Convoy Direction		Opposite Direction		Total		Equivalent Hourly Flow		
Time	*Cars*	*Trucks*	*Cars*	*Trucks*	*Cars*	*Trucks*	*Cars*	*Trucks*	*Total*
9:45am-10:00am	48	14	45	10	93	24	372	96	468
10:00am-10:15am	51	18	62	18	113	36	452	144	596
10:15am-10:30am	59	19	52	15	111	34	444	136	580
10:30am-10:45am	61	10	87	16	148	26	592	104	696
10:45am-11:00am	44	8	59	12	103	20	412	80	492
11:00am-11:15am	46	11	68	10	114	21	456	84	540
11:15am-11:30am	57	12	63	18	120	30	480	120	600
11:30am-11:45am	61	11	53	10	114	21	456	84	540
11:45am-12:00pm	65	12	76	7	141	19	564	76	640

Table A14. Traffic Volumes on US Route 151 Between Platteville and Church Road During Data Collection.

Date: 6/6/01	Convoy Direction		Opposite Direction		Total		Equivalent Hourly Flow		
Time	*Cars*	*Trucks*	*Cars*	*Trucks*	*Cars*	*Trucks*	*Cars*	*Trucks*	*Total*
11:00am-11:15am	36	10	53	9	89	19	356	76	432
11:15am-11:30am	38	11	37	8	75	19	300	76	376
11:30am-11:45am	35	15	29	11	64	26	256	104	360
11:45am-12:00pm	27	8	39	10	66	18	264	72	336
12:00pm-12:15pm	38	6	40	13	78	19	312	76	388
12:15pm-12:30pm	29	12	29	9	58	21	232	84	316
12:30pm-12:45pm	45	21	17	4	62	25	248	100	348
12:45pm-1:00pm	38	5	45	12	83	17	332	68	400
1:00pm-1:15pm	42	11	35	7	77	18	308	72	380

Table A15. Traffic Volumes on US Route 151 Between Church Road and Dickeyville, and US Route 61/State Trunk Highway 35 between Dickeyville and Tennyson, During Data Collection.

Date: 6/6/01	Convoy Direction		Opposite Direction		Total		Equivalent Hourly Flow		
Time	*Cars*	*Trucks*	*Cars*	*Trucks*	*Cars*	*Trucks*	*Cars*	*Trucks*	*Total*
1:30pm-1:45pm	22	6	36	8	58	14	232	56	288
1:45pm-2:00pm	34	4	39	6	73	10	292	40	332
2:00pm-2:15pm	33	4	45	4	78	8	312	32	344
2:15pm-2:30pm	33	4	28	7	61	11	244	44	288
2:30pm-2:45pm	51	5	34	3	85	8	340	32	372
2:45pm-3:00pm	40	5	35	5	75	10	300	40	340
3:00pm-3:15pm	44	3	33	9	77	12	308	48	356