Effectiveness of Dynamic Messaging on Driver Behavior for Late Merge Lane Road Closures

Final Report
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16. Abstract

Efforts to improve safety and traffic flow through merge areas on high volume/high speed roadways have included early merge and late merge concepts and several studies of the effectiveness of these concepts, many using Intelligent Transportation Systems for implementation. The Iowa Department of Transportation (Iowa DOT) planned to employ a system of dynamic message signs (DMS) to enhance standard temporary traffic control for lane closures and traffic merges at two bridge construction projects in western Iowa (Adair County and Cass County counties) on I-80 during the 2008 construction season. To evaluate the DMS system's effectiveness for impacting driver merging actions, the Iowa DOT contracted with Iowa State University's Center for Transportation Research and Education to perform the evaluation and make recommendations for future use of this system based on the results.

Data were collected over four weekends, beginning August 1–4 and ending October 16–20, 2008. Two weekends yielded sufficient data for evaluation, one of transition traffic flow and the other with a period of congestion. For both of these periods, a statistical review of collected data did not indicate a significant impact on driver merging actions when the DMS messaging was activated as compared to free flow conditions with no messaging. Collection of relevant project data proved to be problematic for several reasons. In addition to personnel safety issues associated with the placement and retrieval of counting devices on a high speed roadway, unsatisfactory equipment performance and insufficient congestion to activate the DMS messaging hampered efforts. A review of the data that was collected revealed different results taken by the tube counters compared to the older model plate counters. Although variations were not significant from a practical standpoint, a statistical evaluation showed that the data, including volumes, speeds, and classifications from the two sources were not comparable at a 95% level of confidence. Comparison of data from the Iowa DOT's automated traffic recorders (ATRs) in the area also suggested variations in results from these data collection systems. Additional comparison studies were recommended.

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EFFECTIVENESS OF DYNAMIC MESSAGING ON DRIVER BEHAVIOR FOR LATE MERGE LANE CLOSURES

Final Report
March 2009

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EXECUTIVE SUMMARY

The factors influencing the merging actions of drivers when approaching a lane restriction area on high volume/high speed roadways are of interest to the Iowa DOT. These have been utilized and studied in recent years by other states as a means of promoting safer and less congestive flow through the often problematic merge area of work zones. Both early merging and late merging of traffic have been examined.

With this study, the Iowa Department of Transportation (Iowa DOT) desired to examine the potential benefits of using a system of speed sensors and dynamic message signs (DMS) to enhance traffic flow through work zones. This system will be referred to as the Dynamic Late Merge System, or DLMS. The observation sites were pre-chosen at two bridge replacement sites on Interstate 80 in western Iowa (Adair County and Cass County counties). If the system proved effective, the Iowa DOT could consider utilizing a similar system on future long term lane restriction projects, particularly on the state's Interstate system. Temporary traffic control (TTC) in place at two separate locations consisted of Iowa DOT standard lane closures for each direction of the 4-lane Interstate roadway. Median crossovers were used to conduct traffic through the work areas by sharing the remaining open lanes in 2-lane head-to-head movements.

To assess merging actions by drivers with and without the DLMS activated, the researchers collected traffic speeds, volumes and classifications at three selected spot locations approaching and within the merging areas. The DLMS consisted of several sign messaging units that were activated when the measured traffic speeds dropped below pre-selected levels, the free flow of traffic was hampered and congestion began. For most of the study period the higher reduced average speed level or "trigger" was 50 mph for the first messaging, defined as *transition* flow for this study and the lower average measured speed of 30 mph activated the second messaging. A flow rate below this lower speed setting was defined here as *congested* flow. Only one period (8-1/2 hours in length) of congestion flow and two short periods (6 and 39 minutes in length) of transition flow were recorded during the four weekends of data collection.

For that reason, as well as a result of malfunctions of the data collection equipment and the limited periods of actual traffic speed reductions, few opportunities to evaluate the effectiveness of the DLMS were available during the study period. From the available data, an analysis of driver merging behavior during these periods did not indicate a statistically significant change in merging behavior or overall benefit when the DMS messaging was activated. Nor could any correlation be established between driver merging behavior and vehicle volumes, speeds or classification, from the observations made. Other DMS sign deployment arrays and variation in messaging may yield other results.

However, several factors contributing to those findings must be considered, such as an undependable data collection systems and insufficient traffic volumes to activate the system with a frequency needed to fully evaluate performance. It is therefore suggested that this concept and system be employed only on roadways where normal traffic volumes approach a lane volume of 1500 vehicles per hour. In current practice, the Iowa DOT uses 1350 vph per lane as the upper volume at which to consider additional mitigation techniques to avoid or reduce impacts from potential backup periods. Based on the study experience and performance, the new model NuMetrics plates may be the most feasible data collection equipment for data collection on these high volume roadways, as previous testing using radar emitting devices were not able to recognize travel lanes and data must also be binned.

A review of the retrieved data from the various data collection equipment used indicated some variation in recorded speeds, volumes, and classifications. Although the plates were found to be much easier and less time consuming to place and retrieve in the heavy traffic, most did not perform satisfactorily due to age and lack of prior use. In addition, a limited comparison of data from the old and new plate counters was made with data from permanent Iowa DOT automated traffic recorders (ATRs), the DLMS system sensors, and the Jamar road tubes counter data.

Because of that limited amount of data, the results were found to be comparable from a practical standpoint. However, it was found that none of these data sources yielded statistically consistent and comparable results for traffic speeds, volumes, or classifications. Since traffic data from these sources are vital not only to highway planning and development but also to ongoing research, it is recommended that additional evaluation and comparison of data collection equipment be undertaken in the future.

INTRODUCTION

This report documents the efforts on a project to evaluate the effectiveness of dynamic messaging systems at locations with lane closures on driver behavior. The report also presents findings of these efforts and some recommendations. The findings are based on the deployment of two DLMS on Interstate 80 in western Iowa in Adair and Cass Counties. These locations are shown in Figure 1.

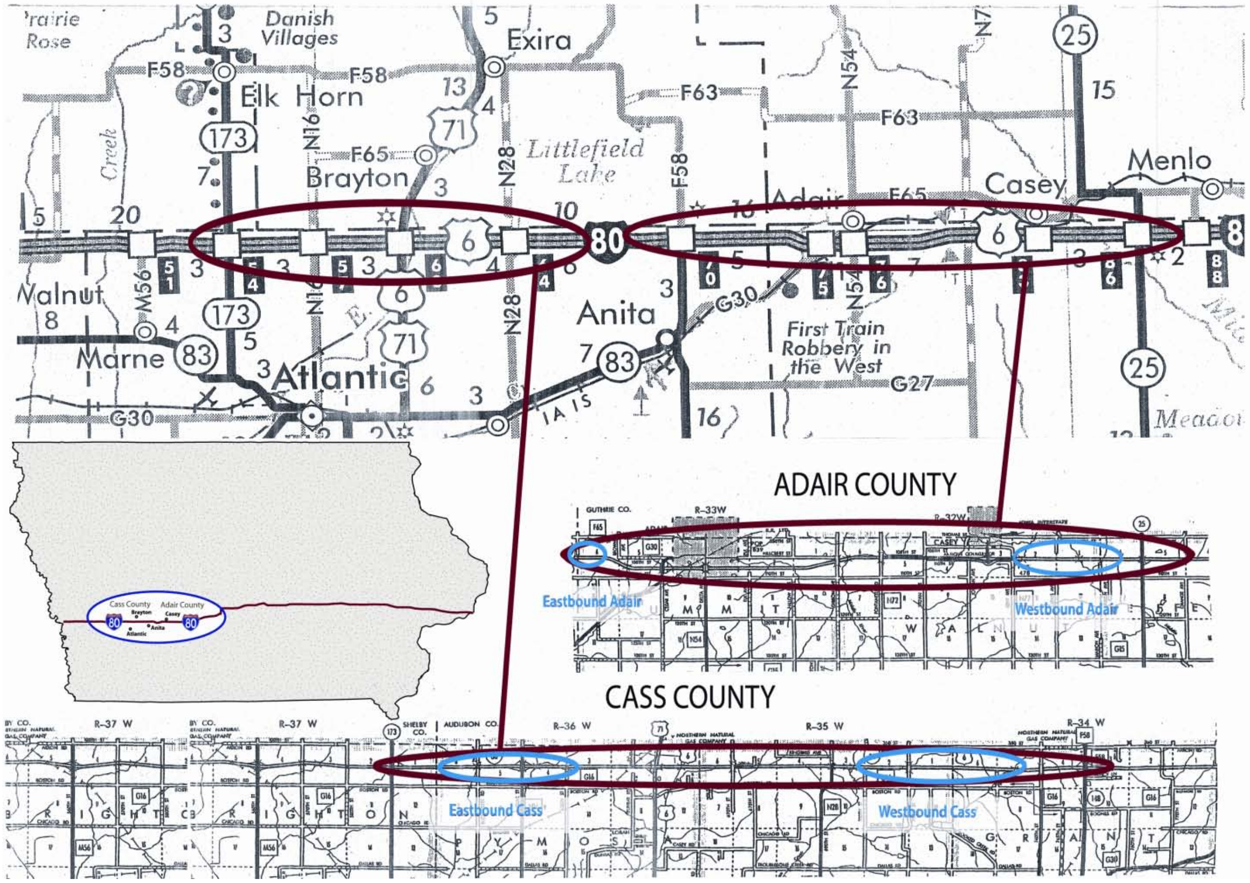


Figure 1. General plan of work area and study sites

Problem Statement

Recent studies involving driver behavior and the temporary traffic control (TTC) signing practices of highway agencies on high speed/high volume highways for long duration work zones have brought to light several significant problem areas. One of those is that, during periods of higher traffic volumes and/or irregular driver actions in a lane merge area, slowdowns can occur and quickly result in traffic backups that may extend beyond the location of any static TTC signing that is present. This situation results in potentially unsafe conditions when vehicles traveling at full highway speed come upon the slowing or stopping traffic when little or no warnings are present. In addition, drivers who are delayed can become confused and frustrated from not knowing cause or duration of the delay.

New (and perhaps better) possible solutions may be found by using traffic-activated dynamic message signs (DMS) to provide both changeable warning near the merge point and constant guidance farther back from the merge point.

The purpose of this study is to evaluate any possible changes in driver behavior from the use of these DMS signs during periods of congestion and, to make recommendations about this system’s value to Iowa’s current TTC practices for long term lane closures on high speed/high volume roadways.

Literature Review

Modeled on the Manual of Uniform Traffic Control Devices (MUTCD), the Iowa DOT has used consistent design standards for selection, sequence, and spacing of traffic control devices for lane closures on its rural Interstate system, and the traveling public has grown accustomed to this standard. However, early studies by Geza Pesti and Patrick McCoy in Nebraska (Pesti et al. 1999) have shown that, in areas of lower “commuter” traffic, these types of static signing failed to adequately handle congestion periods. Moreover, the addition of non-dynamic messages also was found to cause confusion and frustration when no congestion was present and drivers’ expectations were thus violated.

This study by Pesti et al. (1999) led to the concept of variable and dynamic message signs. The authors’ continued research (McCoy and Pesti 2001) on that topic led to the conclusion that the dynamic late merge concept can be a great safety benefit during times of heavy congestion. Having the ability to change the messages for drivers to correspond to changes in traffic flow and/or speed should promote a smoother transition as congestion develops and traffic speeds are slowed. This concept should minimize crashes as well as the frustrations of drivers during those slowdown periods. The authors also noted that selecting the most effective sign messages, types, and spacing seems to be a crucial element for each situation.

A 2004 study in Minnesota conducted by URS Corporation (URS 2004) concluded that the maximum volume throughput through single-lane construction areas on rural Interstates was approximately 1,600 vehicles/hour. This finding will be reviewed with our data for appropriateness.

A more recent study in Virginia by Beacher et al. (2004) found a marked improvement of traffic flow when a DLMS was used, but only for a 3-to-1 lane reduction, No statistically significant change in the capacity was noted in a 2-to-1 lane reduction, and little data was available for analysis. The study also noted that the percentage of heavy vehicles had a strong relationship to vehicle capacity or throughput, and a late merge concept became more efficient than the recommended MUTCD treatment as the percentage of heavy vehicles increased.

The Maryland State Highway Administration evaluated the effectiveness of dynamic late merge systems in highway work zone locations to measure the systems’ impact on vehicle throughput, volume distribution, and queue lengths. This testing utilized portable changeable message signs

(PCMS) to display messages to motorists when the dynamic late merge system is active. Remote traffic microwave sensors (RTMS) were used to detect traffic conditions, and standard TTC signs were in place to inform motorists of the work zone and merging traffic when the dynamic late merge system was not active. The PCMS boards were activated when the RTMS detected lane occupancies of greater than 15% and were deactivated if occupancy was below 5%. The results showed that the use of a dynamic late merge system can improve traffic throughput, balance lane volume distribution, and reduce maximum queue lengths. However, placement of the PCMS and static TTC must to be correct or there will be an increase in stop-and-go maneuvers by motorists confused by the messages being presented (Kang et al. 2006).

In October 2008, the FHWA’s *Comparative Analysis Report: The Benefits of Using Intelligent Transportation Systems in Work Zones* (Luttrell et al. 2008) summarized the benefits of using ITS in work zones on five separate study sites in Washington, DC; Hillsboro, Texas; Kalamazoo, Michigan; Little Rock, Arkansas; and Winston Salem, North Carolina. Projects were accomplished between 1999 and 2006 and utilized different systems. As might be expected with different deployment schedules, data collection difficulties, and varying construction schedules, quantifiable benefits were difficult to assess at some sites. A few showed some quantifiable benefits with more clarity.

METHODOLOGY

The Iowa Department of Transportation (Iowa DOT) selected the sites for this study at two bridge replacement locations on Interstate 80 in western Iowa. One site was near the U.S. 71 Interchange north of the city of Atlantic in Cass County which will be referenced as Cass County throughout this report. The other site was in Adair County near the exit for the town of Adair County (hereafter called Adair County in this report).

Both projects were anticipated to continue under construction at least through Labor Day 2008. In addition, similar projects for replacement of the bridges in the opposing lanes were planned for the 2009 construction season. The location of these projects, only 12–15 miles apart and near a maintenance garage, as well as similar work in the succeeding season, made these sites ideal for the study.

Temporary traffic control (TTC) for these projects consisted of complete closure of the lanes of I-80 in the area of the bridge work with diversion of traffic to the opposing lanes via median crossovers to then pass the construction areas sharing the remaining two lanes in head-to-head travel with opposite direction traffic. Examples of this TTC are shown in the figures below.

Operation of DMS Equipment

DMS signs had previously been installed at these two sites for, both westbound (WB) and eastbound (EB), directions before this study commenced. However, the DMS signs at the WB Cass County location had been relocated to eastern Iowa for use in flooded areas and were not present at the beginning of the data collection. Therefore, it was determined this site would serve as a “control” location, with no DMS signs present. The locations and messages of all the DMS signs in Adair County are shown in Figures 2 and 3 and Table 1. These locations were also typical for the Cass County site, except for the previously mentioned WB direction at Cass County.

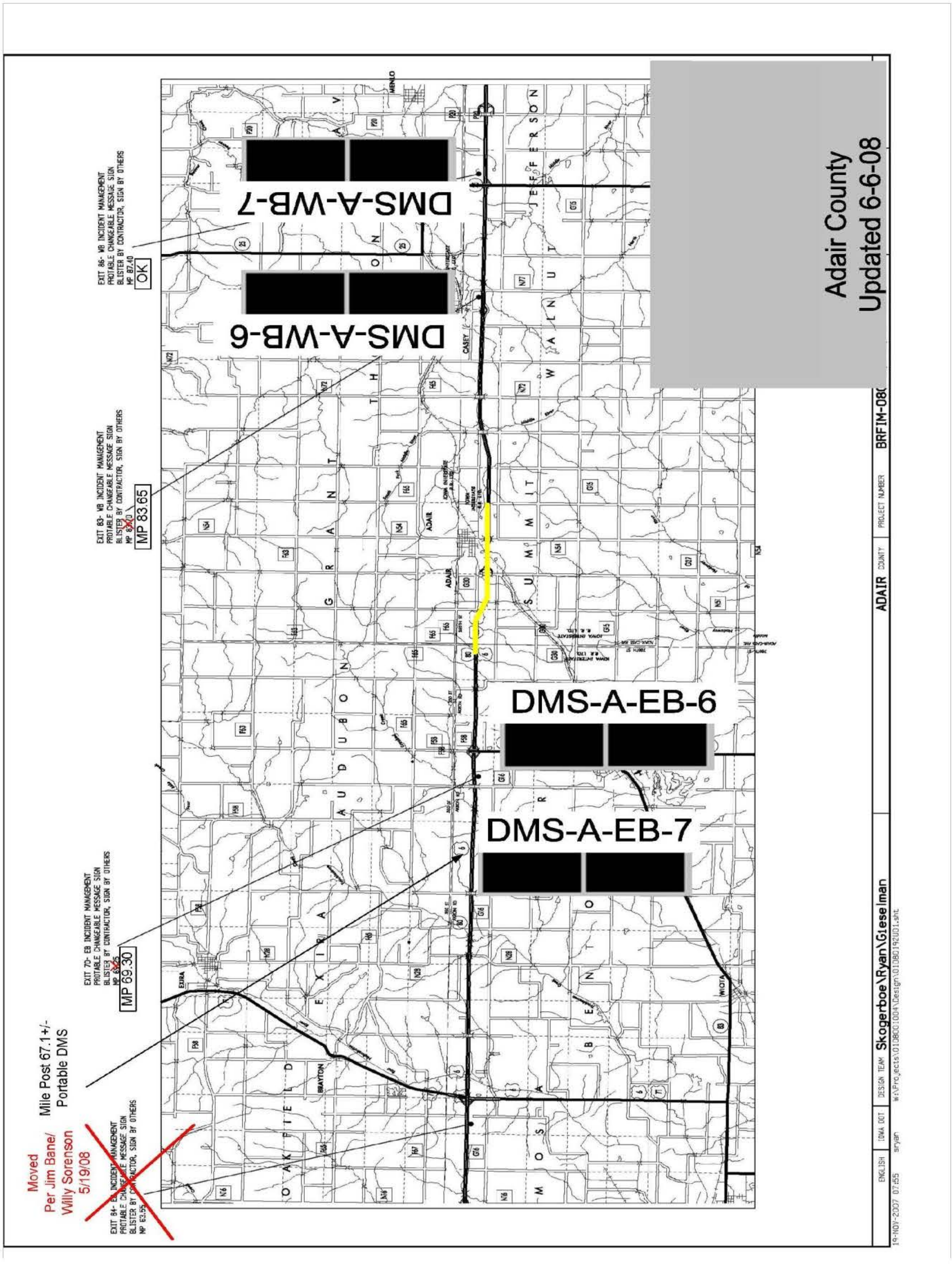


Figure 2. DMS 6 and 7 (placement for Adair County typical for Cass County location)

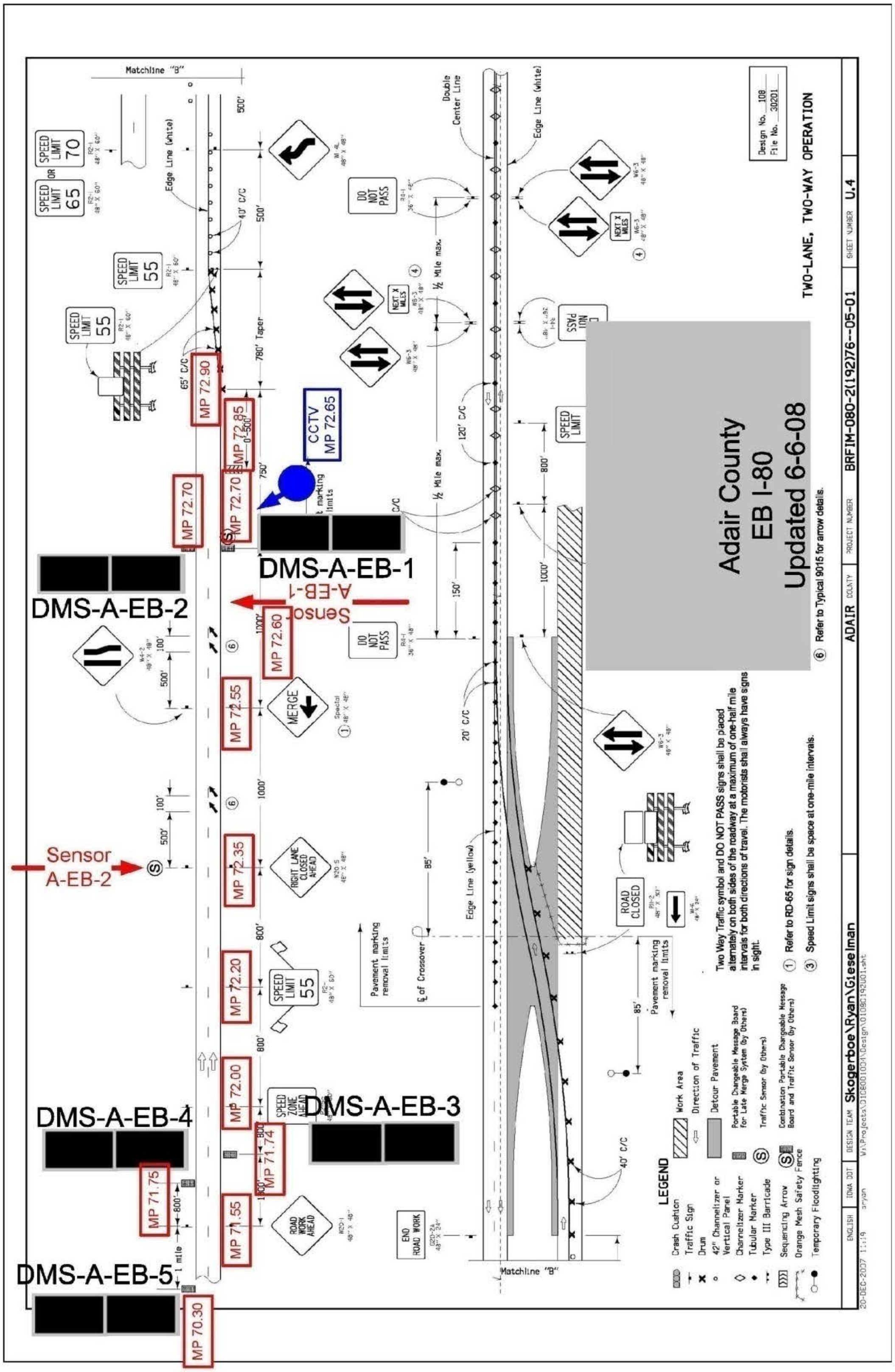


Figure 3. DMS signs 1–5 (placement for EB Adair County typical for Cass County locations)

Table 1. Dynamic Message Signs and messages

DMS Sign Identification	Traffic Flow Situations Message Presented		
	Free Flow	Transition	Congestion
EB-7	Off	Off	Slow Traffic Ahead Use Both Lanes
EB-6	Off	Off	Slow Traffic Ahead Use Both Lanes
EB-5	Off	Merge Ahead Use Both Lanes	Slow Traffic Ahead Use Both Lanes
EB-4	Off	Merge Ahead Use Both Lanes	Slow Traffic Ahead Use Both Lanes
EB-3	Off	Merge Ahead Use Both Lanes	Slow Traffic Ahead Use Both Lanes
EB-2	Off	Merge Here Take Turns	Merge Here Take Turns
EB-1	Off	Merge Here Take Turns	Merge Here Take Turns

To properly collect data to analyze DLMS effectiveness, the process for activating these signs needed to be understood, and the three possible modes of operation needed to be distinguished from each other. Those three modes are explained below.

The initial or normal free flow of traffic does not activate the DLMS and the signs remain blank during these periods, which proved to be most of the time during this study. During free traffic flow, no congestion or back-up of traffic occurs. DMS sign positions and messages (none) for this condition are shown in Figures 2 and 3 and Table 1.

A transition traffic flow condition may be defined by the DMS signs operator, who can revise the signs' messaging based on the relationship between a predetermined and preset upper limit "trigger" speed and the measured average traffic velocity in the merge area. The measured velocity is the average of two speed measurements, taken where sensors are placed. Note that there are two sensors, like the one shown in Figure 5, for each direction of travel. (sensor locations are displayed in Figures 2). These sensors are set to capture vehicle speeds at one-minute intervals, and the DLMS programming will change the message displayed if the average of those "simultaneous" speeds becomes less than the trigger speed. The average speed falling below the upper trigger activates the messages on DMS signs 1 through 5 in that direction of travel. The activated messages are shown in Table 1. The changed message on the signs provides traffic some guidance and awareness about one mile before encountering the TTC static signing. When traffic returns to normal speed and the average measured speed rises above the trigger speed, the DMS signs again become inactive and the sign face becomes blank.

However, if the average measured traffic speed continues to fall below the preset lower limit trigger speed, a congestion flow condition is reached. When this occurs, the DMS messages at locations 3, 4, and 5 changes from “Merge Ahead” to “Slow Traffic Ahead,” The DMS messages at locations 6 and 7 are activated with the messages “Slow Traffic Ahead” and “Use Both Lanes”.

When the average measured traffic speed rises above the lower trigger speed, the DMS messages revert to the transition flow messages and when the average speed rises above the upper trigger speed, the DMS signs again become inactive or blank.

Data Gathering Equipment and Operation

The prime contractor for the entire Lane Merge “package” was Quality Traffic Control (QTC) of Des Moines, IA. ASTI of New Castle, DE provided the cameras, Wavetronics speed sensors, and cellular communications. The portable DMS signs were manufactured by Precision Solar Controls (PSC) of Garland, TX. The DMS signs were 76 in. in height and 127 in. in width. Each unit was capable of displaying up to three lines of text and up to eight characters on each line, with an individual character size of 18 in. tall and 12 in. wide. These trailer-mounted signs are located on the shoulder facing traffic, and normally the bottom of the sign is 5 to 6 ft. above the shoulder (Figure 4). Telescoping masts on other trailers were capable of extending to a height of 162.5 in. for mounting cameras or speed sensors (Figure 5).

Figure 4. Typical installation (may include the DMS, left, and sometimes a solar-powered video camera, right) (photo courtesy of Iowa DOT)

Figure 5. Speed sensor (photo courtesy of Iowa DOT)

To obtain traffic volumes, speeds, and vehicle classifications that correlated to the operation of the DLMS, the locating of equipment for data collection were very important. It was desirable to determine the lane merge habits of drivers when

- no DMS signs were present, WB Cass County only (free flow traffic conditions-control),
- DMS signs were present, but not activated (free flow velocity greater than 50 mph),
- DMS signs were activated, with average measured traffic speeds less than 50 mph but greater than 30 mph, transition traffic flow, and when
- DMS signs were activated, with average measured traffic speeds of less than 30 mph, congested traffic flow.

At the control location in the WB lanes at the Cass County site data was collected where no DMS signs were present during the first observation period. (If these results are not found significantly different from the data at the observation sites where the DMS signs are installed but not operating, both of these sets of data may be combined to provide a larger control base.)

For all data collection locations and times, the following equipment positions were used for gathering the speed, volume, and classification data that were the basis of the study analyses:

- P1 position in both lanes at the approximate location of the TTC static “Road Work Ahead” signs, which were installed about 6,450 ft in advance of the lane closure taper, which is point of lane closure. Data from this location was utilized for determining total and unrestricted traffic data or free flow conditions.
- P2 position, in the lane being closed, at a location approximately 135 ft beyond the TTC “Left [or Right] Lane Closed Ahead” signs, or about 2,615 ft in advance of the point of

closure. Determining the actual placement of data gathering equipment at the P2 and P3 positions was often a compromise between allowing adequate driver reaction time after viewing the dynamic messaging signs and selecting a safe location and sight distance for data equipment placement.

- P3 position, in the lane being closed, at a location approximately 125 ft past the TTC "Merge" and Lane Ends Symbol signs, or about 1,625 ft in advance of the point of closure.

Once selected, these data gathering positions were used for all the observation periods. See Figure 6 for placement of data gathering equipment relative to DMS signs.

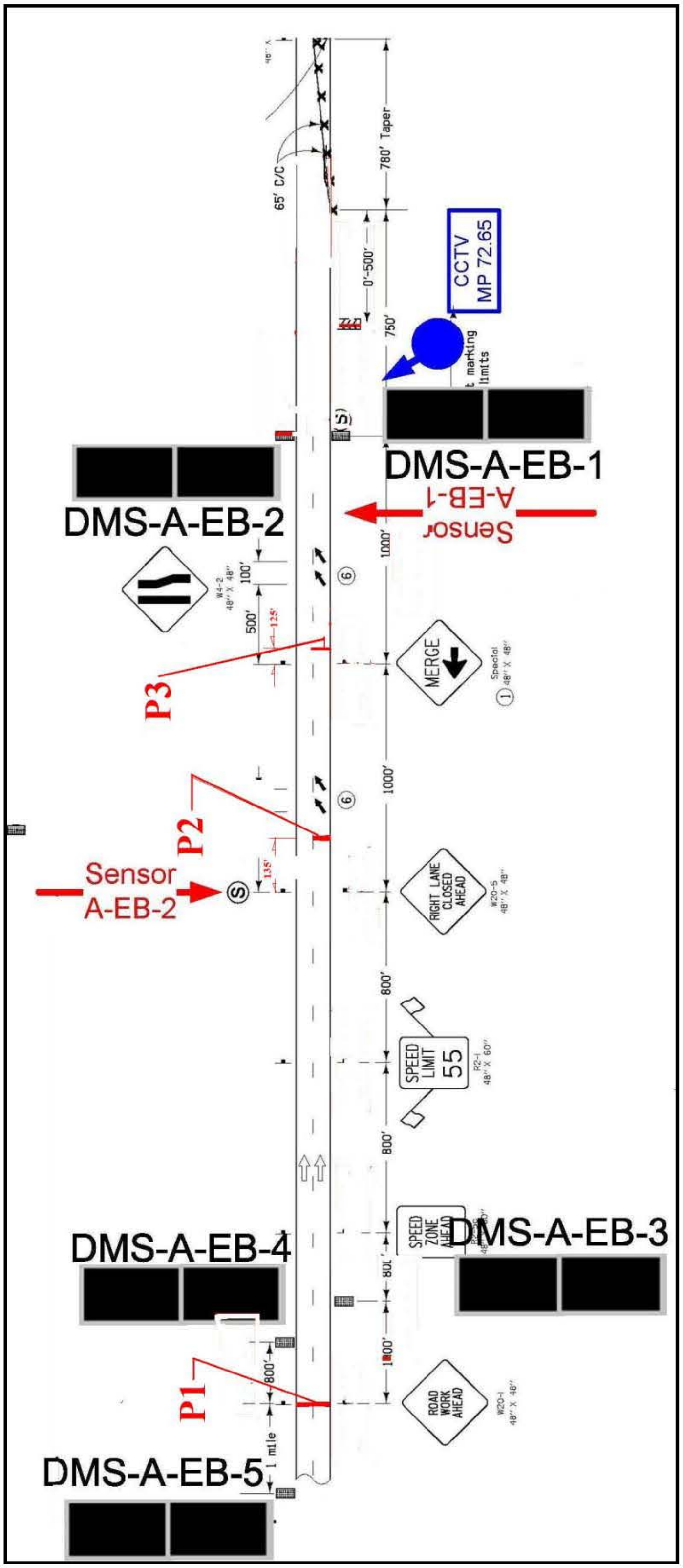


Figure 6. P1, P2, and P3 positions relative to static TTC and DMS signs

Following location selection for data gathering, the equipment to be used was obtained and examined for proper operation. Data gathering was initiated using heavy-duty road tubes and Jamar model TRAX Flex HS counters, shown in Figure 7 (see product specifications in Appendix B). Heavy duty tubes were selected in consideration of anticipated wear from high volume truck traffic.

Figure 7. Typical Jamar counter and HD road tubes (photo courtesy of Brad Grefe, CTRE)

By using four properly spaced tubes at the P1 counter location, traffic volume, speed, and vehicle classification was obtained in both lanes simultaneously.

Two properly spaced road tubes at the positions P2 and P3 were required to record the traffic volumes, speeds, and vehicle classifications in the lane being closed. (See Figure 7 for locations chosen.) Open lane data were determined mathematically at both the P2 and P3 positions as the difference in the total P1 information (both lanes) minus the data for the respective closing lane information at P2 and P3.

Once sufficient data were obtained, driver behavior was to be defined by the percentage of drivers (by vehicle classification) that remained in the closing lane at P2 and P3 during the three possible DMS messages.

Once the parameters were selected by the DOT to determine when the DMS sign messages would activate, all traffic data for both lanes was determined at P1, and the vehicle percentages for each desired element and situation were calculated and tabulated.

The process of sorting, calculating, and tabulating the data was repeated for any time periods when the measured traffic speed fell below the trigger speeds at P2 and/or P3, which activated the DLMS, as detailed in Table 2.

Any final conclusions for the DLMS effectiveness were to be based on the locations of lane merges, as defined by significant shifts in the noted percentages of vehicles, by classification remaining in the closing lanes at positions P2 and P3.

The collected data was summarized in the form shown in Table 2.

Table 2. Sample data tabulation form

	DMS-No Message >50 mph Free flow traffic			**DMS-Message On <50 mph Transition flow traffic**			**DMS-Message On <30 mph Congested flow traffic**		
	Percent of total traffic in closing lane			**Percent of total traffic in closing lane**			**Percent of total traffic in closing lane**		
Vehicle axles	**at P1**	**at P2**	**at P3**	**at P1**	**at P2**	**at P3**	**at P1**	**at P2**	**at P3**
2	23	18	8	25	20	12	25	24	12
3–4	5	3	1	6	4	2	8	6	2
5+	13	9	5	15	10	6	14	12	8

DATA COLLECTION

Data collection was conducted over four separate weekends. The data collection periods were from the Friday at 12:00 pm till the following Monday at 8:00 am. Traffic volumes during these time periods were anticipated to be highest, at two separate approaches to the construction areas on I-80 near the Adair County and the Cass County exits.

NuMetric plates were installed by centering the plate in the middle of the driving lane and placing a cover of 12” wide road tape, with the non-adhesive backing still attached, over the top of the unit and then taping the corners and edges with strips of 4” wide road tape. . The Jamar road tubes were installed by laying the tubes in the vendor specified setup pattern and using 4” wide road tape to hold the tubes to the pavement. At position 1, two tubes were laid across both lanes with two tubes across one lane. Positions 2 and 3 the tubes were only installed in the lane that was to be closed. Both types of equipment were used in each location to provide a back-up in case of failure of some units and as an opportunity to compare results from different data collection methods. Notes from the collection periods at each installation site are described below.

August 1–4, 2008

Approach at WB Cass County

No DMS signs were on site because of their use in flooding areas in other parts of the state. Consequently, this location was used as the control location for this study. Heavy-duty road tubes were used with Jamar traffic counters and NuMetrics electronic plates at this location for this observation period from Friday p.m. through the following Monday a.m.

Approach at WB Adair County

DMS signs were in place at this location, with the trigger speeds preset with a 50 mph upper limit and a 30 mph lower limit for activating the sign messaging as was explained earlier. Heavy-duty road tubes were used with Jamar traffic counters for this observation period from Friday p.m. through the following Monday a.m.

General note: Even with the Adair County Iowa DOT maintenance personnel providing excellent traffic control, the high volume of traffic on I-80 made the operation of laying the road tubes, especially in the open lane, potentially hazardous when placing the hold-down tape. Particularly concerning was installation of tape near the centerline of the two lanes (Figures 8 and 9).

Figure 8. Position 1 setup (photo by Brad Grefe, CTRE)

Figure 9. Position 2 road tube setup with Iowa DOT truck in background (photo by Brad Grefe, CTRE)

Although cutting the tape and removing the tubes was a relatively quick operation, the removal of residual tape from the road tubes after use was a very extensive and laborious effort, though it was necessary for repeated usages. The NuMetrics plates initially used were older (1997) models and did not function well.

August 8–11, 2008

EB Adair County

DMS signs were in place at this location, with the trigger speeds preset for a 50 mph upper limit and a 30 mph lower limit for activation of messaging. In addition to the heavy-duty road tubes and Jamar counters, NuMetrics plates were again placed to gather data. The Jamar counter at location P2 did not function correctly, but the NuMetrics plate at that location did collect data for a substantial portion of this period. Therefore, the information gathered by both methods was compared and statistically tested for correlation and, when possible, the plate data was used to complete the information needed for analysis. (This also proved to be a safer, yet accurate, method of data collection since installation of the plates was a much quicker operation than required for road tubes.) The total observation period was from Friday p.m. through the following Monday a.m., but the only portion of data used was when all counters at a site were working, because it was later determined that data from the two collection systems were not compatible. Iowa DOT maintenance personnel noted an extensive traffic backup in the EB direction at Adair County on Friday from the early afternoon until approximately 9:00 p.m. and again on Sunday from about 5:00 p.m. to 9:00 p.m. Some tube damage was noted on P3: the end plug was missing and the tube pulled slightly from under the tape (see Figure 10). More illustrations of the tubes and hardware damage are included in Appendix C.

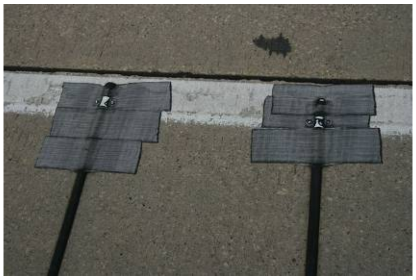


Figure 10. Road tube end plug missing (photo by Brad Grefe, CTRE)

EB Cass County

DMS signs were installed at this location, with the trigger speeds preset for a 50 mph upper limit and a 30 mph lower limit for activation of messaging. Heavy-duty road tubes with Jamar traffic counters were used for this observation period from Friday p.m. through the following Monday a.m.

Incorrect connection of the road tubes at location P1 required data manipulation before processing to provide a corrected data set for this counter. A severed road tube found at the P2 position may have been caused when the metal end plate embedded in a vehicles’ tires. (see Figure 11).

Figure 11. Severed end of road tube (photo by Brad Grefe, CTRE)

General note: Once again, even with the Iowa DOT traffic control in place, the same safety issues described earlier were still a concern. Additionally, only data before failure were retrievable and were analyzed.

Several of the older NuMetrics plates again did not function correctly during this test and were returned to the vendor for repairs. It was proposed to purchase new models of NuMetrics plates for completing this (and future) research.

August 14–18, 2008

EB Adair County

DMS signs were in place at this location. However, due to extensive traffic speed reductions the previous weekend the trigger speeds were reset for a 40 mph upper limit and a 20 mph lower limit for activation of the messaging. The heavy-duty road tubes with Jamar counters were used at the P2 and P3 locations, supplemented with older NuMetrics plates borrowed from the Iowa DOT District 5 office. Data at the P1 position in both lanes were obtained only from the NuMetrics plates to minimize the installation time in the open lane. (Figures 12 and 13)

Figure 12. Placing NuMetrics plate counter (photo by Brad Grefe, CTRE)

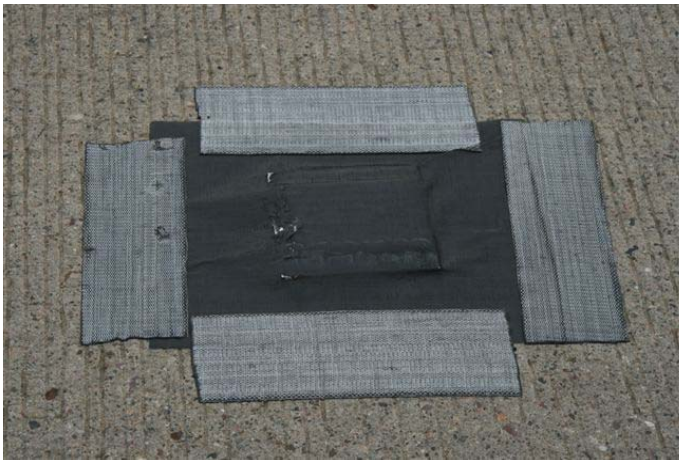


Figure 13. Typical NuMetrics plate counter installation (photo by Brad Grefe, CTRE)

Additionally, the counters were placed on a Thursday morning, instead of Friday, in the hopes that traffic volume was reduced somewhat. Pickup of the equipment was accomplished on the following Monday a.m.

WB Adair County

DMS signs were in place at this location. Trigger speeds were reset with a 40 mph upper limit and a 20 mph lower limit for activating the messaging. Although the Iowa DOT hoped that this adjustment would reduce the number of DMS activations, this action also reduced the potential data that would be collected during activation periods. Heavy-duty road tubes (in the closing lane only) were used with Jamar traffic counters and NuMetrics plate counters installed at all other positions during this observation period from Thursday a.m. through the following Monday a.m.

General notes: With the static Iowa DOT TTC in place and the placement of the road tubes only in the closing lane, safety risks were minimized. Most of the older NuMetrics plates had been returned for repairs, and the borrowed District 5 plates were again used here.

October 17–20, 2008

In anticipation of a large volume of traffic being generated on Interstate 80 by Nebraska football fans traveling to and returning from a football game at Iowa State University in Ames , it was decided to gather traffic data for this weekend. Only NuMetrics plate counters were used at the Cass County location in both EB and WB lanes. For this study the plates were programmed to collect data from Friday at 12:00 pm through Monday at 1:00 am. The revised study period was in response to expected higher traffic levels and issues with NC-97 model plates ending studies early because of insufficient memory. In addition the plates collected data into 1-hour bins to allow for greater data collection. The Cass County (Atlantic) DMS signs seemed to have the most activity so this site in the EB lanes was chosen for data collection. This week’s data collection therefore required very minimal time for research staff to install and remove equipment in the open lane of traffic (for two plates in the P1 positions only).

EB Cass County

DMS signs were present at this location. Trigger speeds were set with a 40 mph upper limit and a 20 mph lower limit for activation of the messaging. The four recently repaired older model NuMetrics plates (Figure 14) were used at all EB locations, with no road tubes placed. The plates were programmed to begin data collection on Friday at noon until Monday at 1 a.m. in 60 minute bins.

Figure 14. NuMetrics plates, older model Hi Star NC- 97, left, and new model NC- 100/200, right (photos from www.qttinc.com)

WB Cass County

DMS signs were in place at this location with trigger speeds set with a 40 mph upper limit and a 20 mph lower limit for activation of the messaging. Four of the newly arrived Model NC-100/200 NuMetrics plates (Figure 14) were used for data collection. The plates were programmed to become active on Friday at noon and end on Monday at 1 a.m. in 60 minute bins.

General notes: Previously, the researchers had only occasional anecdotal verification from motorists that the DMS signs were providing the designed messaging during actual traffic slowing and back-up periods. However, e-mails messages generated by the DMS system for activations below and above the trigger speeds were sent to Iowa DOT staff by the DMS vendor and, beginning on September 26th a copy of these notices were provided to the researchers. To verify the correct operation of the DMS equipment, the on-site cameras (Figure 15) had previously been redirected to provide a view of the DMS signs to assure that they were functioning properly.

WB Adair County

EB Adair County

EB Cass County

WB Cass County

Figure 15. Video cameras views at all four data collection sites (photos by Iowa DOT)

DATA REDUCTION AND ORGANIZATION

Jamar Download

Raw data from the Jamar analyzer (road tube) were downloaded to the computer through a serial port cable. The Jamar analyzer utilized TraxPro software to download the data. This program allows the user to define parameters such as the time period in which the user is interested and has limit capabilities in producing graphs and reports. TraxPro can export the data into Microsoft Excel for data manipulation. The Jamar data downloads in a sequential order, and therefore each line of the Excel spreadsheet represents data for one vehicle. These data included the vehicle speed and length, which are important for this study.

NuMetrics Downloading

Data from the NuMetrics plates were downloaded through an interface that connects the plate to the processing computer. NuMetrics utilized Highway Data Management (HDM) and Highway Data Sequential (HDS) programs for data downloading and analysis. The NC-97 plates used HDM software, while NC-200 plates can utilize either HDM or HDS programs. Similar to the TraxPro software, these programs have report creation capability or can export the data into Excel spreadsheets. However, unlike the road tubes, the older NC-97 plates bin data into bins of varying length with a minimum 15 minute time period. The data includes total volume for that period, average speed, and the number of vehicles that fall within a certain length.

Tables

After the data had been downloaded from the analyzers and exported into Excel, it was possible to identify vehicle speeds below the thresholds set for each weekend. Using the conditional formatting tool on Excel, the cells containing speed data were assigned colors based on which threshold the speed fell below. With colors assigned to cells, blocks of slowdown periods were easily identifiable. Periods of DMS activation were noted by determining common periods during which the measured speeds at both P2 and P3 were less than the trigger speeds (initially 50 mph and 30 mph).

Information pertaining to those specific traffic slowdown (transition and congestion) periods was entered into a table to summarize volume and average speed for the time period(s). Data were also presented in the tables to depict average speed and volume for time periods when the traffic was flowing at speeds greater than the determined thresholds (free flow). In addition, the tables showed total traffic for the closed lane as gathered from the traffic analyzers. By subtracting the difference in the number of vehicles recorded between different positions in the closing lane (e.g., Position 1 minus Position 2 or Position 2 minus Position 3), the number of vehicles in the open lane could be ascertained. Additionally, this information was disseminated into vehicle classifications.

To separate data into vehicle classifications, the conditional formatting tool in Excel was utilized. The desired divisions were identified by colors using the length data gathered by the analyzer. After assigning colors to the vehicle lengths, the “Filter” function was then applied to all the columns narrowing the data down to the selected vehicle class. By highlighting the speed column and filtering by colors, an average speed for the selected class could be gathered. The plate analyzers bin the vehicles by length requiring the user to add column data together into three classifications. Volume by vehicle classification could then be determined from the combined column information

Graphs

Graph data utilized the same data utilized for table creation. Because of the large quantity of data gathered by the traffic analyzers, it was prohibitive to show all the individual data. Therefore, the data for volume, speed, and vehicle classification were binned into 15 minute periods. Graphs were created for volume, average speed, and vehicle classification for Position 1 road tubes and plates for each location for each weekend. The Jamar sequential data was narrowed to only the data that were necessary to create the graphs (Date, Time, Length, and Speed). To reduce the sequential data to 15 minute bins, the times recorded for individual vehicles was isolated using the text-to-column feature in Excel. By separating the recorded times by the colons in the time stamp, hours, minutes, seconds, and a.m./p.m. were split into separate cells. With these data, it was possible to create 15 minute periods of time by utilizing the CONCATENATE formula in Excel. This formula utilized the minute column that was created from the time stamp to assign a number between 1 and 4. Number 1 is for the first quarter of the hour (:00–:14), number 2 is for the second quarter (:15–:29), number 3 is for the third quarter (:30–:45) and number 4 covers the final quarter of the hour (:45–:59). To obtain the volume, a count was taken using the subtotal function of the lines of data that fell into each of the four quarters. The counts were copied into a summary spreadsheet to create a graph. The subtotal function was used again to obtain the average speed data for each of the quarters, with the results copied into the summary spreadsheet.

Finally, the vehicle classifications for the time quarters were calculated by using the CONCATENATE formula to divide the data into quarters. An additional column was added to apply a class number based on the length of the vehicle using an (IF Statement) formula. This formula assigns a number 1 through 3 based on the length of the vehicle. Three more columns were added, one for each of the vehicle classifications. Using another IF formula, a 1 was placed in the corresponding column based on the length of the vehicle. Using the subtotal function, the 1s in each column were added up, providing the number of each class of vehicle. The results of this subtotal were also carried over to the summary spreadsheet.

DATA SUMMARY, STATISTICAL REVIEW, AND EVALUATION

Comparing Vehicle Classification (WB Adair County Position 2, August 14–18)

Since different data gathering systems were used during this study, it was concluded that a comparison of results from the Jamar and NuMetrics equipment would be advisable.

A test of proportions was used to determine whether vehicle classifications were similar with the two data collection methods used. Volume data from an older NuMetrics plate were compared to Jamar pneumatic road tube data at the P2 position on the third weekend to evaluate whether the proportion of different vehicle classes was similar.

The test of proportionality is given by (Ott and Longnecker 2001).

$$z = \frac{\hat{\pi}_1 - \hat{\pi}_2}{\sqrt{\frac{\hat{\pi}_1(1-\hat{\pi}_1)}{n_1} + \frac{\hat{\pi}_2(1-\hat{\pi}_2)}{n_2}}} \qquad (1)$$

Where:

z = z-statistic

$\hat{\pi}$ = sample proportion (number of successes divided by sample size (*n*))

n = sample size

The null hypothesis is that the proportions are the same.

The difference in volumes over four days was 1,054 vehicles (approximately 250 vehicles per day). It would appear that either the NuMetrics units are underestimating or the Jamar system is overestimating the recorded traffic volumes. The significance of this will be discussed later in this report. Assuming two axles represents a passenger vehicle (PC), three or four axles represents a single-unit vehicle (SU), and five or more axles represents a multi-unit, vehicle, class percentages are provided in Table 3. As shown, the Jamar and NuMetrics methods provide different proportions for all vehicle classes (PC, SU, and MU). The differences were statistically significant at the 95% level of significance. However, as shown, the differences are not large (0.2% for PC, 1% for SU, and 0.2% for MU).

Table 3. Percentage vehicles in each classification using tube and plate counters

	Jamar	**NuMetrics**	**Assessment**
PC	90.1%	88.9%	Difference is statistically significant
SU	2.9%	3.9%	Difference is statistically significant
MU	7.0%	7.2%	Difference is statistically significant

Table 3 suggests that even if the volume estimates were similar, the NuMetrics and Jamar may not be classifying vehicles in the same manner.

Comparing Speed (WB Adair County Position 2, August 14–18)

A reliable test for speed data comparison between the collection systems could not be devised, because the data binning could only permit comparison of an average of an average. However, the data are roughly normally distributed and similar to standard speed study results, so a statistical t-test was performed on the speed data. The p value was 0, which indicates that the speeds were not the same at the 95% level of confidence. Therefore, it can be concluded that although the speeds calculated by the two devices are not statistically the same, they are comparable for all practical purposes.

Comparing Volume (WB Adair County, Position 2, August 14–18)

A statistical test of proportions was performed on the traffic volume data collected from each system. If it is assumed that the Jamar system analyzer provides the most accurate data, the chi-squared test can be used to determine whether the NuMetrics device provides comparable results. However, the test of proportions indicated that the volume data from these two systems were not the comparable at the 95% level of confidence, so it might be concluded that the two systems are not collecting data in the same manner. Again, they should be comparable for purposes of this study.

Statistical Analysis of Merging Behavior

Tables 4 and 5 show the results of the statistical t-tests for variation in vehicle merging actions with the DMS messaging activated and without that messaging (DMS signs blank). The data utilized here focused on time periods when vehicle speeds were below pre-determined trigger speeds.

Table 4 shows the results from August 1 when there were two periods where average traffic speed was below the 50 mph upper trigger. An objective of this study was to compare the percentage of vehicles by class from the total number of vehicles (both lanes) that were in the closing lane at position 1 with the percentage still in that lane at positions 2 and 3. The column titled “No DMS” (signs off) shows the percentage of total vehicles by class of traffic flowing at greater than 50 mph. The “with DMS” (signs on) column shows the percentage of total vehicles by class of traffic flowing at less than 50 mph but greater than 30 mph.

Table 4 shows that at position 2 and 3, vehicles with 2 axles show a higher percentage in the closing lane when the DMS’s are off than when activated. This is the opposite of what was anticipated. Vehicles with 5+ axles show the opposite, in that there are a greater number of large trucks in the closing lane when the DMS’s messaging is activated. Vehicles with 3-4 axles also show a greater percentage in the closing lane at positions 2 and 3 when the DMS signs are activated. Note however that some of these observations are not statistically different at a 95% confidence level.

Table 3. Statistical testing results of vehicle merging WB Adair County August 1, 2008

Comparing no DMS > 50 to With DMS < 50
Percentage of Vehicles in closing lane of Total Traffic Recorded at Position 1

	Fraction merging at point (i)					
	at P1		**at P2**		**at P3**	
Vhcle Axles	No DMS	With DMS	No DMS	With DMS	No DMS	With DMS
2	33%	35%	27%	24%	11%	8%
	stat different at 95%		stat different at 95%		stat different at 95%	
3–4	17%	23%	14%	15%	6%	21%
	not stat different at 95% but statistically different at 90%		not stat different at 95% or 90%		stat different at 95%	
5+	13%	15%	9%	15%	4%	7%
	not stat different at 95% or 90%		stat different at 95%		stat different at 95%	

Table 5 shows the percentage of vehicles for the significant reduction in traffic speed recorded on August 8 in the EB lanes of Adair County. Vehicles with 2 axles and 5+ axles have a higher percentage of vehicles in the closing lane at positions 2 and 3 with the DMS signs off. This, is also opposite of what was expected. However, 3–4 axle vehicles show a higher percentage of vehicles in the closing lane at position 2 when the DMS's are on. At position 3 the data shows that there is a similar percentage of 3–4 axle vehicles in the open and closing lane. Again, some of these observations are not statistically different at a 95% level of confidence.

Table 4. Statistical testing results of vehicle merging EB Adair County August 8, 2008

Comparing no DMS > 50 to With DMS < 30
Percentage of Vehicles in closing lane of Total Traffic Recorded at Position 1

	Fraction merging at point (i)					
	at P1		at P2		at P3	
Vhcle Axles	No DMS	With DMS	No DMS	With DMS	No DMS	With DMS
2	65%	35%	48%	31%	19%	14%
	stat different at 95%		stat different at 95%		stat different at 95%	
3–4	40%	38%	33%	48%	16%	16%
	not stat different at 95% or 90 %		stat different at 95%		not stat different at 95% or at 90%	
5+	48%	42%	29%	20%	15%	13%
	stat different at 95%		stat different at 95%		stat different at 95%	

The results of the statistical testing indicate that 3-4 axle vehicles show non-statistically significant differences at position 2 on August 1 and position 3 on August 8. While the 2 axle and 5+ axle vehicles results show statistically significant differences at positions 2 and 3 both weekends. A comparison of results for these weekends does not seem to indicate a consistent impact on driver merging behavior for any classification from the DMS messaging.

COMPARISON OF DATA COLLECTION SYSTEMS

During analysis and data review, some significant variations in the data were noted between collection systems. To assess these differences, a comparison of both systems was made against the Iowa DOT's permanent automatic traffic recorders (ATRs) at the Cass County (Atlantic) site. Side fire radar units, commonly known as "Wavetronics" in Iowa, have been mentioned as an alternative, but experiences of other researchers have shown that in addition to requiring "binning" of the data into time intervals, these units can not differentiate between lanes and may not record data accurately when two vehicles are parallel or in close proximity in adjacent lanes.

For EB direction of travel near ATR # 11530 a comparison was made using new NuMetrics plate data, and for the WB lanes near ATR # 11570, a comparison was made using Jamar road tube collection system. This ATR site, near MP 62 and two miles east of the US 71 (Cass County) Interchange, was chosen for comparing data because no interchanges are located between the ATR and data collection site that would possibly affect traffic flow in the WB lanes. The Jamar road tubes, near-by DLMS traffic data sensor, and ATR should all have experienced the same number of vehicles. For the EB direction traffic however it is possible that the data obtained with the new NuMetrics plates may not agree with the ATR data due to possible impacts on traffic volumes from the US 71 (Cass County) Interchange. Since no correlation could be established where all units had definitely measured the same vehicles in the WB lanes as described above, no analysis was performed for the data from EB lanes with the plates. Locations of all counters for this location (WB) are shown in Appendix A in Figure A.24 and tabulated in Table A.16. The data are summarized in Table A.17.

The older NuMetrics plates borrowed from the Iowa DOT District 5 office also proved to be unreliable, with only scattered success in their operation. Some were repaired but still did not function correctly, and others performed satisfactorily only sporadically. The statistical review of the older plates' counts, speeds, and classifications compared with data from the Jamar road tube counters revealed considerable inconsistencies. Moreover, when either of those traffic data were compared to the data taken from the permanent Iowa DOT ATR recorders, both systems yielded inconsistent results.

New NuMetrics plate data collectors were not available for use until the final weekend collection period in October 2008. Although the data collected by these new counters were the most consistent (i.e., about 8.5% lower) with the Iowa DOT ATR recorder results, other data comparison tests made near the CTRE office failed to provide sufficient data to correlate the results of the Jamar road tubes, the older NuMetrics plates, and the new plates .

Because the only useful data sets that were collected without relying on a combination of these data collection systems are those for the "control location" at WB Cass County and the transition periods observed at WB Adair County on the first weekend, August 1-4th. Therefore, the older NuMetrics plate data have been combined with the road tube data when available and necessary to provide the fullest possible analysis of each observation period. Therefore this report is able to provide general information only about the effectiveness of the DMS messaging during congested flow conditions, but cannot present the detailed statistical certainty that was initially intended.

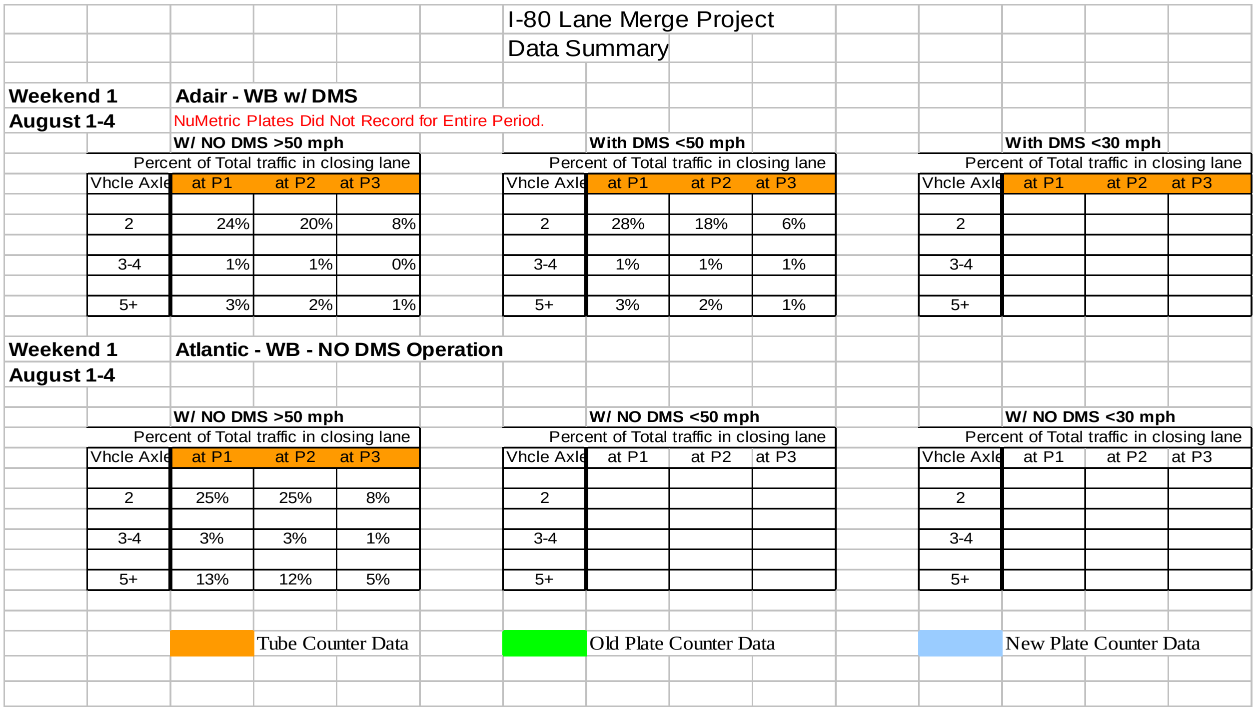
Although the number of trigger speed events experienced during the four weekends during which data collection was undertaken was very limited, one event, on August 8th at EB Adair County, was of sufficient duration to provide over 13,000 vehicles that could experience and react to the DLMS . Statistical standards would indicate that the quantity of data collected should be more than enough to provide a relatively accurate evaluation of DLMS effectiveness for influencing driver behavior if data collected by each system had been compatible.

Overview of Data

The cumulative data shown in Tables 6 through 8 represent the data collected at each location for weekend when the data collection devices at P1, P2, and P3 were all performing properly.

Two short periods of transition speed messages, one a period of 6 minutes involving some 211 vehicles and a second period of 39 minutes duration involving about 1,038 vehicles, occurred during the afternoon of August 1st at the WB Adair County site. These events were the only evidence found of the initial DMS sign activation during a transition period (average speed falling below the upper trigger). The data from both these short periods have been combined in Table 6. Data collection was all by road tube counters for this period and the “control location” at WB Cass County during the same collection period.

Table 5. Data summary from August 1–4 at WB Adair County and WB Cass County



I-80 Lane Merge Project
Data Summary

Weekend 1 **Adair - WB w/ DMS**
August 1-4 NuMetric Plates Did Not Record for Entire Period.

	W/ NO DMS >50 mph				**With DMS <50 mph**				**With DMS <30 mph**		
	Percent of Total traffic in closing lane				Percent of Total traffic in closing lane				Percent of Total traffic in closing lane		
Vhcle Axle	at P1	at P2	at P3	Vhcle Axle	at P1	at P2	at P3	Vhcle Axle	at P1	at P2	at P3
2	24%	20%	8%	2	28%	18%	6%	2			
3-4	1%	1%	0%	3-4	1%	1%	1%	3-4			
5+	3%	2%	1%	5+	3%	2%	1%	5+			

Weekend 1 **Atlantic - WB - NO DMS Operation**
August 1-4

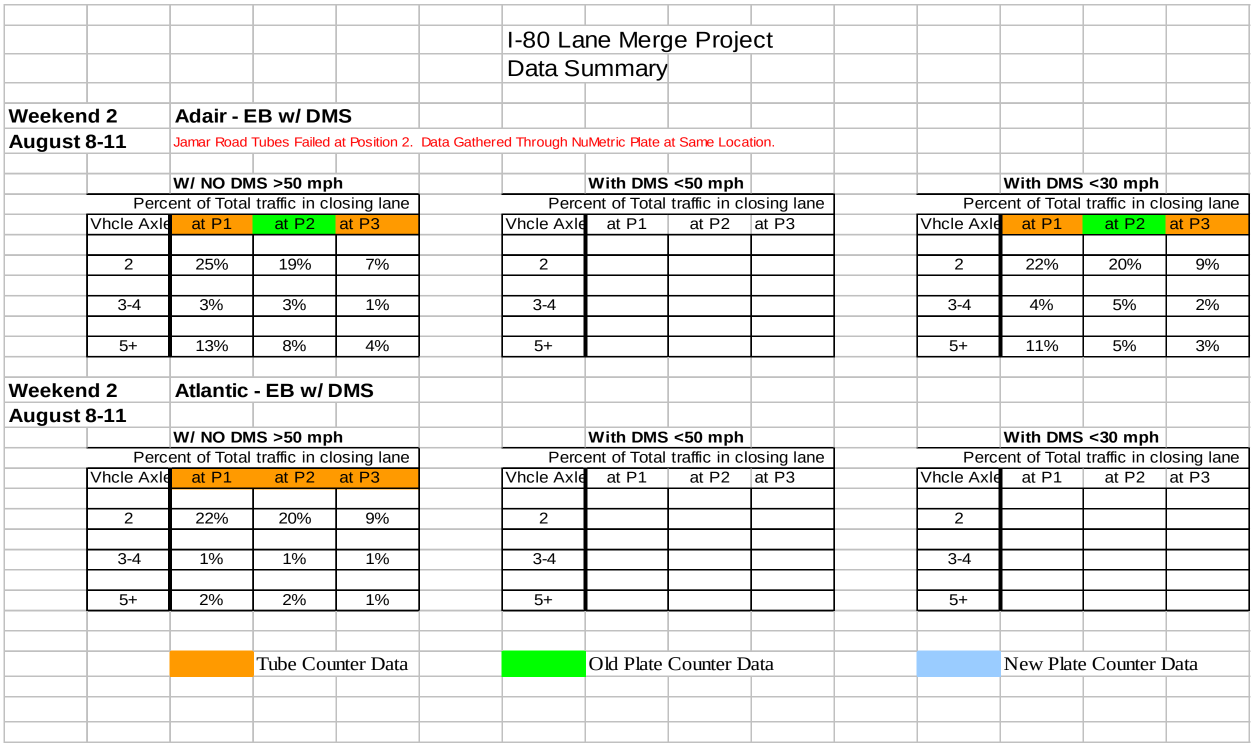
	W/ NO DMS >50 mph				**W/ NO DMS <50 mph**				**W/ NO DMS <30 mph**		
	Percent of Total traffic in closing lane				Percent of Total traffic in closing lane				Percent of Total traffic in closing lane		
Vhcle Axle	at P1	at P2	at P3	Vhcle Axle	at P1	at P2	at P3	Vhcle Axle	at P1	at P2	at P3
2	25%	25%	8%	2				2			
3-4	3%	3%	1%	3-4				3-4			
5+	13%	12%	5%	5+				5+			

🟧 Tube Counter Data 🟩 Old Plate Counter Data 🟦 New Plate Counter Data

A congestion speed event during the weekend of August 8–11 (Table 7) was of sufficient duration (about 8½ hours) that it involved nearly 5,000 vehicles. Many of those vehicles indicated speeds of less than 10 mph at the P1 position, which is the location of the initial static TTC signing (Road Work Ahead) from the point of lane closure. This speed reduction and traffic back-up period extended from 12:30 p.m. to 9:00 p.m. on August 8th. A review of the data for this congestion speed period, assuming that traffic data collected from the two systems were interchangeable, has indicated that there was no statistically significant difference in the drivers' behavior (i.e., lane change patterns) during the period in which the DMS messaging was activated for the lower trigger speed.

There was also a reduced speed and traffic backup period with speeds less than 10 mph on the evening of Sunday the 10th between about 5:45 p.m. and 8:15 p.m. This period was not analyzed because one of the counters had stopped operating earlier and a full set of data for the period was therefore not available. However, the active DMS signs that were furthest away (9.5 miles) from the closure point did provide additional warning to over 8 miles of potentially queued traffic, which included vehicles that had not yet reached the static TTC signing. Therefore, the DLMS did provide additional information and degree of safety for drivers, despite the apparent minimal impact on driver behavior regarding merging actions.

Table 6. Data summary from August 8–11 at EB Adair County and EB Cass County



I-80 Lane Merge Project
Data Summary

Weekend 2 **Adair - EB w/ DMS**
August 8-11 Jamar Road Tubes Failed at Position 2. Data Gathered Through NuMetric Plate at Same Location.

W/ NO DMS >50 mph

Percent of Total traffic in closing lane

Vhcle Axle	at P1	at P2	at P3
2	25%	19%	7%
3-4	3%	3%	1%
5+	13%	8%	4%

With DMS <50 mph

Percent of Total traffic in closing lane

Vhcle Axle	at P1	at P2	at P3
2			
3-4			
5+			

With DMS <30 mph

Percent of Total traffic in closing lane

Vhcle Axle	at P1	at P2	at P3
2	22%	20%	9%
3-4	4%	5%	2%
5+	11%	5%	3%

Weekend 2 **Atlantic - EB w/ DMS**
August 8-11

W/ NO DMS >50 mph

Percent of Total traffic in closing lane

Vhcle Axle	at P1	at P2	at P3
2	22%	20%	9%
3-4	1%	1%	1%
5+	2%	2%	1%

With DMS <50 mph

Percent of Total traffic in closing lane

Vhcle Axle	at P1	at P2	at P3
2			
3-4			
5+			

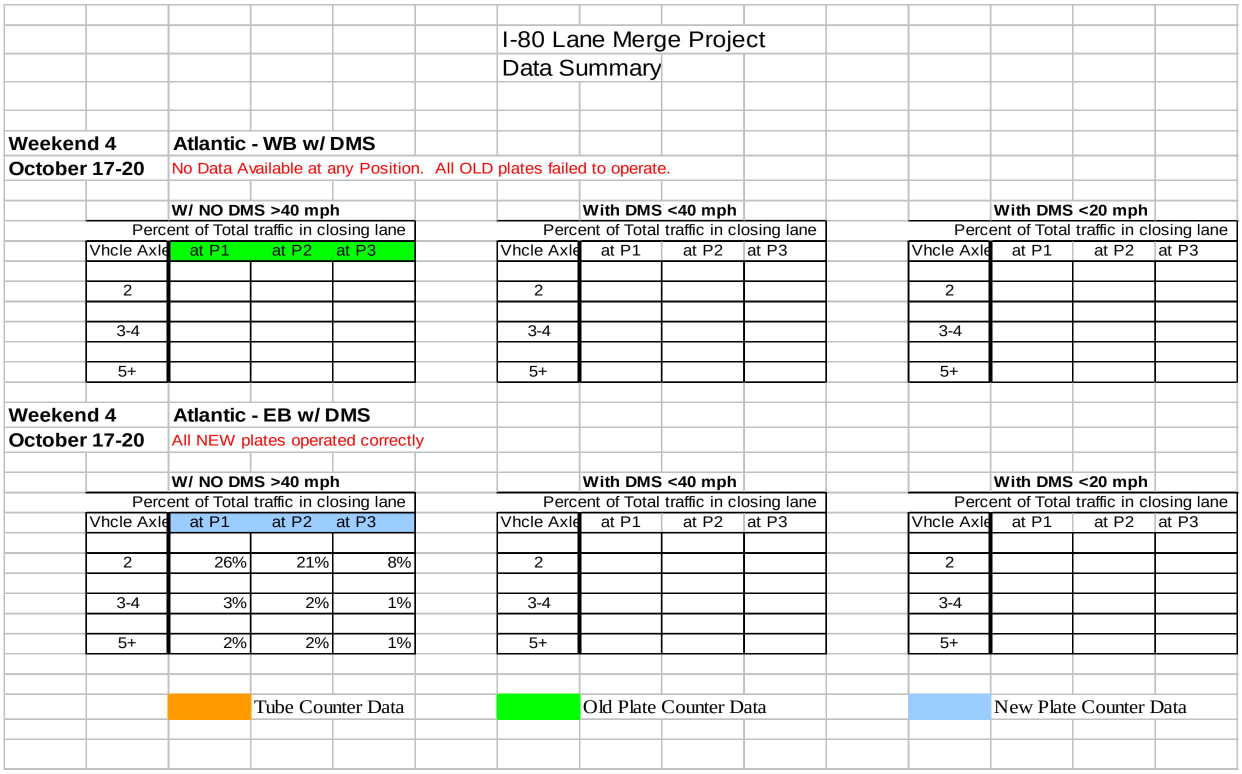
With DMS <30 mph

Percent of Total traffic in closing lane

Vhcle Axle	at P1	at P2	at P3
2			
3-4			
5+			

🟧	Tube Counter Data	🟩	Old Plate Counter Data	🟦	New Plate Counter Data

Table 7. Data summary from October 17–20 at WB Cass County and EB Cass County



I-80 Lane Merge Project
Data Summary

Weekend 4 **Atlantic - WB w/ DMS**
October 17-20 No Data Available at any Position. All OLD plates failed to operate.

W/ NO DMS >40 mph

Percent of Total traffic in closing lane			
Vhcle Axle	at P1	at P2	at P3
2			
3-4			
5+			

With DMS <40 mph

Percent of Total traffic in closing lane			
Vhcle Axle	at P1	at P2	at P3
2			
3-4			
5+			

With DMS <20 mph

Percent of Total traffic in closing lane			
Vhcle Axle	at P1	at P2	at P3
2			
3-4			
5+			

Weekend 4 **Atlantic - EB w/ DMS**
October 17-20 All NEW plates operated correctly

W/ NO DMS >40 mph

Percent of Total traffic in closing lane			
Vhcle Axle	at P1	at P2	at P3
2	26%	21%	8%
3-4	3%	2%	1%
5+	2%	2%	1%

With DMS <40 mph

Percent of Total traffic in closing lane			
Vhcle Axle	at P1	at P2	at P3
2			
3-4			
5+			

With DMS <20 mph

Percent of Total traffic in closing lane			
Vhcle Axle	at P1	at P2	at P3
2			
3-4			
5+			

🟧 Tube Counter Data 🟩 Old Plate Counter Data 🟦 New Plate Counter Data

Effect of Traffic Volume on Congestion

The possible relationship of traffic volume to the initiation of a transition speed or congestion period might be analyzed by reviewing the graphs located in Appendix A that show each weekend's data. Enlargements of the graphs for the periods leading up to the two transition speed periods on Friday, August 1, and the congestion periods on Friday, August 8, and Sunday, August 10, are shown in yellow in Figures 16 and 17.

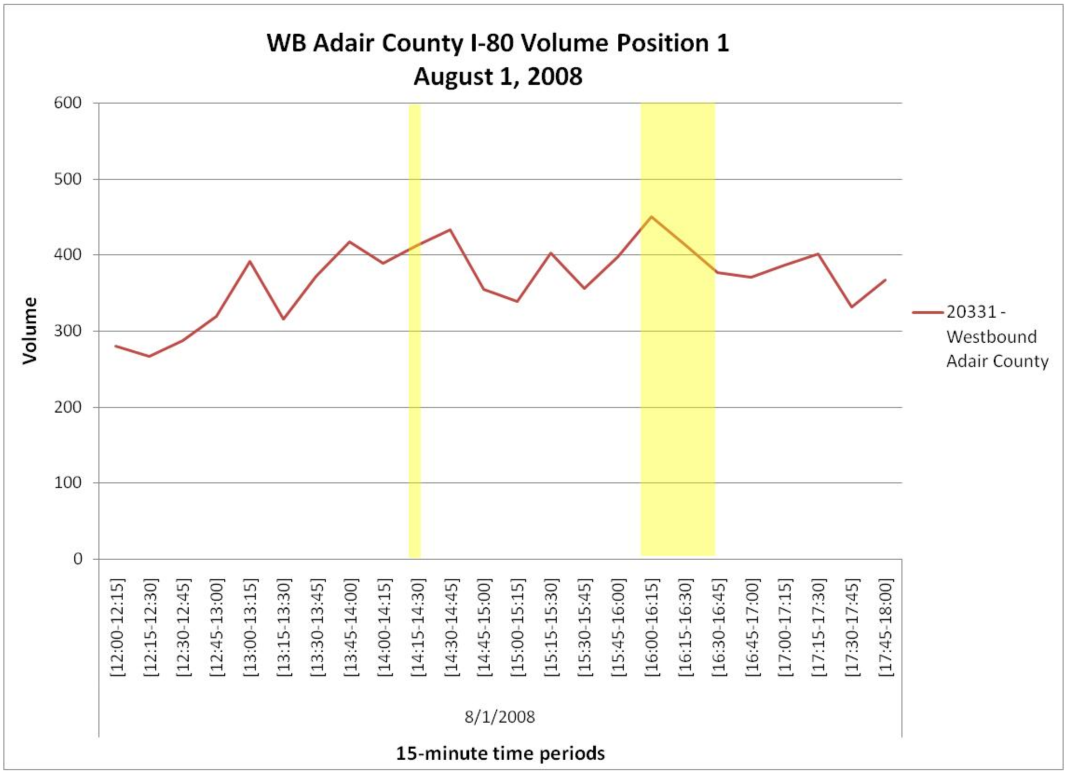


Figure 16. Traffic volume WB Adair County on August 1 during two transition periods

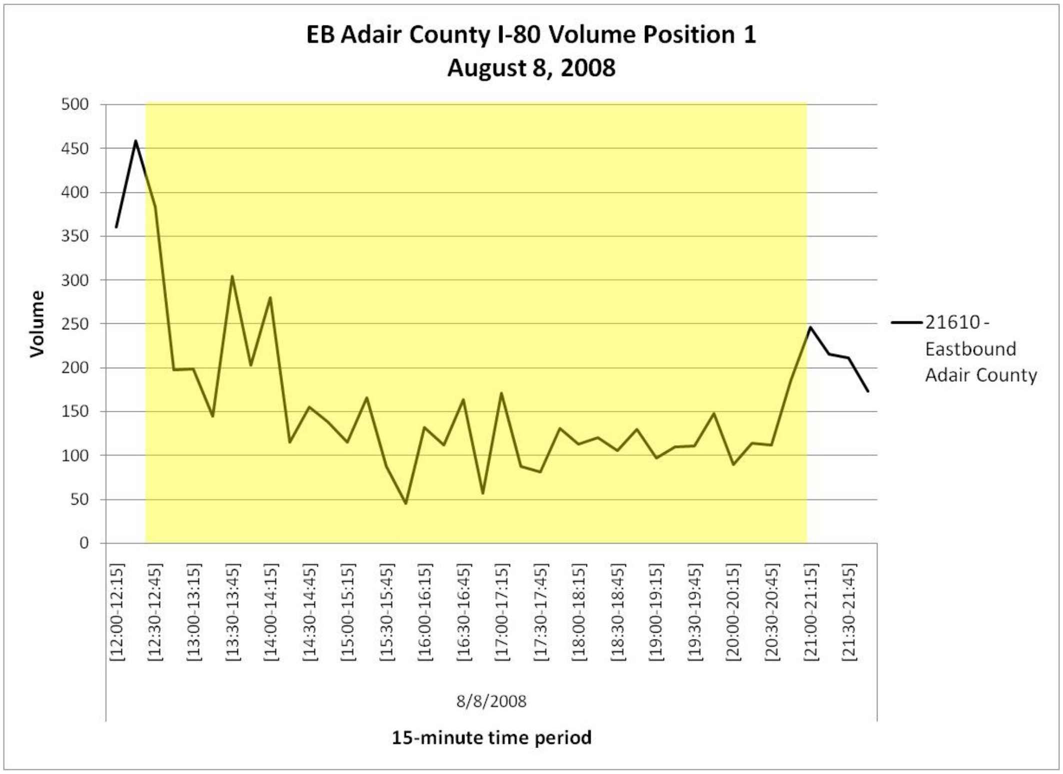


Figure 17. Traffic volume EB Adair County on August 8 during congestion period

In a review of the volume data from other weekends, four other periods were found to have equal or greater volumes (up to 450 vehicles per 15 minute period) during which no slowdowns or backups occurred. This observation might concur with the findings from the previously mentioned Minnesota study (URS 2004) that the maximum throughput on a single-lane construction area on rural Interstates is approximately 1,600 vehicles per hour.

Effect of Speed on Congestion

The relationship of traffic speed to the commencement of a congestion period may be analyzed by reviewing the graphs located in Appendix A that show each weekend's data. Enlargements of the graphs for the period leading up to the backup periods shown in yellow on Friday, August 8, and Sunday, August 10, are shown in Figures 18 and 19.

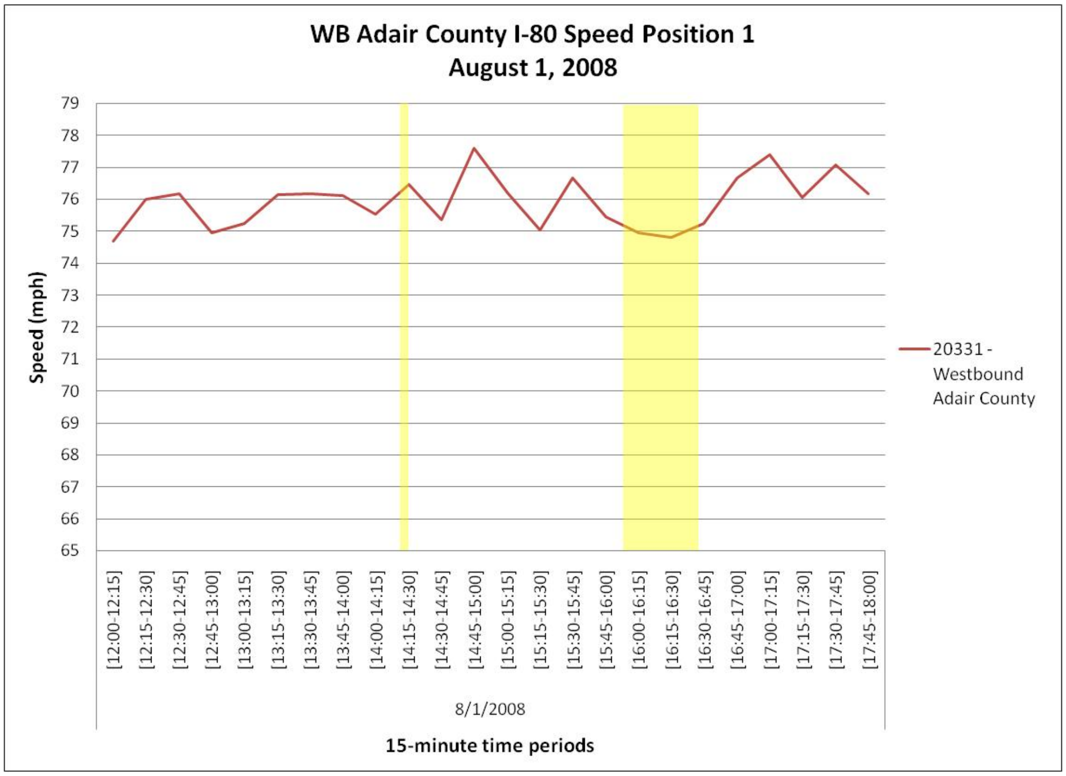


Figure 18. Traffic speed WB Adair County on August 1 during two transition periods

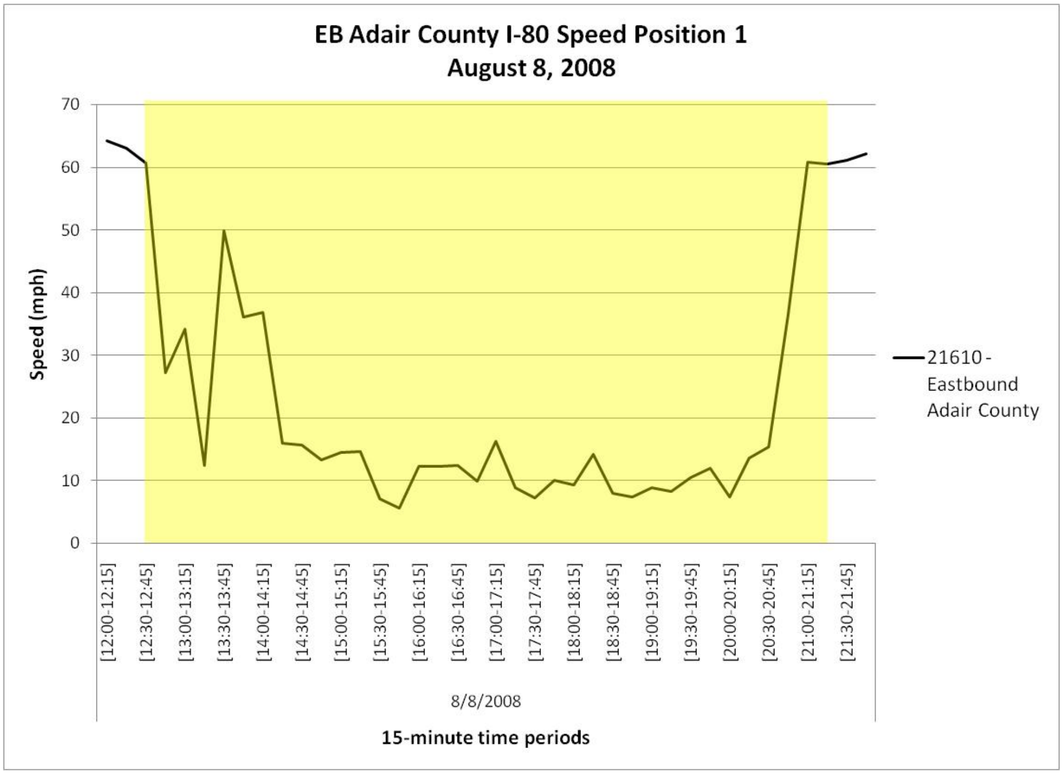


Figure 19. Traffic speed EB Adair County on August 8 during congestion period

A review of the data collected during other weekends indicated several other time periods when equal or lesser average speeds were recorded during which no traffic slowdowns or backups occurred. It appears that average vehicle speed is not a causal factor for congestion, but rather a consequence of that congestion. However, it is also obvious that a random slow moving vehicle could be the cause of a significant slowing of all traffic in a single lane during times of high traffic volumes.

Effect of Vehicle Classification on Congestion

The relationship between traffic classification (i.e., number of heavy (5+ axle) trucks) and the commencement of a congestion period may be analyzed by reviewing the graphs found in Appendix A that show each weekend’s data. Enlargements of the graphs for the period leading up to the backup periods shown in yellow on Friday, August 8, and Sunday, August 10th, are shown in Figures 20 and 21.

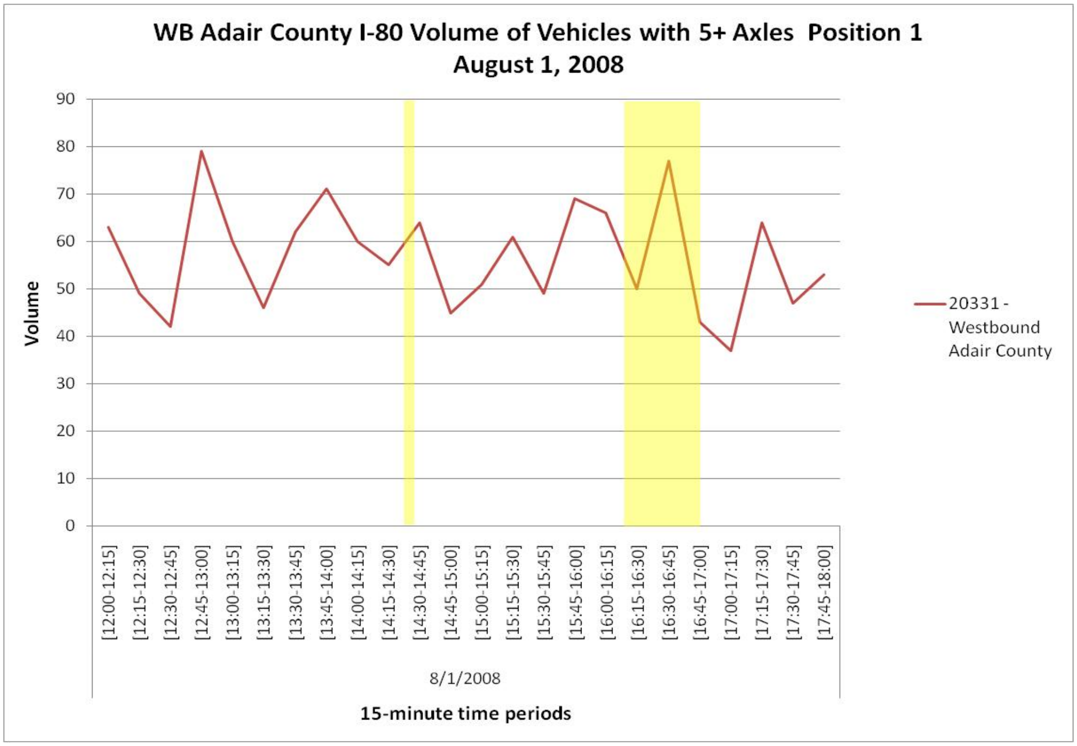


Figure 20. Heavy truck volume WB Adair County on August 1 during two transition periods

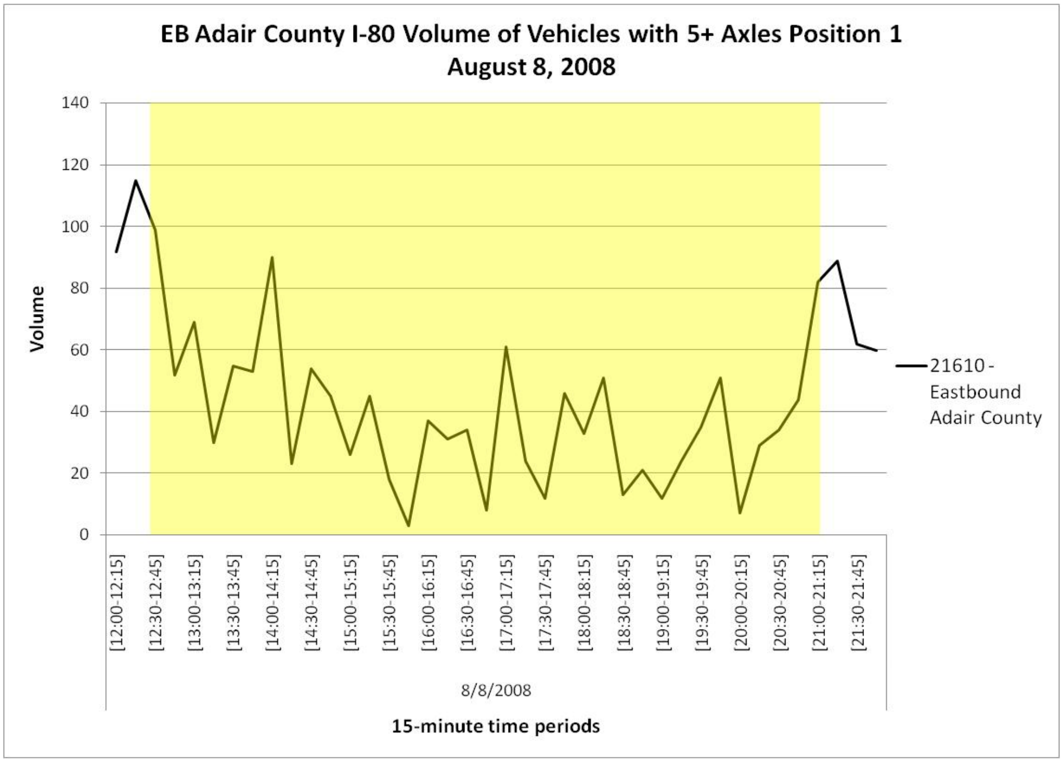


Figure 21. Heavy truck (5+ axles) volume EB Adair County on August 8 during congestion period

A review of the data from other weekends indicated seven other periods when an equal or greater number of five or more axle trucks (above 115 vehicles per 15 minute period) during which no traffic slowdowns or backups occurred. Therefore, although the number of large trucks can have a significant relationship to the total traffic volume throughput, as suggested by the Beacher et al. (2004) study described earlier, the volumes that occurred during the one congestion period experienced in this study did not seem to contribute to that congestion. Influence of large trucks on congestion may be more significantly impacted by roadway grades and cross-over geometrics than on volume of that truck traffic.

A final review of the late merge data previously presented in Tables 3 & 4 is illustrated below in graphical form in the figures below. These graphs again show the percentages of vehicles in the closing lane at locations P1, P2, and P3, by classification under all the available DMS options. The information is first shown for the control situation (Figure 22), where no DMS signs are in place at all. Then the information was combined from all weekends where the DMS signs were in place (Figure 23), but not activated (i.e. the speeds remained above the upper trigger speed). Figure 24 shows the merge data for the transition flows of traffic (DMS signs 1-5 activated) on the first weekend. The final Figure, 25 shows the data for the congestion flow of traffic during the second weekend with all DMS messages activated.

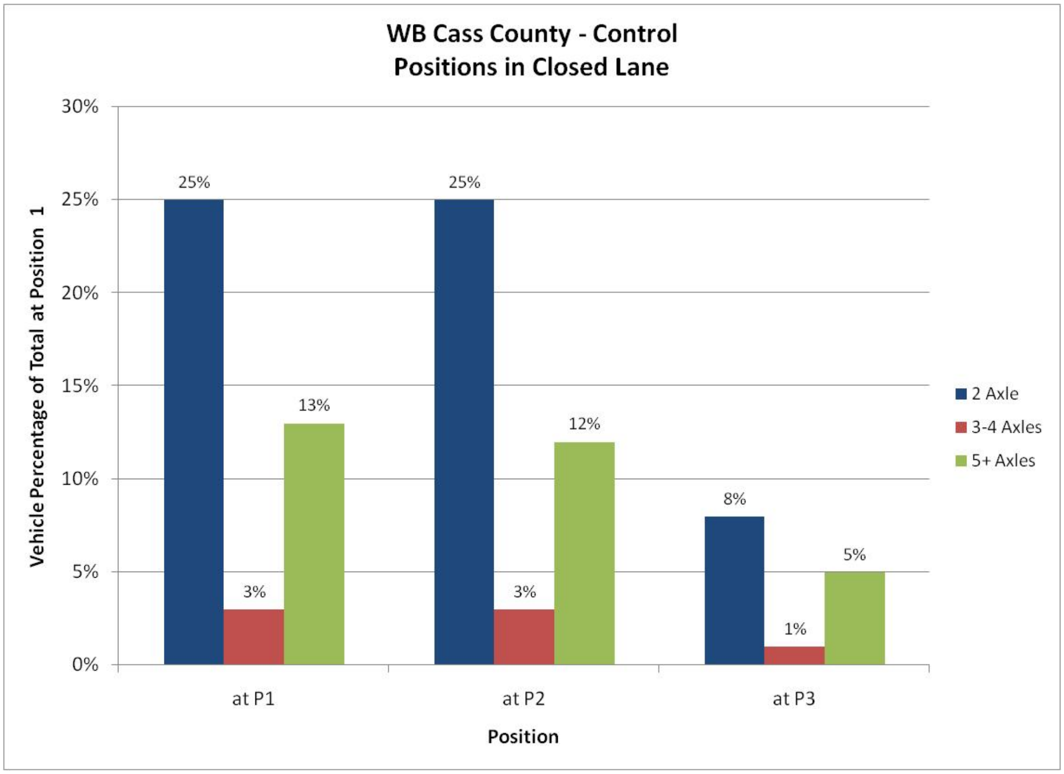


Figure 22. Free flow with no DMS signs present

Note that the amount of early merging taking place by cars and heavy trucks is less with no DMS signs present than with them on the job, but not activated. This would indicate that the mere presence of DMS signs on the site promotes early merging.

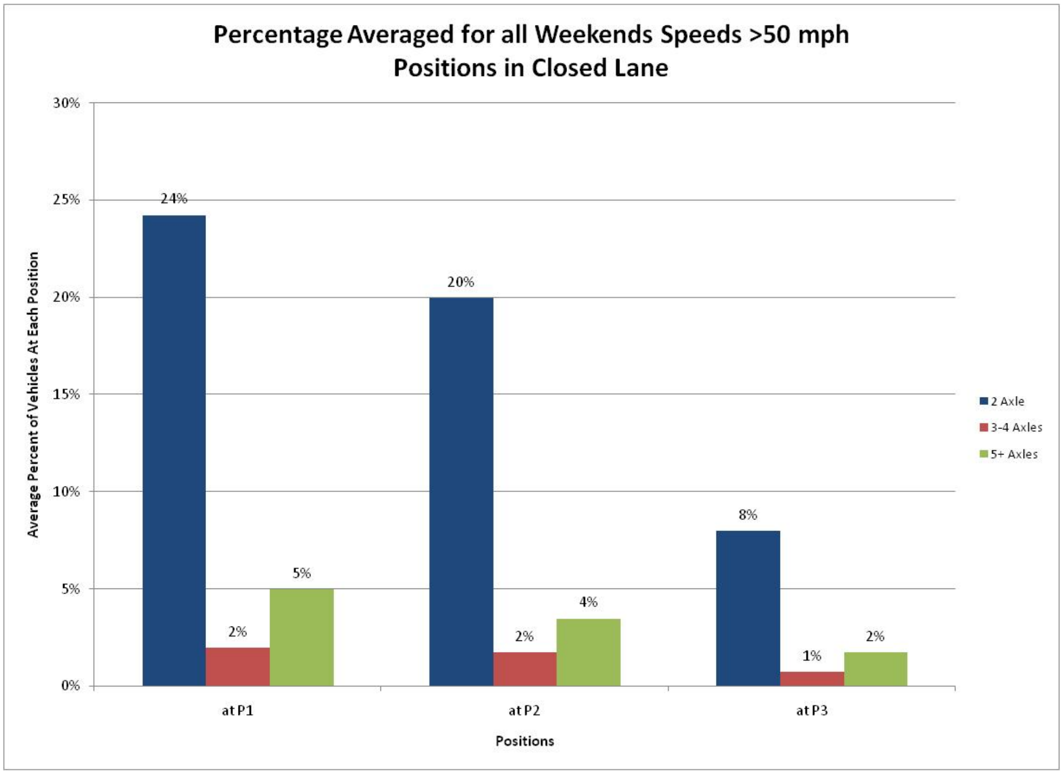


Figure 23. Free flow with DMS signs present but not activated

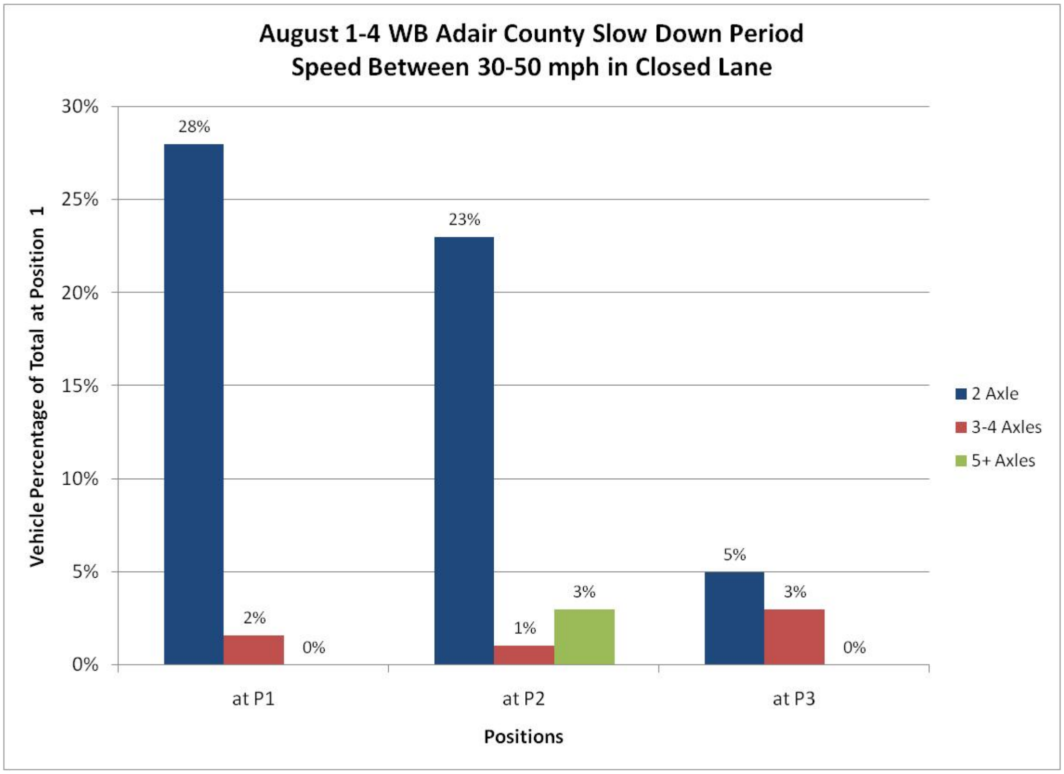


Figure 24. Transition flow with DMS signs activated

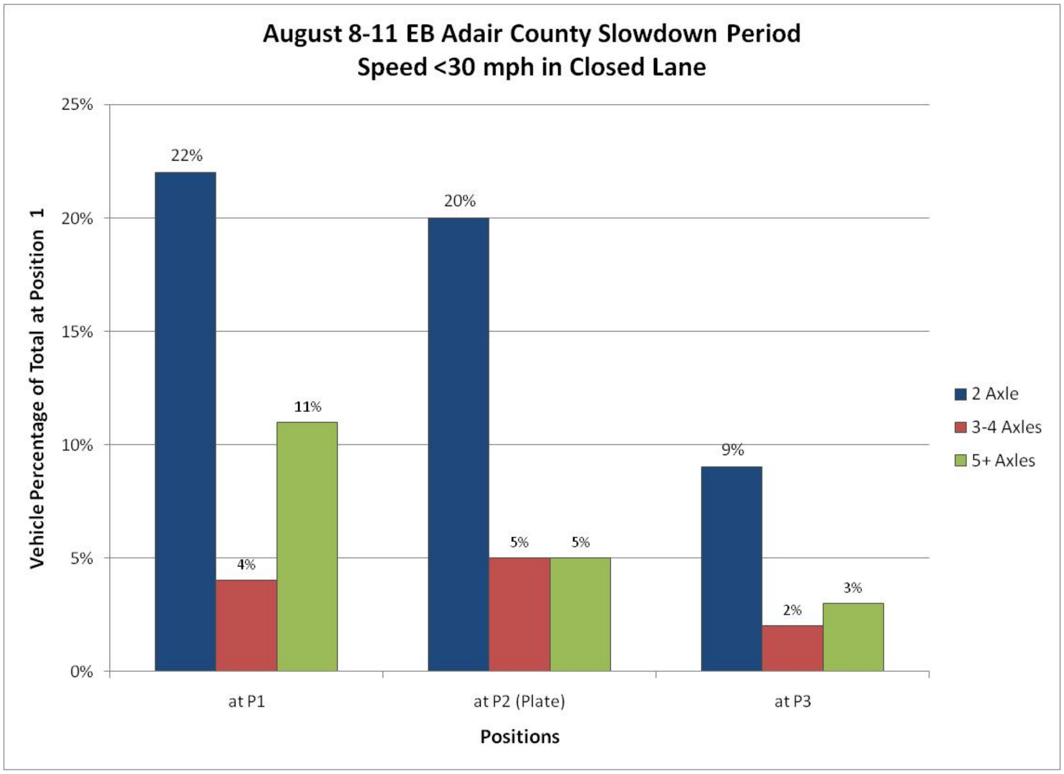


Figure 25. Congestion with all DMS signs activated

CONCLUSIONS AND RECOMMENDATIONS

Collection of relevant project data for analysis proved to be challenging. In addition to the obvious personnel safety issues associated with the placement and retrieval of counting devices on open lanes of an Interstate highway, lack of equipment reliability and insufficient traffic congestion to activate the DLMS hampered data collection efforts. The numerous problems with the collection equipment used are noted in the report and Appendix A. These problems compromised attempts to gather uniform, consistent, and relevant data. The high volume of heavy truck traffic at the data collection sites evidently damaged the road tubes and hold-down tape. This damage was discussed earlier in this report and also shown in Appendices A and C. The older NuMetrics plates used initially for supplemental data collections were found to be inconsistent in performance and new devices were quickly ordered and utilized as soon as received.

Although the Jamar road tube data collection system seemed to be the most consistent and reliable devices used in this study, the severe damage to the heavy-duty, “D” road tubes from heavy truck traffic resulted in incomplete data collection because of tube failures early in the collection process. If this study were to be repeated, a more resilient and reliable hold-down system than tape should be designed for the tubes. Additionally, a more secure method for retaining the necessary tube end plugs in place needs to be developed. Using flat metal plate hold-downs at both ends of the tubes (off the traveled way where possible) would be a recommendation, but fastening those plates securely to the pavement structure would remain problematic both in potential damage to the pavement surface and in the time of exposure to moving traffic during the installation process.

For greater safety during equipment placement and pickup, the use of the newer model NuMetrics plate counters (NC-200) should be strongly considered, especially if this system can provide accurate and reliable data. The newer plates, which have the capability of identifying individual vehicles, seem to provide improved versatility and reliability than the older (Hi Star NC-97) models.

Since neither of the project data collection systems were found to be entirely reliable and comparable, further comparison testing of data collection devices, including the Iowa DOT’s ATR counters, needs to be undertaken to determine comparative accuracy and the circumstances when each system is most appropriate for use. It would be recommended to undertake a comparative study of traffic data collected by road tubes, plate collectors, DOT ATR units, side fire radar units and manual counts. However it should be noted that variation in data from the Jamar road tubes and NuMetrics plates, while statistically significant were in fact quite minor and acceptable for most studies.

Although data collection equipment did not function properly at all times and traffic volumes at the collection sites were not sufficient to activate to DMS messaging during much of the study period, some conclusions can be drawn and recommendations made following analysis of the usable data.

Results of statistical analyses of the data from two weekends when traffic speed reductions were observed did not indicate any significant impact on driver merging behavior, regardless of vehicle classification, from the DMS messaging deployed. Other DMS sign deployment arrays and variation in messaging may yield other results.

It was concluded that traffic volumes on I-80 in the western Iowa study sites were insufficient to adequately test the capability and effectiveness of the DLMS. Therefore, it is not possible to predict a lane capacity (volume per hour), at which a system like this should be deployed. The traffic volumes observed with this study were, for the most part, below that level. The use of this type of DLMS to encourage late merging and potentially enhanced traffic capacity might be considered for other, more heavily traveled segments of Iowa's Interstate system where hourly volumes are closer to a single-lane capacity of approximately 1,500 vehicles per hour. In fact, current DOT practice is to consider extraordinary mitigation for potential delay and queue build-up when traffic volume is expected to surpass 1,350 vph per lane.

Although the DLMS had been in service for several weeks before this study began, it was obvious that, with a complicated system such as this, numerous technical difficulties can, and do occur. Also, the small number of activations, or trigger events, experienced at these sites (as recorded by both the data collectors and the e-mail notification system that was developed later to advise interested parties of potential traffic slowdowns) would make the DLMS a very expensive tool unless deployed where frequent activation would be assured. This also points to the need to evaluate the speed thresholds to trigger the DMS (ie 50 and 30 mph for most of our test).

Activation of the messaging on the DMS units located most distant from the actual merge point, apparently provided sufficient advance information to drivers during the congestion period during the August 8–11 weekend since no crashes were recorded or complaints received from drivers during that time. Therefore using traffic speed sensors, real time activated changeable message signs located in advance of lane restrictions could possibly be used to advise traffic of potential congestion ahead less expensively than a complete DLMS. The type of system deployed for this study should probably be reserved for roadways with considerably higher traffic volumes than usually exist at the locations evaluated in this study. With more frequent periods of reduced speeds and congestion, the full benefit of this DLMS would prove to be much more effective.

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APPENDIX A. DATA COLLECTED

The following information was gathered during each of the four collection weekends, along with supporting informational data and is organized in this appendix by *each* location for *each* weekend as follows:

- Data collection notes
- Figure showing counter placements (P1, P2, P3)
- Counter Information Table (Placement, Type, Number(s), & Operational Summary
- Tabular Data showing worksheet and Summary in Tabular form
- Graphical data presentation for the period collected, showing:
    - Average Vehicle Volumes (Both lanes)
    - Average Vehicle Speeds (Both lanes)
    - Average Heavy truck (5+ Axle) Volumes (Both lanes)

August 1–4, 2008

WB Cass County

Data collection was conducted east of the construction site in the westbound lanes. The driving lane was the closed lane at this location. Jamar road tubes were placed across both lanes at Position 1 (P1) prior to DMS's 3 and 4. Road tubes were laid across the closing lane at P2 after the "Right Lane Closed" static sign and at P3 after the static "Merge" sign. NuMetric plates were deployed at each position in the same lanes as the road tubes.

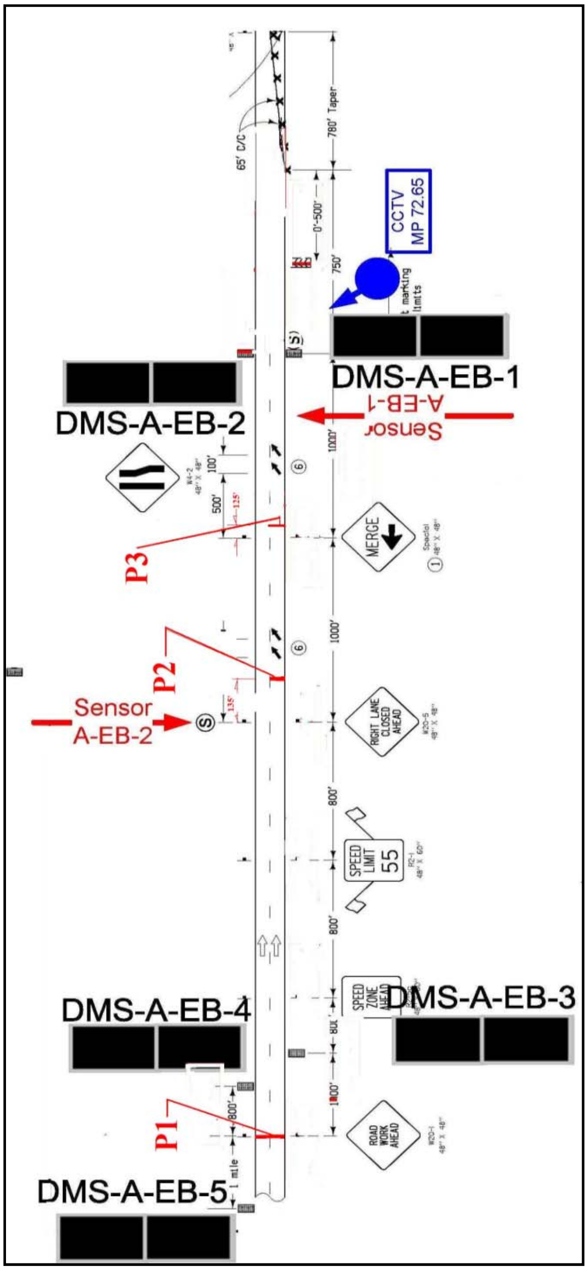


Figure A.1. Counter placement–WB Cass County

Table A.1. Counter information at WB Cass County–August 1-4, 2008

Location	Counter Type	Number	Functional Summary
P1	Jamar tubes	21608	
	Older Plate	3404/3413	Plates failed due to insufficient setup time.
P2	Jamar tubes	20334	
	Older Plate	3407	Plates failed due to insufficient setup time
P3	Jamar tubes	21610	
	Older Plate	3411	Plate gathered data from 10:00AM-4:30PM on 8/1/2008

General note: NuMetrics plates must be installed a minimum of 30 minutes prior to the programmed start time of data collection by the unit.

Table A.2. Data worksheet and summary–WB Cass County–August 1-4, 2008

Late Merge I-80 Study
August 1-4, 2008
Atlantic, IA Westbound
Closed Lane 1

1/14/2009 2:28 PM

21608(Tube) (Position 1) Time Periods Total for Both Lanes	**Lane**	**Average Speed (entire period)**	**Volume by Lane**	
Vehicle Count for Time F	1	75 mph	25,552	**For Entire Counting Period**
	2	72 mph	36,237	
			61,789	

Combined Data Speeds Greater than 50 mph - Period between Aug 1 12:00PM & Aug 4 8:00AM

	Lane	**Position**	**Average Speed**	**Vehicle Class**	**Count**	**Total Vehicles - P1**	**Percentage**
21610	1	3	66 mph	0-239	4,996	25,552	20%
				240-479	922	25,552	4%
				480+	3,103	25,552	12%
					9,021		35%
20334	1	2	64 mph	0-239	15,346	25,552	60%
				240-479	1,936	25,552	8%
				480+	7,630	25,552	30%
					24,912		97%

Breakdown of Vehicle Count - Over 50 mph

	21608	20334	21610
Lane 1	25,552	24,912	9,021
Lane 2	36,237	36,877	52,768
	61,789	61,789	61,789

	Positions	P1		P2		P3	
	Classifications	21608	Percentage	20334	Percentage	21610	Percentage
Lane 1	0-239	15,677	25%	15,346	25%	4,996	8%
	240-479	2,000	3%	1,936	3%	922	1%
	480+	7,875	13%	7,630	12%	3,103	5%
	Total Lane 1	25,552	41%	24,912	40%	9,021	15%
Lane 2	0-239	24,270	39%	24,601	40%	34,951	57%
	240-479	3,344	5%	3,408	6%	4,422	7%
	480+	8,623	14%	8,868	14%	13,395	22%
	Total Lane 2	36,237	59%	36,877	60%	52,768	85%
	61789	61,789	100%	61,789	100%	61,789	100%

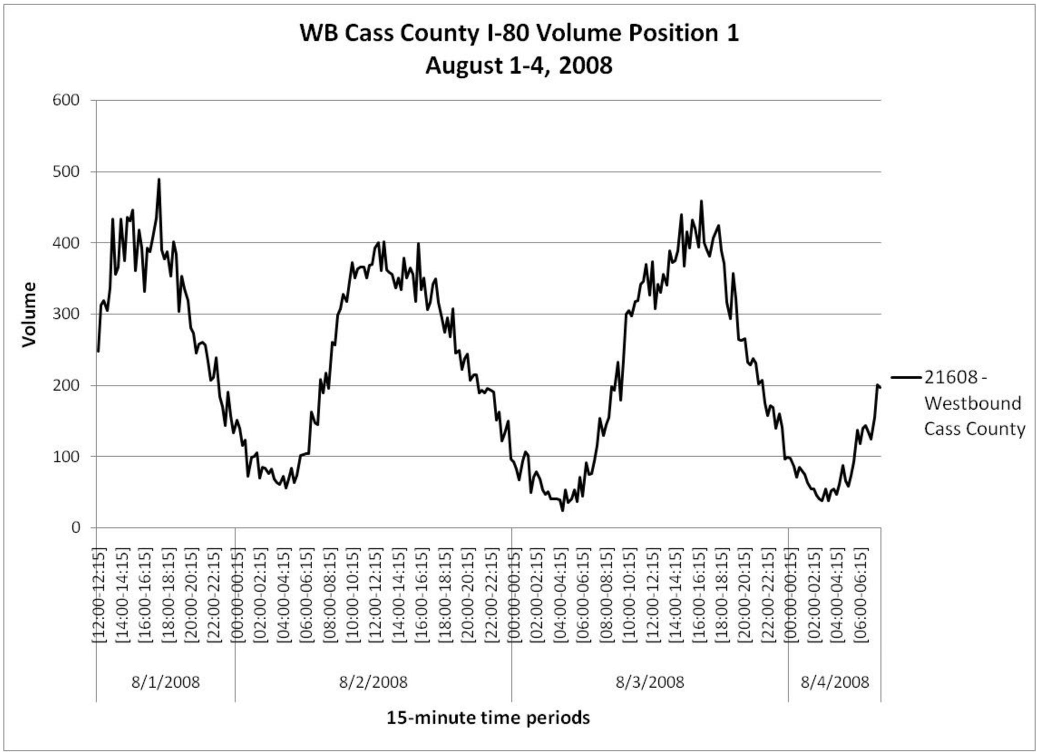


Figure A.2. Average vehicle volume (both lanes) at P1–August 1–4, 2008

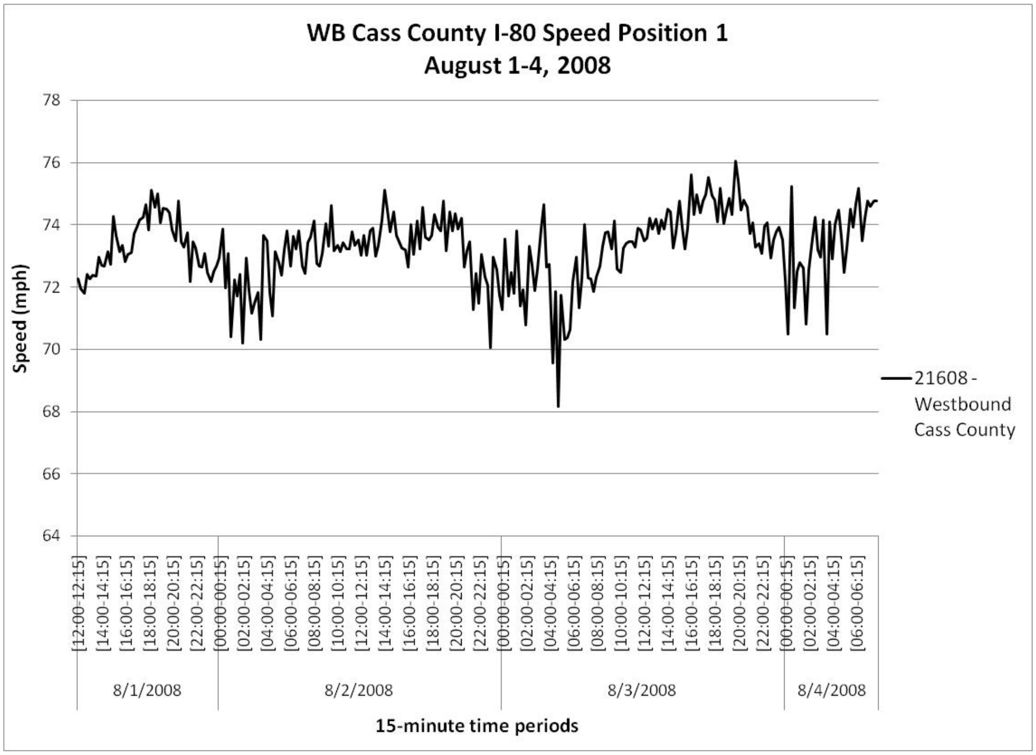


Figure A.3. Average vehicle speed (both lanes) at P1–August 1–4, 2008

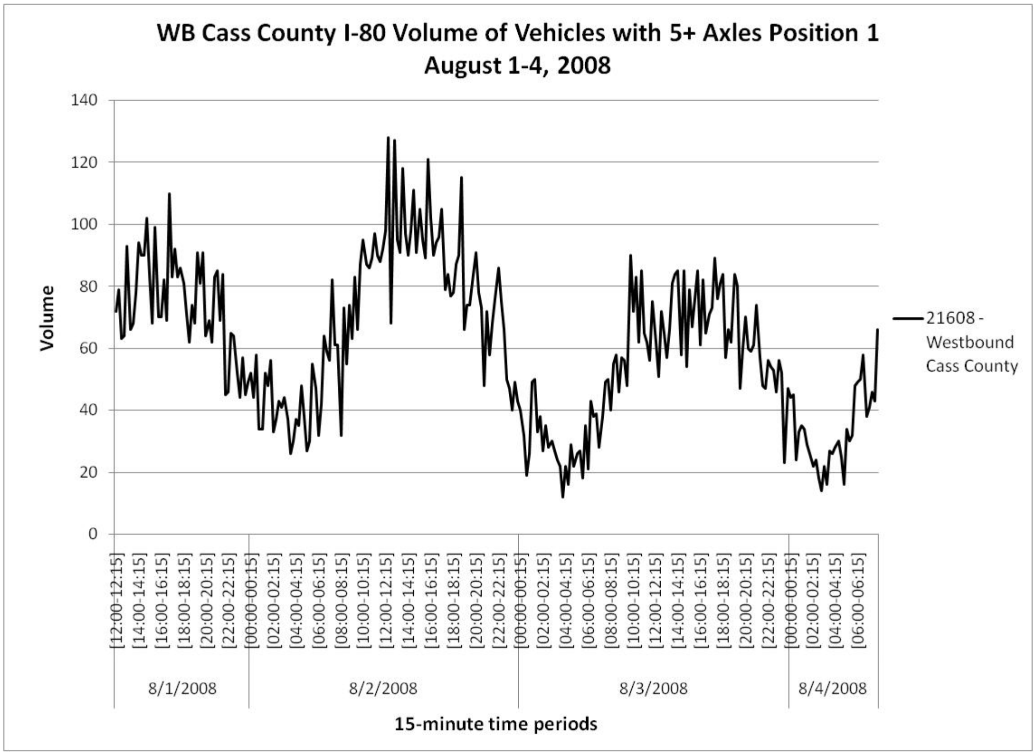


Figure A.4. Average heavy truck (5+ axles) volumes (both lanes) at P1 position–August 1–4, 2008

WB Adair County

Data collection was conducted east of the construction site in the westbound lanes. The passing lane was the closed lane at this location. Jamar road tubes were placed across both lanes at Position 1 (P1) prior to DMS's 3 and 4. Road tubes were laid across the closing lane at P2 after the "Right Lane Closed" static sign and at P3 after the static "Merge" sign. NuMetric plates were not deployed at each position in the same lanes as the road tubes.

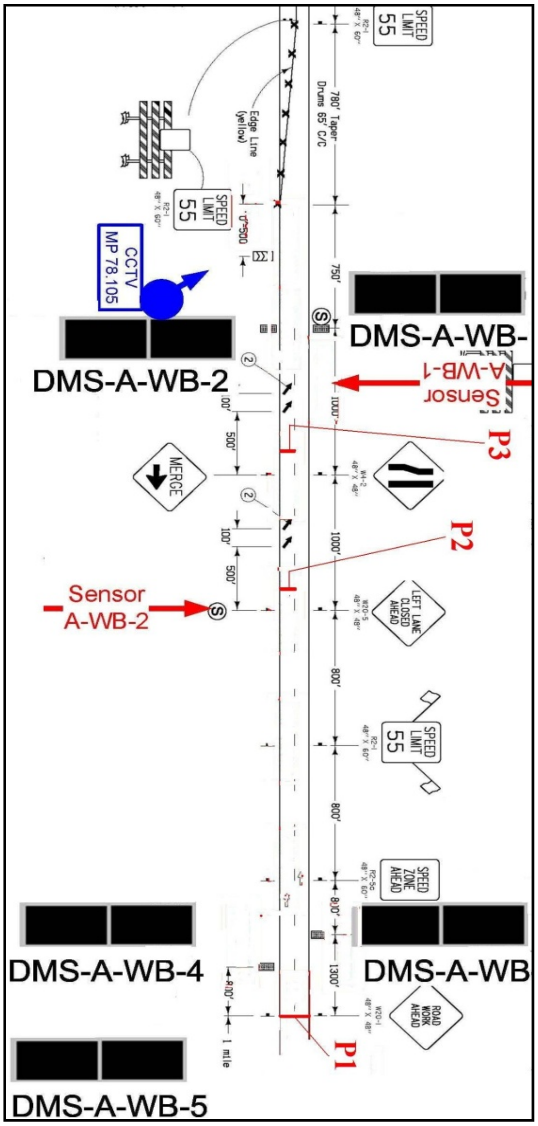


Figure A.5. Counter placement–WB Adair County–August 1–4, 2008

Table A.3. Counter information at WB Adair County–August 1–4, 2008

Location	Counter Type	Number	Functional Summary
P1	Jamar	20331	
	Old Plate		**Plates not installed at this location**
P2	Jamar	20335	
	Old Plate		**Plates not installed at this location**
P3	Jamar	21610	
	Old Plate		**Plates not installed at this location**

General note: Data gathered during this period included only a couple relatively short periods that should have activated DMS message operation (evidenced by the recorded trigger speeds) at the 30< speed< 50 mph (transition) in the WB Adair County direction. While three 10 minute intervals were noted at location P3 for WB Adair County where 30 < vel < 50 mph, there are no corresponding speed reductions at P2, so the average speed would NOT activate the lights.

Table A.4. Data worksheet and summary–WB Adair County–August 1–4, 2008

Late Merge I-80 Study 1/14/2009 2:46 PM
August 1-4, 2008
Adair, IA Westbound
Reporting Period 8/1 12:00PM - 8/4 8:00AM
Closed Lane 2

20331 (Tube) (Position 1) Time Periods Total for Both Lanes	**Lane**	**Average Speed**	**Volume by Lane**	
Vehicle Count for Time Period	1	74 mph	38,167	**For Entire Counting Period**
	2	75 mph	14,717	
			52,884	

Combined Data Speeds 31-50 mph - Period between Aug 1 2:40PM - 2:46PM

	Lane	**Position**	**Average Speed**	**Vehicle Class**	**Count**	**Total Vehicles - P1**	**Percentage**
20330	2	3	39 mph	0-239	11		
				240-479	6		
				480+	1		
					18		
20335	2	2	49 mph	0-239	48		
				240-479	2		
				480+	7		
					57		
20331	1	1	77 mph	0-239	109		
				240-479	10		
				480+	27		
					146		
	2	1	75 mph	0-239	59		
				240-479	5		
				480+	1		
					65		
					211		

Breakdown of Vehicle Count

	20331	20335	20330
Lane 1	146	154	193
Lane 2	65	57	18
	211	211	211

	Positions	P1		P2		P3	
	Classifications	20331	Percentage	20335	Percentage	20330	Percentage
Lane 1	0-239	109	52%	120	57%	157	74%
	240-479	10	5%	13	6%	9	4%
	480+	27	13%	21	10%	27	13%
	Total Lane 1	146	69%	154	73%	193	91%
Lane 2	0-239	59	28%	48	23%	11	5%
	240-479	5	2%	2	1%	6	3%
	480+	1	0%	7	3%	1	0%
	Total Lane 2	65	31%	57	27%	18	9%
		211	100%	211	100%	211	100%

Table A.4. Data worksheet and summary–WB Adair County (continued)

Combined Data Speeds 31-50 mph - Period between Aug 1 4:25PM - 5:04PM

	Lane	**Position**	**Average Speed**	**Vehicle Class**	**Count**	**Total Vehicles - P1**	**Percentage**
20330	2	3	32 mph	0-239	63		
				240-479	12		
				480+	12		
					87		
20335	2	2	42 mph	0-239	186		
				240-479	11		
				480+	20		
					217		
20331	1	1	76 mph	0-239	525		
				240-479	56		
				480+	130		
					711		
	2	1	74 mph	0-239	286		
				240-479	15		
				480+	26		
					327		
					1038		

Breakdown of Vehicle Count

	20331	20335	20330
Lane 1	711	821	951
Lane 2	327	217	87
	1,038	1,038	1,038

	Positions	P1		P2		P3	
	Classifications	20331	Percentage	20335	Percentage	20330	Percentage
Lane 1	0-239	525	51%	625	60%	748	72%
	240-479	56	5%	60	6%	59	6%
	480+	130	13%	136	13%	144	14%
	Total Lane 1	711	68%	821	79%	951	92%
Lane 2	0-239	286	28%	186	18%	63	6%
	240-479	15	1%	11	1%	12	1%
	480+	26	3%	20	2%	12	1%
	Total Lane 2	327	32%	217	21%	87	8%
		1,038	100%	1,038	100%	1,038	100%

Combined Breakdown of Vehicle Count 30-50mph

	20331	20335	20330
Lane 1	857	975	1,144
Lane 2	392	274	105
	1,249	1,249	1,249

	Positions	P1		P2		P3	
	Classifications	20331	Percentage	20335	Percentage	20330	Percentage
Lane 1	0-239	634	51%	745	60%	905	72%
	240-479	66	5%	73	6%	68	5%
	480+	157	13%	157	13%	171	14%
	Total Lane 1	857	69%	975	78%	1,144	92%
Lane 2	0-239	345	28%	234	19%	74	6%
	240-479	20	2%	13	1%	18	1%
	480+	27	2%	27	2%	13	1%
	Total Lane 2	392	31%	274	22%	105	8%
		1,249	100%	1,249	100%	1,249	100%

Table A.4. Data worksheet and summary–WB Adair County (continued)

Combined Data Speeds Greater than 50 mph - Period between Aug 1 12:00PM & Aug 4 8:00AM

	Lane	Position	Average Speed	Vehicle Class	Count	Total Vehicles - P1	Percentage
20330	2	3	65 mph	0-239	4,161		
				240-479	217		
				480+	388		
					4,766		
20335	2	2	71 mph	0-239	10,340		
				240-479	512		
				480+	937		
					11,789		
20331	1	1	75 mph	0-239	25,459		
				240-479	2,978		
				480+	8,679		
					37,116		
	2	1	73 mph	0-239	12,287		
				240-479	603		
				480+	1,339		
					14,229		
					51,345		

Breakdown of Vehicle Count - Over 50 mph

	20331	20335	20330
Lane 1	37,116	39,556	46,579
Lane 2	14,229	11,789	4,766
	51,345	51,345	51,345

	Positions	P1		P2		P3	
	Classifications	20331	Percentage	20335	Percentage	20330	Percentage
Lane 1	0-239	25,459	50%	27,406	53%	33,585	65%
	240-479	2,978	6%	3,069	6%	3,364	7%
	480+	8,679	17%	9,081	18%	9,630	19%
	Total Lane 1	37,116	72%	39,556	77%	46,579	91%
Lane 2	0-239	12,287	24%	10,340	20%	4,161	8%
	240-479	603	1%	512	1%	217	0%
	480+	1,339	3%	937	2%	388	1%
	Total Lane 2	14,229	28%	11,789	23%	4,766	9%
		51,345	100%	51,345	100%	51,345	100%

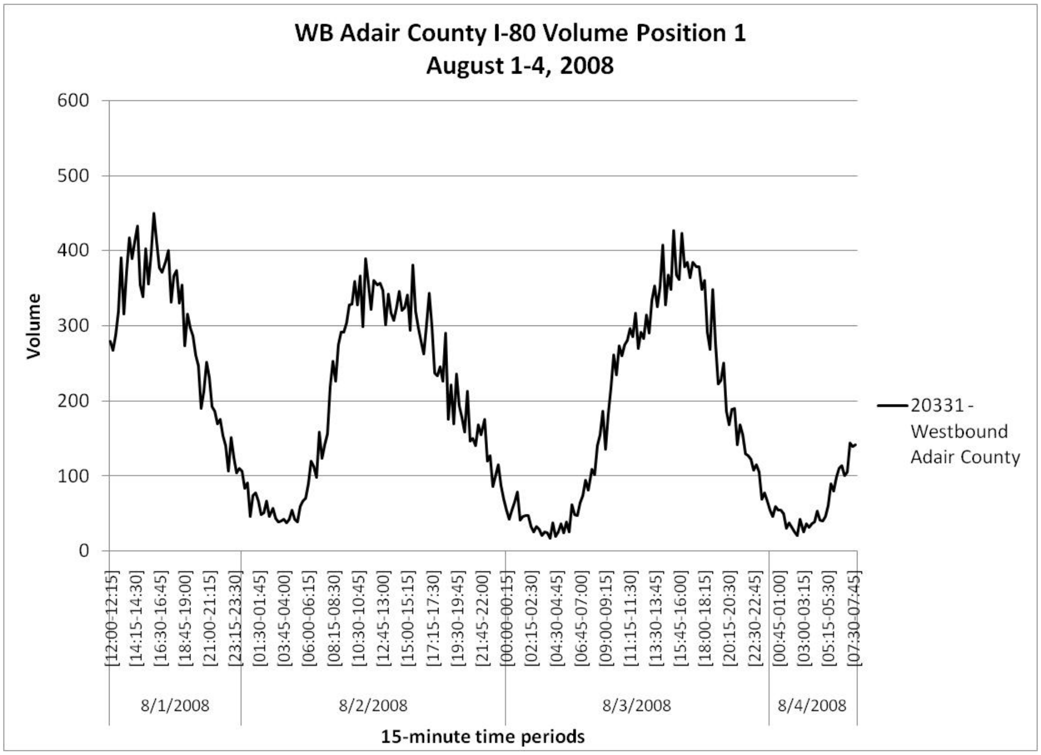


Figure A.6. Average vehicle volume (both lanes) at P1–August 1–4, 2008

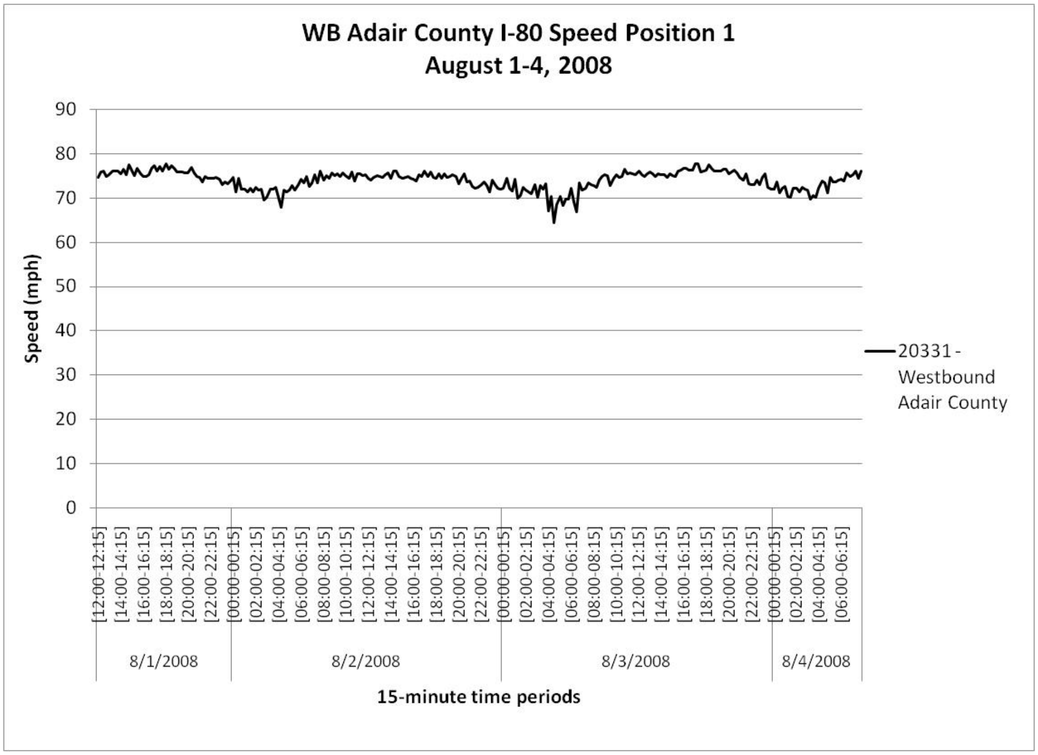


Figure A.7. Average vehicle speed (both lanes) at P1–August 1–4, 2008

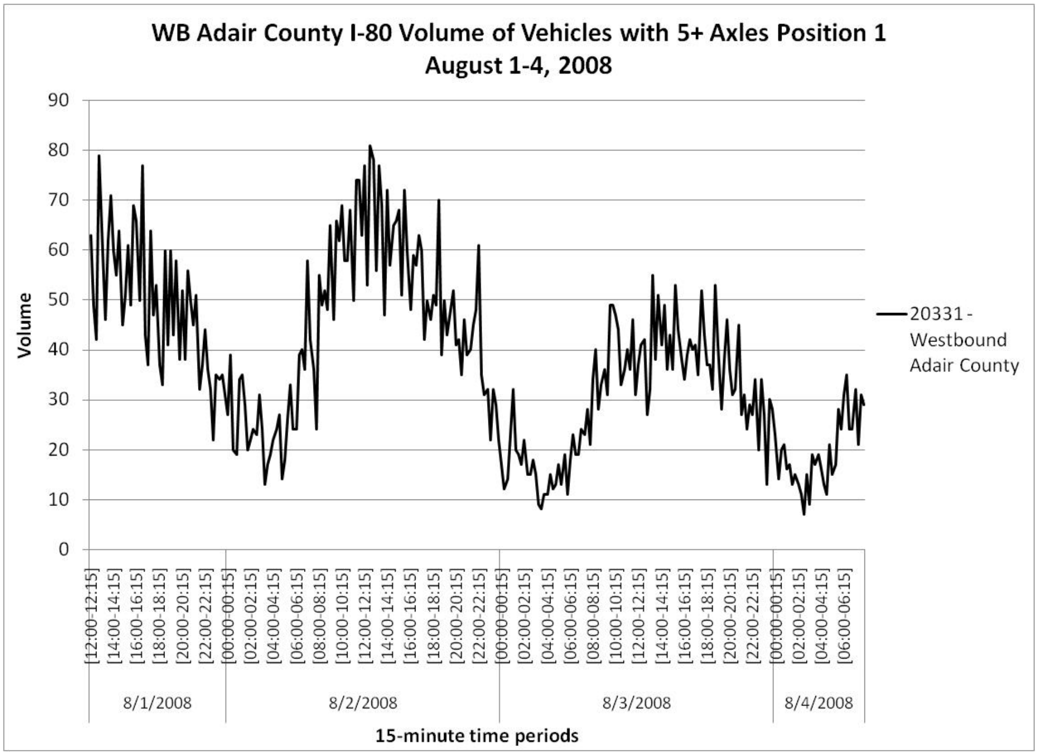


Figure A.8. Volume of heavy truck traffic at position 1 (both lanes) –August 1–4, 2008

August 8–11, 2008

EB Adair County

Data collection was conducted west of the construction site in the eastbound lanes. The driving lane was the closed lane at this location. Jamar road tubes were placed across both lanes at Position 1 (P1) prior to DMS's 3 and 4. Road tubes were laid across the closing lane at P2 after the "Right Lane Closed" static sign and at P3 after the static "Merge" sign. NuMetric plates were deployed at each position in the same lanes as the road tubes.

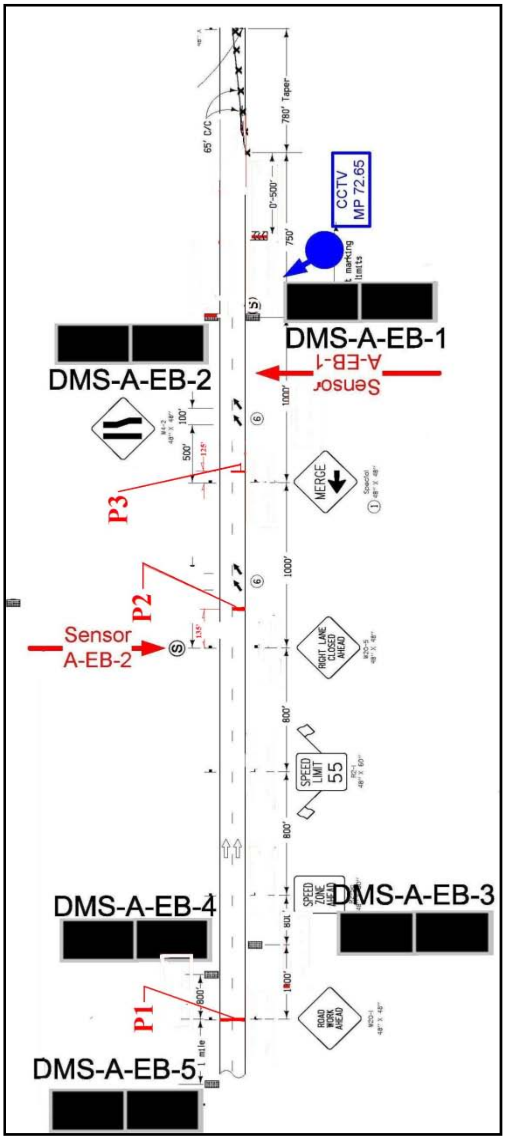


Figure A.9. Counter placement–EB Adair County–August 8–11, 2008

Table A.5. Counter information at EB Adair County–August 8–11, 2008

Location	Counter Type	Number	Functional Summary
P1	Jamar tubes	21610	
	Older Plate	3407	
P2	Jamar tubes	8783	Jamar counter defective
	Older Plate	3411	
P3	Jamar tubes	21569	
	Older Plate	3413	**Did not collect data**

General note: Jamar counter 8783 failed. Plates were not programmed correctly and stopped recording on 8/10/2008 at 8:00 am instead of 8/11/2008 at 8:00 am.

Table A.6. Data worksheet and summary–EB Adair County–August 8–11, 2008

Late Merge I-80 Study	1/15/2009 1:11 PM
August 8-11, 2008	
Adair, IA Eastbound	
Close Lane 1	

21610 (Tube) (Position 1) Time Periods Total for Both Lanes	**Lane**	**Average Speed (entire period)**	**Volume by Lane**	
Vehicle Count for Time Period	1	58 mph	13,149	**For Entire Counting Period**
	2	57 mph	18,848	
			31,997	

21610 (Tube) (Position 1) Time Periods Total for Both Lanes	**Lane**	**Average Speed (entire period)**	**Volume by Lane**
Vehicle Count for Time Period	1	23	1,822
12:30 PM - 9:00 PM	2	23	3,106
Average speed < 30 mph;			4,928
2nd DMS Message On			

Combined Data Speeds Less than 30 mph - Period between 12:30PM - 9:00PM available for Plate and Tube

	Lane	**Position**	**Date**	**Time**	**Average Speed (mph)**	**Vehicle Class**	**Count**
21569	1	3	8/8/2008	12:30PM-9:00PM	18	0-239	448
						240-479	80
						480+	161
							689
3411	1	2	8/8/2008	12:30PM-9:00PM	21	0-239	962
						240-479	243
						480+	248
							1,453

Breakdown of Vehicle Count - Under 30 mph

Lane Totals

	21610	3411	21569
Lane 1	1,822	1,453	689
Lane 2	3,106	3,475	4,239
	4,928	4,928	4,928

Vehicle Classification Totals

	Positions	P1		P2		P3	
Lane	Classifications	21610	Percentage	3411	Percentage	21569	Percentag
Lane 1	0-239	1,091	22%	962	20%	448	9%
	240-479	192	4%	243	5%	80	2%
	480+	539	11%	248	5%	161	3%
	Lane 1 Totals	1,822	37%	1,453	29%	689	14%
Lane 2	0-239	2,063	42%	2,192	44%	2,706	55%
	240-479	313	6%	262	5%	425	9%
	480+	730	15%	1,021	21%	1,108	22%
	Lane 2 Totals	3,106	63%	3,475	71%	4,239	86%
	4928	4,928	100%	4,928	100%	4,928	100%

Table A.7. Data worksheet and summary–EB Adair County (continued)

Late Merge I-80 Study
August 8-11, 2008
Adair, IA Eastbound

21610 (Tube) (Position 1) Time Periods Total for Both Lanes	**Lane**	**Average Speed (entire period)**	**Volume by Lane**
Vehicle Count for Time Period	1	63	11,327
8-8: 12-12:30 PM+ 9PM-8AM or	2	63	15,742
Average speed >50 mph;			27,069
NO DMS Message On			

Combined Data Speeds Greater than 50 mph - Period between Aug 8 12:00PM - 12:30PM & Aug 8 9:00PM - Aug 10 8:00AM available for Plate and Tube

	Lane	**Position**	**Date**		**Average Speed (mph)**	**Vehicle Class**	**Count**
21569	1	3	8/8/2008	Entire Period Less < 30 mph and 30 to 50 mph periods	61	0-239	2,009
						240-479	353
						480+	1,106
							3,468
3411	1	2	8/8/2008	Entire Period Less < 30 mph and 30 to 50 mph periods	62	0-239	5,013
						240-479	747
						480+	2,169
							7,929

Breakdown of Vehicle Count - Over 50 mph

Lane Totals

	21610	3411	21569
Lane 1	11,327	7,929	3,468
Lane 2	15,743	19,141	23,602
	27,070	27,070	27,070

Vehicle Classification Totals

	Positions	P1		P2		P3	
Lane	Classification	21610	Percentage	3411	Percentage	21569	Percentag
Lane 1	0-239	6,827	25%	5,013	19%	2,009	7%
	240-479	901	3%	747	3%	353	1%
	480+	3,600	13%	2,169	8%	1,106	4%
	Lane 1 Totals	11,328	42%	7,929	29%	3,468	13%
Lane 2	0-239	10,447	39%	12,261	45%	15,265	56%
	240-479	1,342	5%	1,496	6%	1,890	7%
	480+	3,953	15%	5,384	20%	6,447	24%
	Lane 2 Totals	15,742	58%	19,141	71%	23,602	87%
	27070	27,070	100%	27,070	100%	27,070	100%

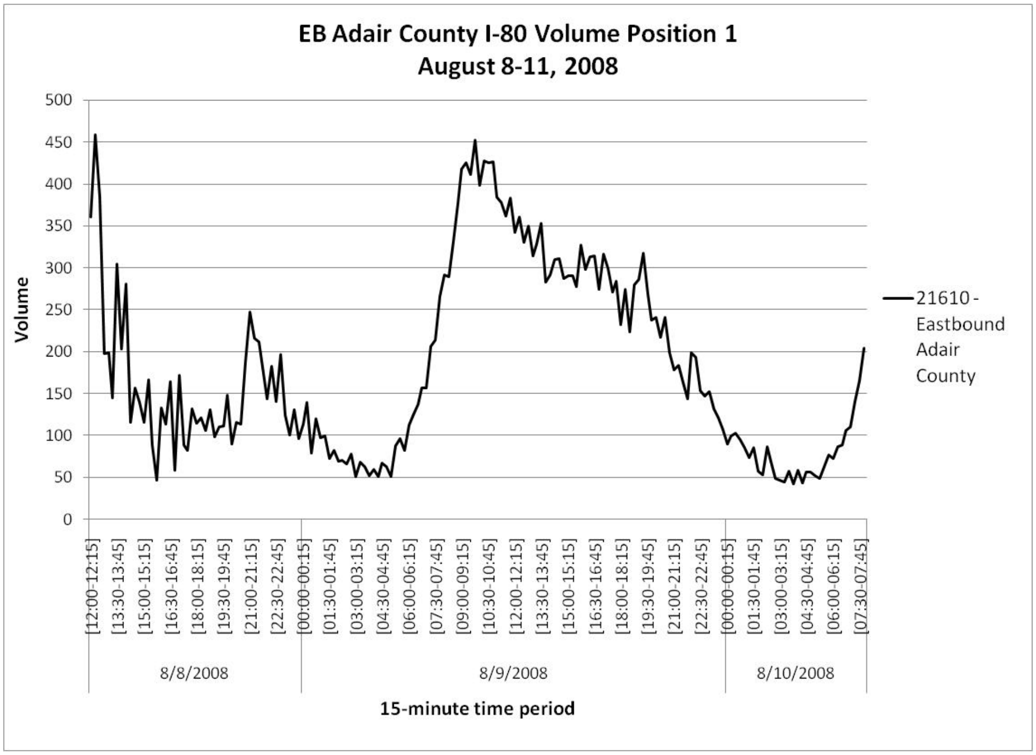


Figure A.10. Average vehicle volume (both lanes) at P1–August 8–11, 2008

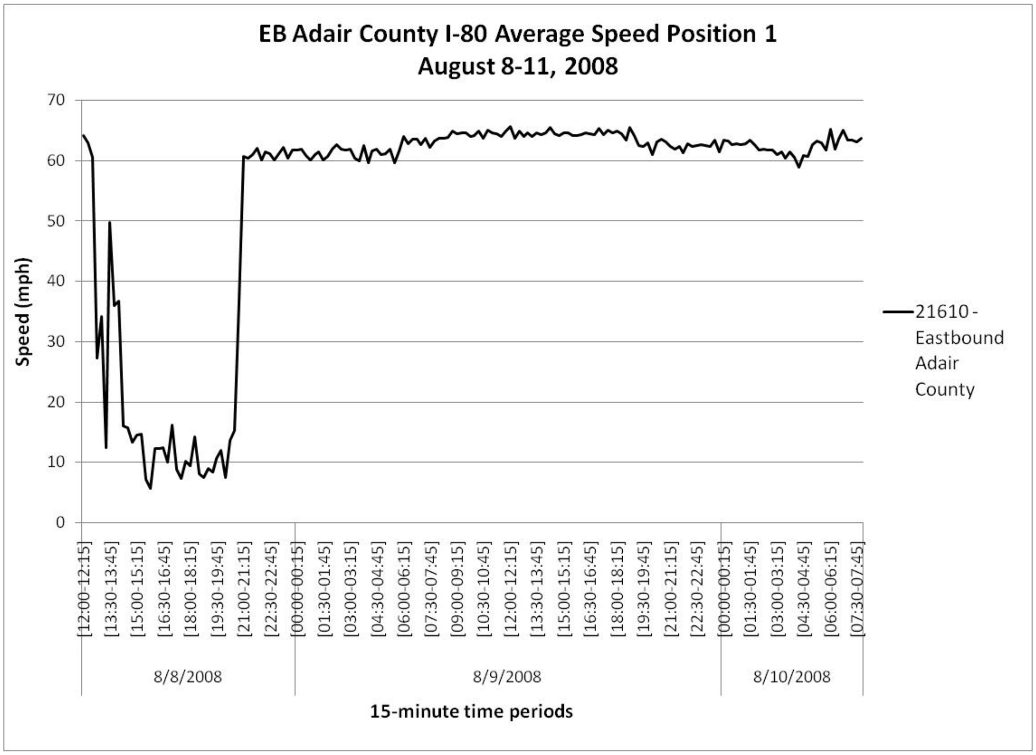


Figure A.11. Average vehicle speed (both lanes) at P1–August 8–11, 2008

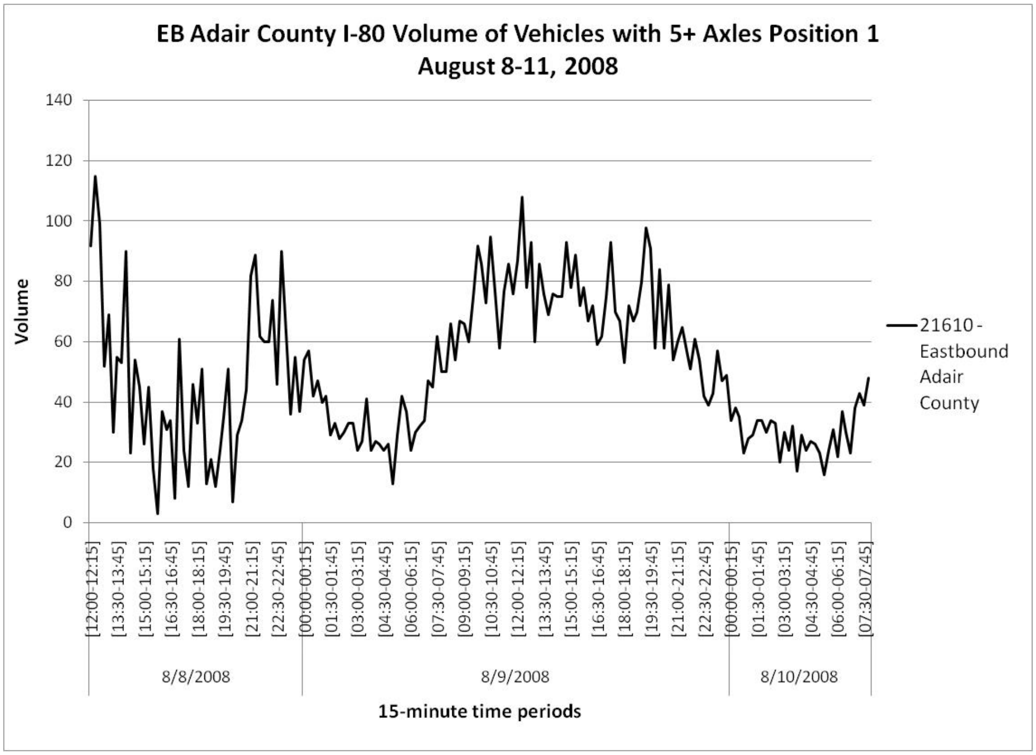


Figure A.12. Volume of heavy truck traffic at position 1 (both lanes)–August 8–11, 2008

EB Cass County

Data collection was conducted west of the construction site in the eastbound lanes. The passing lane was the closed lane at this location. Jamar road tubes were placed across both lanes at Position 1 (P1) prior to DMS's 3 and 4. Road tubes were laid across the closing lane at P2 after the "Right Lane Closed" static sign and at P3 after the static "Merge" sign. NuMetric plates were not deployed at each position in the same lanes as the road tubes.

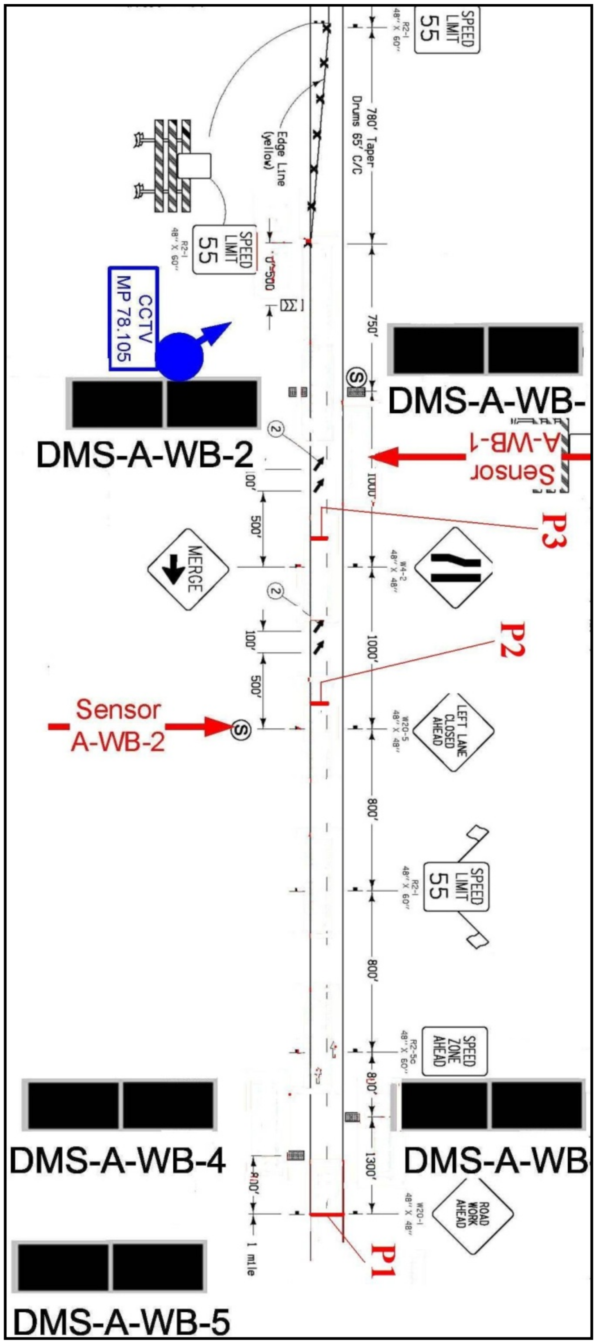
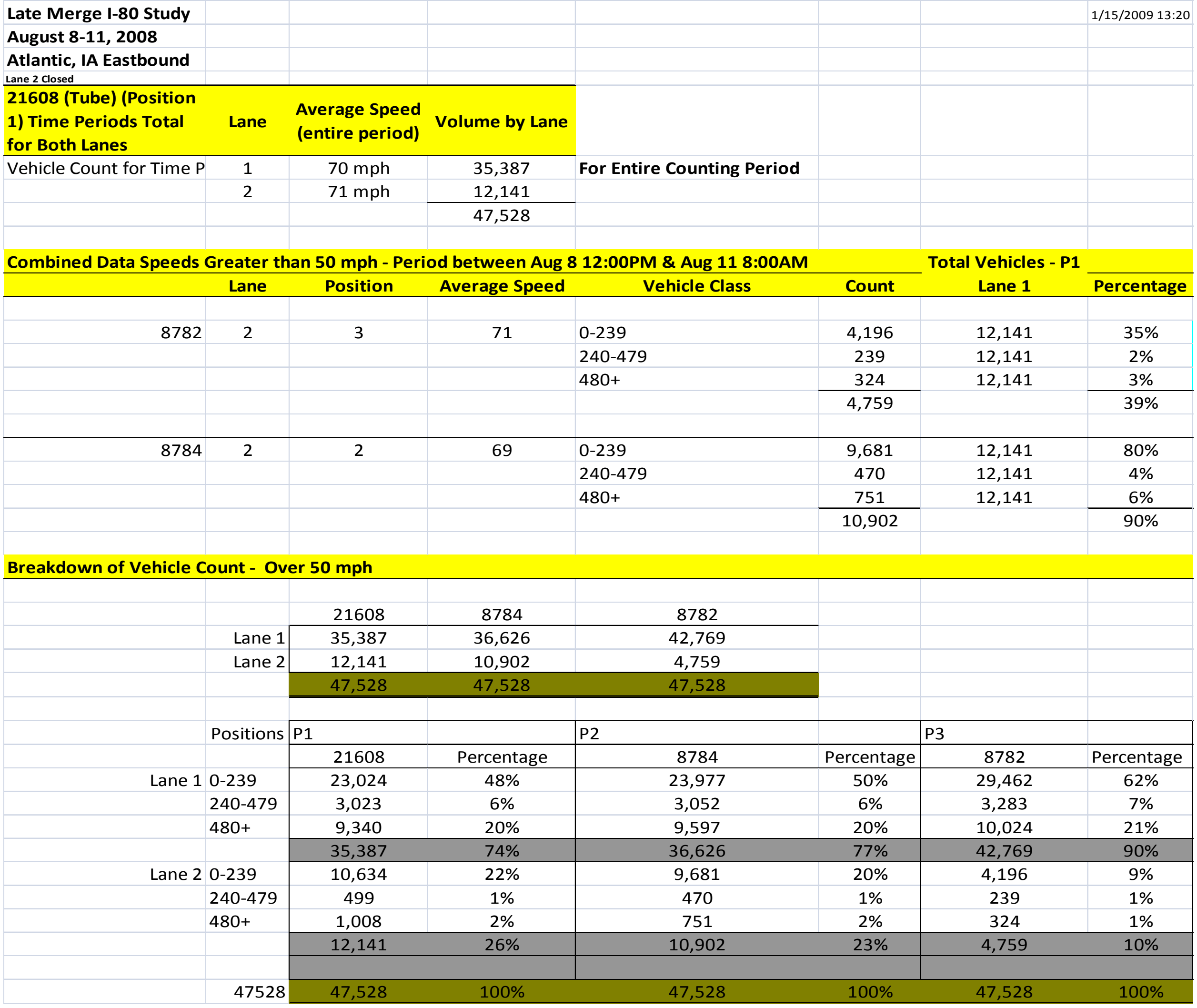


Figure A.13. Counter placement–EB Cass County–August 8–11, 2008

Table A.8. Counter information at EB Cass County–August 8–11, 2008

Location	Counter Type	Number	Functional Summary
P1	Jamar tubes	21608	
	Older Plate		**Plates Not Installed At This Location**
P2	Jamar tubes	8784	
	Older Plate		**Plates Not Installed At This Location**
P3	Jamar tubes	8782	
	Older Plate		**Plates Not Installed At This Location**

Table A.9. Data worksheet and summary–EB Cass County



Late Merge I-80 Study							1/15/2009 13:20
August 8-11, 2008							
Atlantic, IA Eastbound							
Lane 2 Closed							
21608 (Tube) (Position 1) Time Periods Total for Both Lanes	**Lane**	**Average Speed (entire period)**	**Volume by Lane**				
Vehicle Count for Time P	1	70 mph	35,387	**For Entire Counting Period**			
	2	71 mph	12,141				
			47,528				
Combined Data Speeds Greater than 50 mph - Period between Aug 8 12:00PM & Aug 11 8:00AM						**Total Vehicles - P1**	
	Lane	**Position**	**Average Speed**	**Vehicle Class**	**Count**	**Lane 1**	**Percentage**
8782	2	3	71	0-239	4,196	12,141	35%
				240-479	239	12,141	2%
				480+	324	12,141	3%
					4,759		39%
8784	2	2	69	0-239	9,681	12,141	80%
				240-479	470	12,141	4%
				480+	751	12,141	6%
					10,902		90%
Breakdown of Vehicle Count - Over 50 mph							
		21608	8784	8782			
	Lane 1	35,387	36,626	42,769			
	Lane 2	12,141	10,902	4,759			
		47,528	47,528	47,528			
	Positions	P1		P2		P3	
		21608	Percentage	8784	Percentage	8782	Percentage
Lane 1	0-239	23,024	48%	23,977	50%	29,462	62%
	240-479	3,023	6%	3,052	6%	3,283	7%
	480+	9,340	20%	9,597	20%	10,024	21%
		35,387	74%	36,626	77%	42,769	90%
Lane 2	0-239	10,634	22%	9,681	20%	4,196	9%
	240-479	499	1%	470	1%	239	1%
	480+	1,008	2%	751	2%	324	1%
		12,141	26%	10,902	23%	4,759	10%
	47528	47,528	100%	47,528	100%	47,528	100%

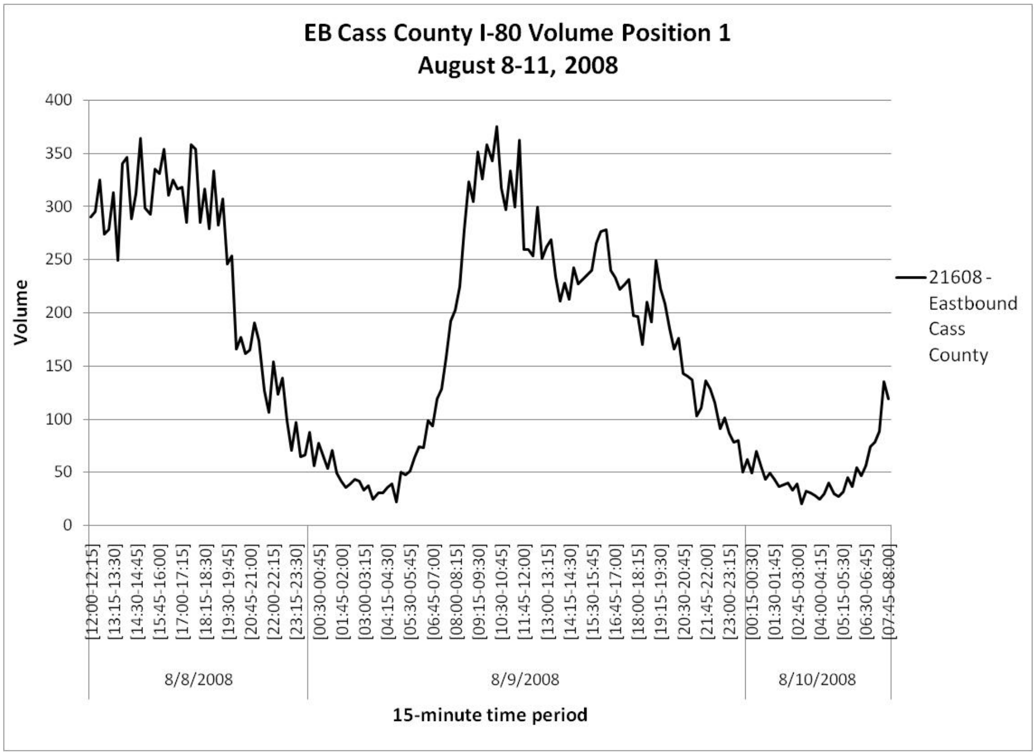


Figure A.14. Average vehicle volume (both lanes) at P1–August 8–11, 2008

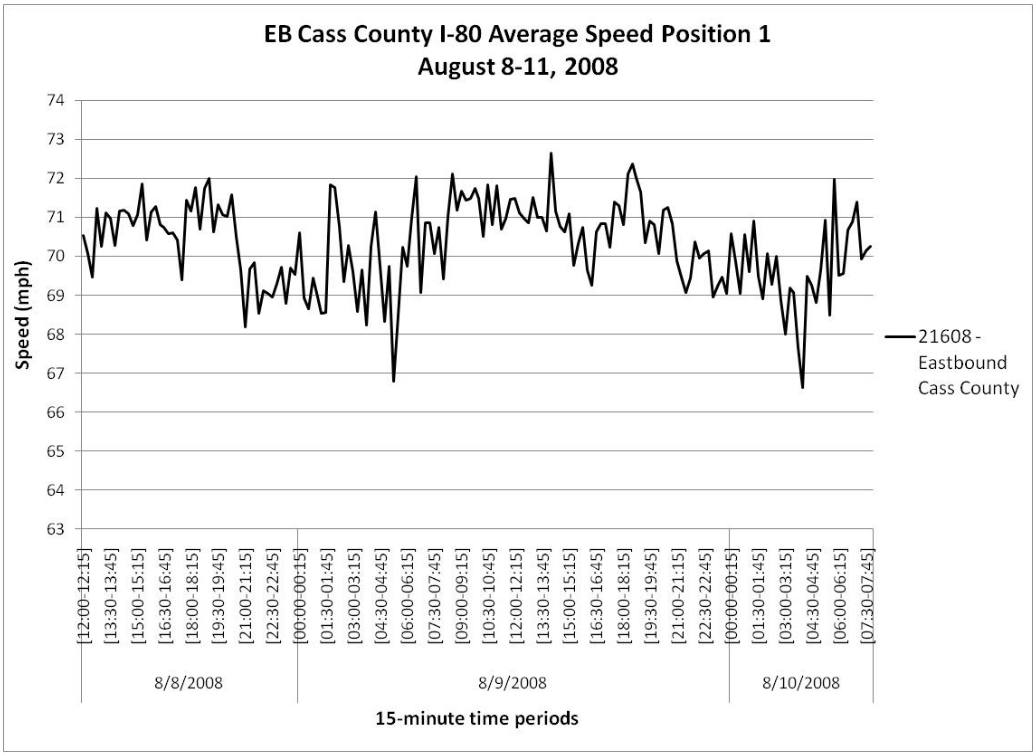


Figure A.15. Average vehicle speed (both lanes) at P1–August 8–11, 2008

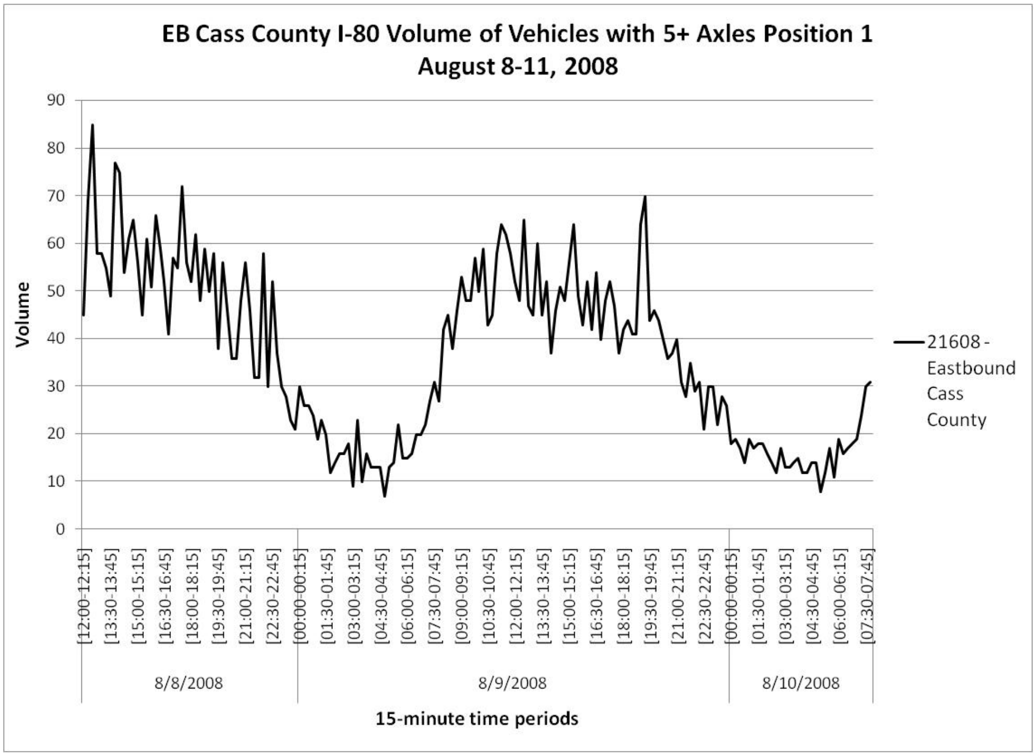


Figure A.16. Volume of heavy truck traffic at position 1 (both lanes)–August 8–11, 2008

August 14–18, 2008

EB Adair County

Data collection was conducted west of the construction site in the eastbound lanes. The driving lane was the closed lane at this location. Jamar road tubes were placed across the closing lane only at Position 1 (P1) prior to DMS's 3 and 4. Road tubes were laid across the closing lane at P2 after the "Right Lane Closed" static sign and at P3 after the static "Merge" sign. NuMetric plates were deployed at each position in the same lanes as the road tubes as well as in the open lane.

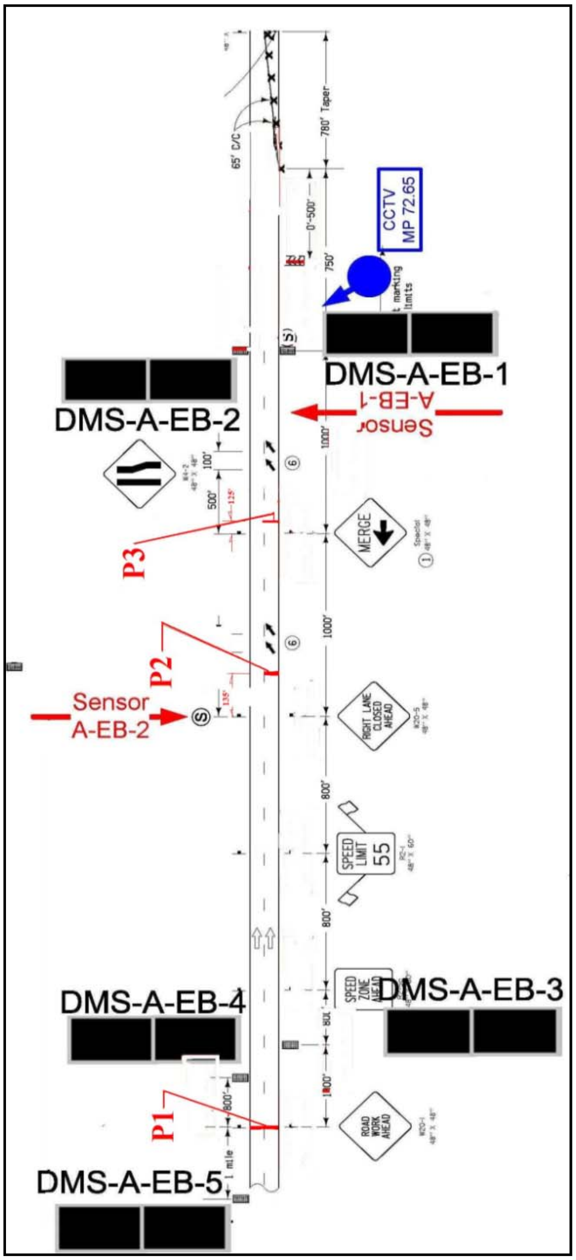


Figure A.17. Counter placement —EB Adair County–August 14–18, 2008

Table A.10. Counter placement at EB Adair County–August 14–18, 2008

Location	Counter Type	Number	Functional Summary
P1	Jamar tubes	8783	Unit 8783 failed
	Older Plates	2247/2251/3411	Unit 2247 software could not read
P2	Jamar tubes	8784	
	Older Plate	2248	
P3	Jamar tubes	8782	
	Older Plate	7576	Downloading error

General note: Because of relatively low volumes of traffic and the reduction of the “trigger” speeds before this weekend’s count, data gathered during this period included NO “trigger” events as there were no major slowdown periods. Due to the failure of both counters at P1, no data percentages could be calculated or tabulated.

Tube analyzers at position1were only installed in the closing lane instead of across both lanes like prior weekends. NuMetrics plates were utilized in the open lane.

Table A.11. Data worksheet and summary—EB Adair County–August 14–18, 2008

Late Merge I-80 Study					1/15/2009 1:32 PM		
August 14-18, 2008							
Adair, IA Eastbound							
Reporting Period 8/14 12:00PM - 8/18 8:00		Counter in Lane 1 (Driving Lane) had too many unclassified vehicles. Plate failed to gather data. No data available for lane 1 at position 1.					
Position 1							
Lane 1							
8783 (Tube)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	1			Too many unclassified vehicles. Bad data.			
2247 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	1			Counter Failed to gather data.			
Lane 2							
3411 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	2	67 mph	16,394				
2251 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	2			Counter Stopped Gathering Data 8/18 @1:00AM			
Position 2							
8784 (Tube)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	1	65 mph	23,835				
2248 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	1	65 mph	21,952				
Position 3							
8782 (Tube)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	1	65 mph	9,546				
7576 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	1			Counter Failed			
Breakdown of Vehicle Count							
		8783	8784	8782			
	Lane 1		23,835	9,546			
	Lane 2						
		0	23,835	9,546			

		P1		P2		P3	
		8783/3411	Percent of Total Traffic P1	8784	Percent of Total Traffic P1	8782	Percent of Total Traffic P1
Lane 1	0-240	0	0%	14,819	90%	5,680	35%
CLOSING LANE	241-480	0	0%	1,328	8%	647	4%
	481+	0	0%	7,688	47%	3,222	20%
		0	0%	23,835	145%	9,549	58%
Lane 2	0-240	14,370	88%	-449	-3%	8,690	53%
	241-480	531	3%	-797	-5%	-116	-1%
	481+	1,490	9%	-6,198	-38%	-1,732	-11%
		16,391	100%	-7,444	-45%	6,842	42%
		16,391	100%	16,391	100%	16,391	100%

Unable to create graphs because of missing data at position 1.

WB Adair County

Data collection was conducted east of the construction site in the westbound lanes. The passing lane was the closed lane at this location. Jamar road tubes were placed across the closing lane only at Position 1 (P1) prior to DMS's 3 and 4. Road tubes were laid across the closing lane at P2 after the "Right Lane Closed" static sign and at P3 after the static "Merge" sign. NuMetric plates were deployed at each position in the same lanes as the road tubes as well as in the open lane.

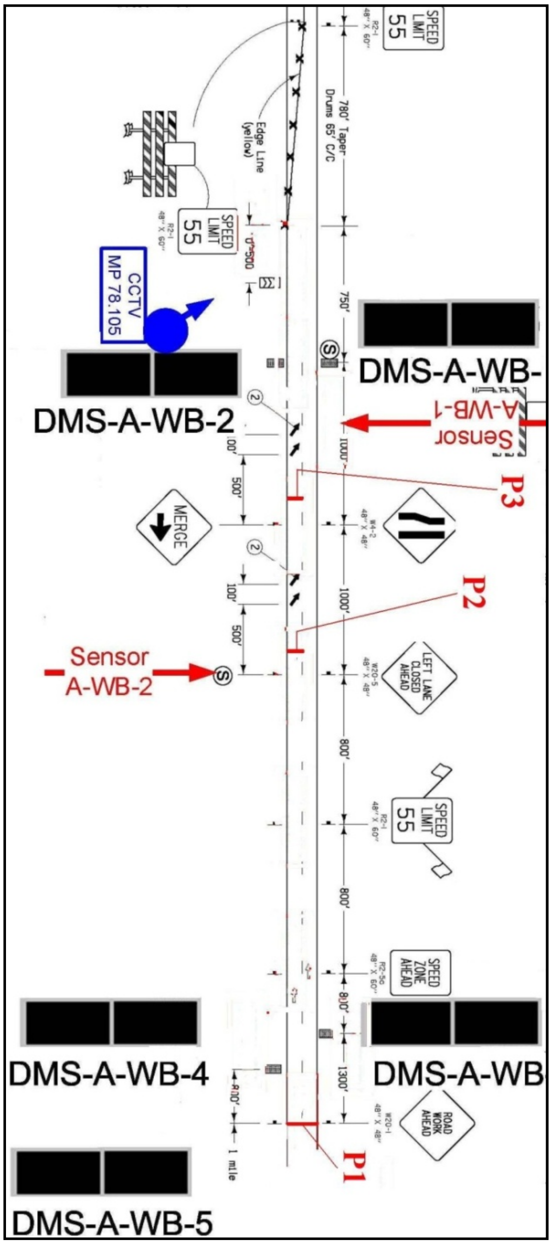


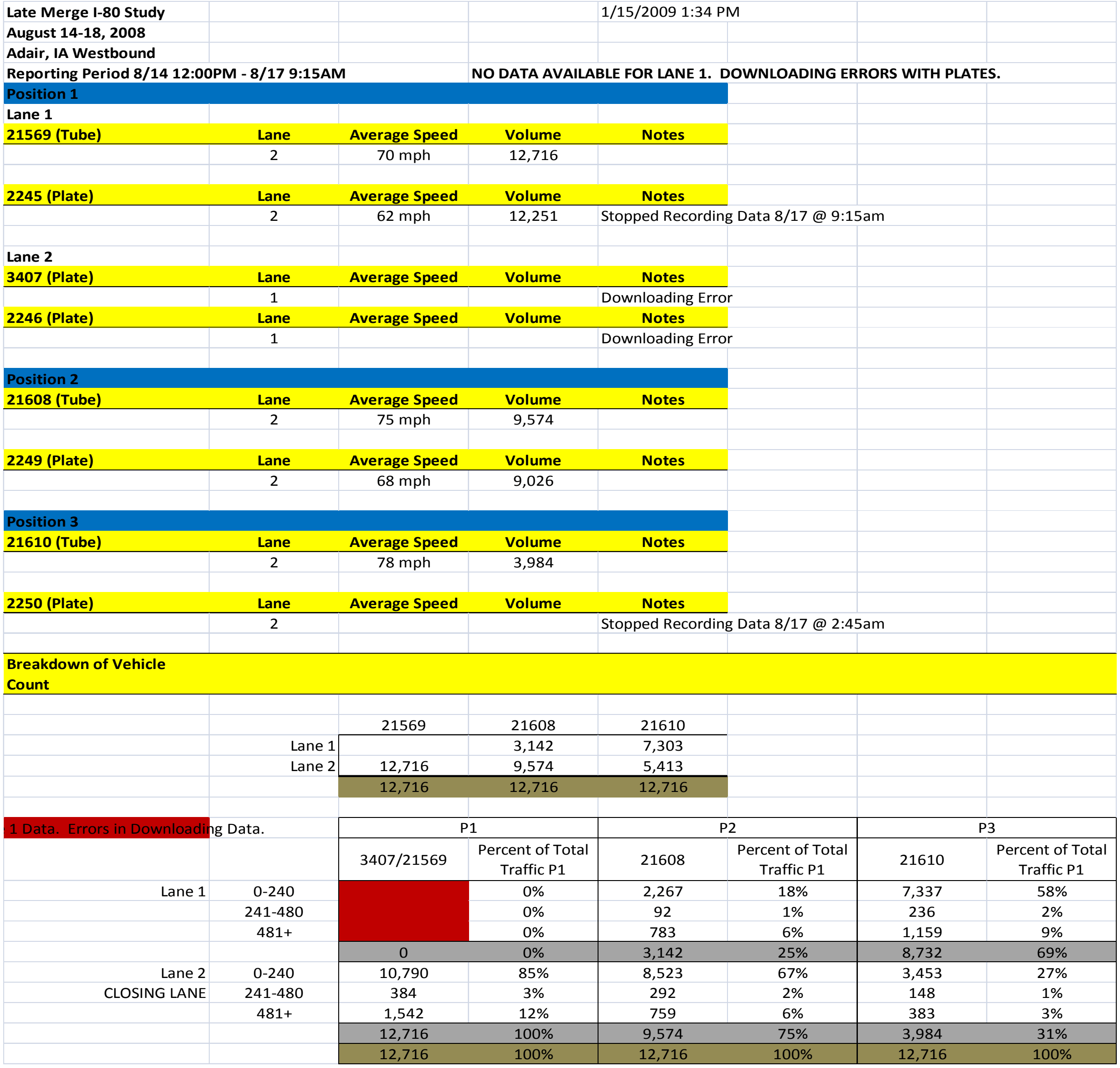
Figure A.18. Counter placement–WB Adair County–August 14–18, 2008

Table A.12. Counter placement at WB Adair County–August 14–18, 2008

Location	Counter Type	Number	Functional Summary
P1	Jamar tubes	21569	
	Older Plate	3407/2246/2245	All plates had download errors
P2	Jamar tubes	21608	
	Older Plate	2249	
P3	Jamar tubes	21610	
	Older Plate	2250	Memory maxed out on unit

General note: Road tube analyzers at position 1 were only installed in the closing lane instead of across both lanes like prior weekends. NuMetrics plates were utilized in the open lane but failed to operate correctly.

Table A.13. Data worksheet and summary–WB Adair County–August 14–18, 2008



Late Merge I-80 Study				1/15/2009 1:34 PM
August 14-18, 2008				
Adair, IA Westbound				
Reporting Period 8/14 12:00PM - 8/17 9:15AM			**NO DATA AVAILABLE FOR LANE 1. DOWNLOADING ERRORS WITH PLATES.**	
Position 1				
Lane 1				
21569 (Tube)	**Lane**	**Average Speed**	**Volume**	**Notes**
	2	70 mph	12,716	
2245 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**
	2	62 mph	12,251	Stopped Recording Data 8/17 @ 9:15am
Lane 2				
3407 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**
	1			Downloading Error
2246 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**
	1			Downloading Error
Position 2				
21608 (Tube)	**Lane**	**Average Speed**	**Volume**	**Notes**
	2	75 mph	9,574	
2249 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**
	2	68 mph	9,026	
Position 3				
21610 (Tube)	**Lane**	**Average Speed**	**Volume**	**Notes**
	2	78 mph	3,984	
2250 (Plate)	**Lane**	**Average Speed**	**Volume**	**Notes**
	2			Stopped Recording Data 8/17 @ 2:45am

Breakdown of Vehicle Count

		21569	21608	21610
	Lane 1		3,142	7,303
	Lane 2	12,716	9,574	5,413
		12,716	12,716	12,716

🟥 1 Data. Errors in Downloading Data.		P1		P2		P3	
		3407/21569	Percent of Total Traffic P1	21608	Percent of Total Traffic P1	21610	Percent of Total Traffic P1
Lane 1	0-240	🟥	0%	2,267	18%	7,337	58%
	241-480	🟥	0%	92	1%	236	2%
	481+	🟥	0%	783	6%	1,159	9%
		0	0%	3,142	25%	8,732	69%
Lane 2	0-240	10,790	85%	8,523	67%	3,453	27%
CLOSING LANE	241-480	384	3%	292	2%	148	1%
	481+	1,542	12%	759	6%	383	3%
		12,716	100%	9,574	75%	3,984	31%
		12,716	100%	12,716	100%	12,716	100%

Unable to create graphs because of missing data at position 1.

October 16–20, 2008

WB Cass County

Data collection was conducted east of the construction site in the westbound lanes. The driving lane was the closed lane at this location. Jamar road tubes were not utilized during this weekend. NuMetric plates were deployed at P1, P2, and P3 same as prior weekends.

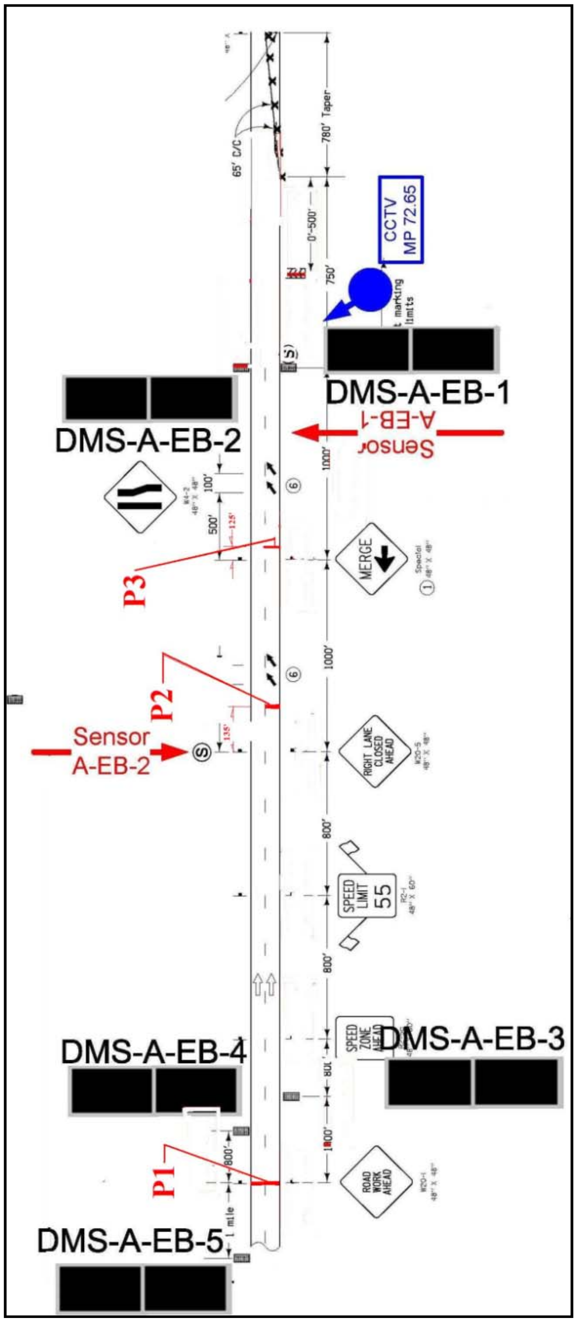


Figure A.19. Counter placement–WB Cass County–October 16–20, 2008

Table A.14. Counter placement at WB Cass County–October 16–20, 2008

Location	Counter Type	Number	Functional Summary
P1	Older Plate	3408/3407	Failed to download data
P2	Older Plate	3404	Failed to download data
P3	Older Plate	3413	

General note: Plates 3408, 3407, 3404 all failed to download data.

No worksheet or summary available for this location due to lack of data gathered.

EB Cass County

Data collection was conducted west of the construction site in the eastbound lanes. The passing lane was the closed lane at this location. Jamar road tubes were not utilized during this weekend. NuMetric plates were deployed at P1, P2, and P3 same as prior weekends.

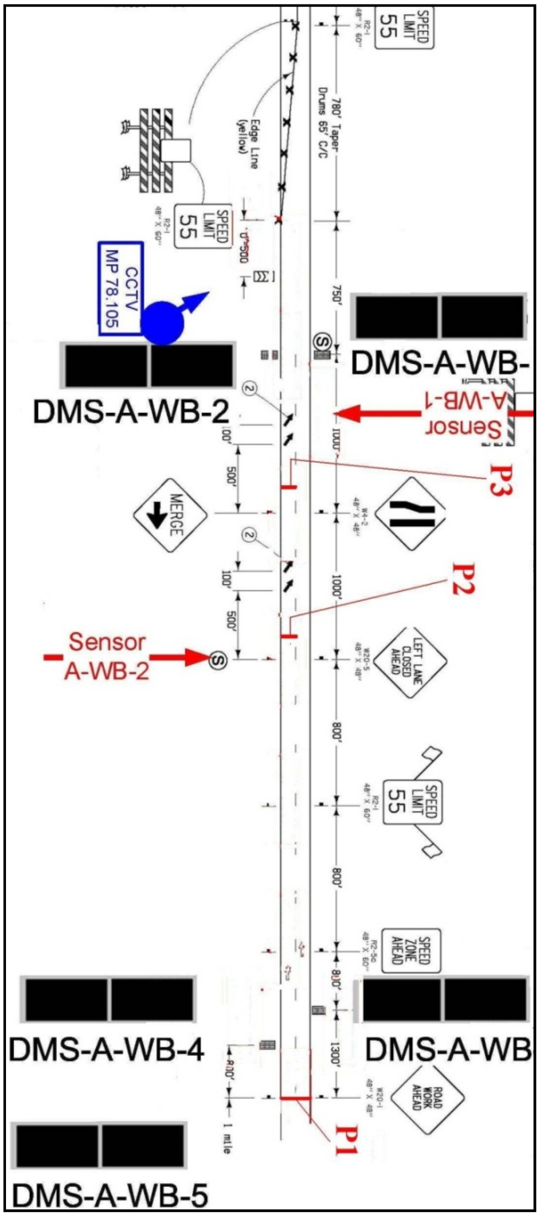


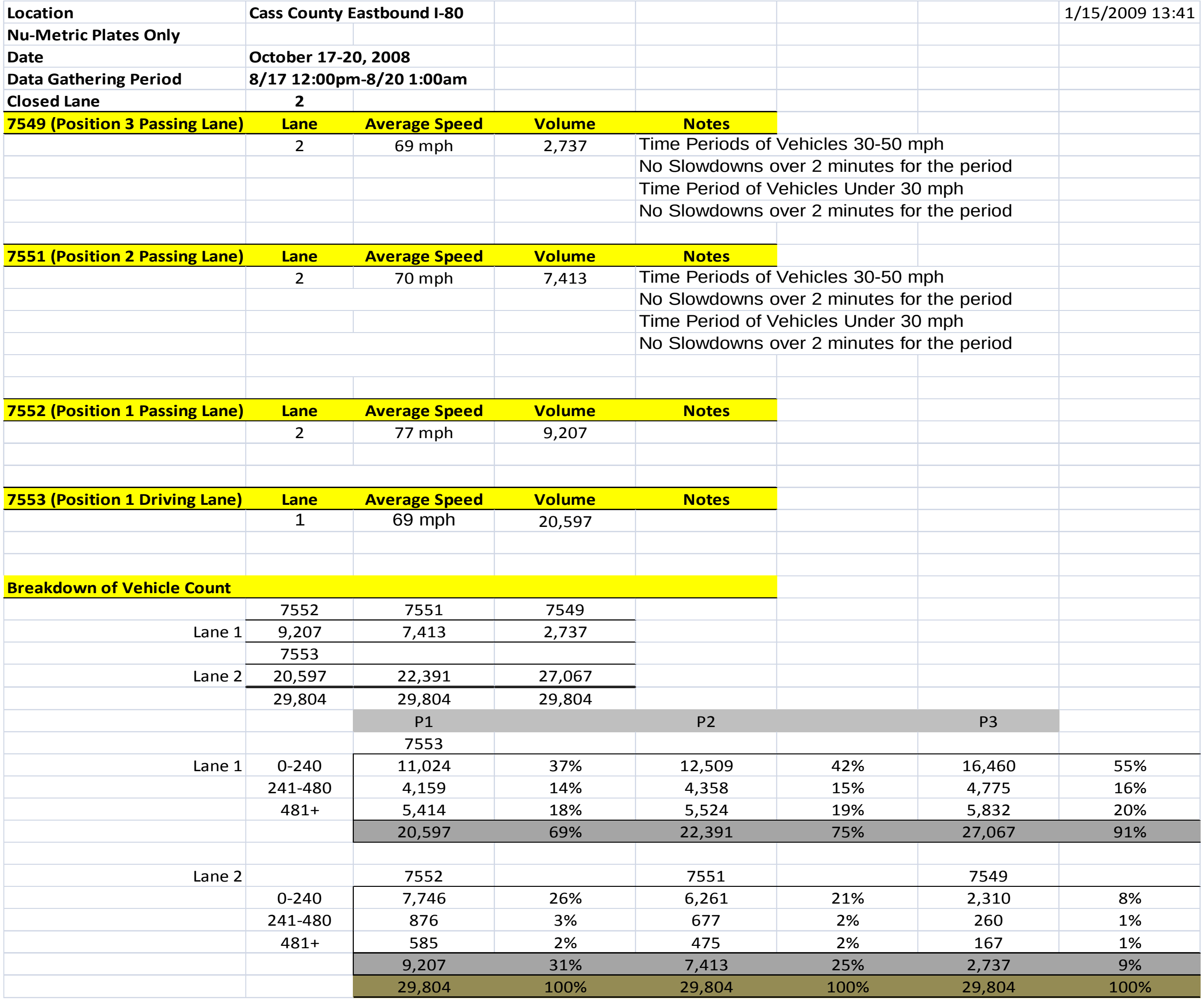
Figure A.20. Counter placement–EB Cass County–October 16–20, 2008

Table A.15. Counter placement at EB Cass County–October 16–20, 2008

Location	Counter Type	Number	Functional Summary
P1	New Plate	7553	
	New Plate	7552	
P2	New Plate	7551	
P3	New Plate	7549	

General note: New NuMetrics plates operated as programmed. Collected traffic data for entire study period.

Table A.16. Data worksheet and summary–EB Cass County–October 16–20, 2008



Location	**Cass County Eastbound I-80**						1/15/2009 13:41
Nu-Metric Plates Only							
Date	**October 17-20, 2008**						
Data Gathering Period	**8/17 12:00pm-8/20 1:00am**						
Closed Lane	**2**						
7549 (Position 3 Passing Lane)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	2	69 mph	2,737	Time Periods of Vehicles 30-50 mph			
				No Slowdowns over 2 minutes for the period			
				Time Period of Vehicles Under 30 mph			
				No Slowdowns over 2 minutes for the period			
7551 (Position 2 Passing Lane)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	2	70 mph	7,413	Time Periods of Vehicles 30-50 mph			
				No Slowdowns over 2 minutes for the period			
				Time Period of Vehicles Under 30 mph			
				No Slowdowns over 2 minutes for the period			
7552 (Position 1 Passing Lane)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	2	77 mph	9,207				
7553 (Position 1 Driving Lane)	**Lane**	**Average Speed**	**Volume**	**Notes**			
	1	69 mph	20,597				
Breakdown of Vehicle Count							
	7552	7551	7549				
Lane 1	9,207	7,413	2,737				
	7553						
Lane 2	20,597	22,391	27,067				
	29,804	29,804	29,804				
		P1		P2		P3	
		7553					
Lane 1	0-240	11,024	37%	12,509	42%	16,460	55%
	241-480	4,159	14%	4,358	15%	4,775	16%
	481+	5,414	18%	5,524	19%	5,832	20%
		20,597	69%	22,391	75%	27,067	91%
Lane 2		7552		7551		7549	
	0-240	7,746	26%	6,261	21%	2,310	8%
	241-480	876	3%	677	2%	260	1%
	481+	585	2%	475	2%	167	1%
		9,207	31%	7,413	25%	2,737	9%
		29,804	100%	29,804	100%	29,804	100%

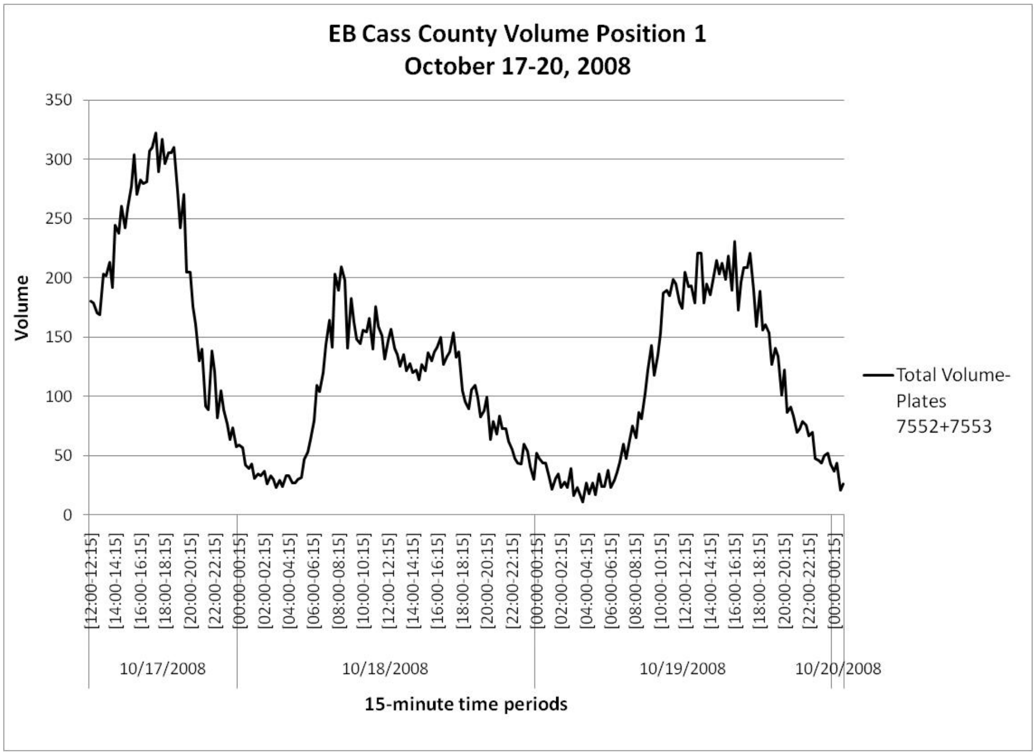


Figure A.21. Average vehicle volume (both lanes) at P1–October 16–20, 2008

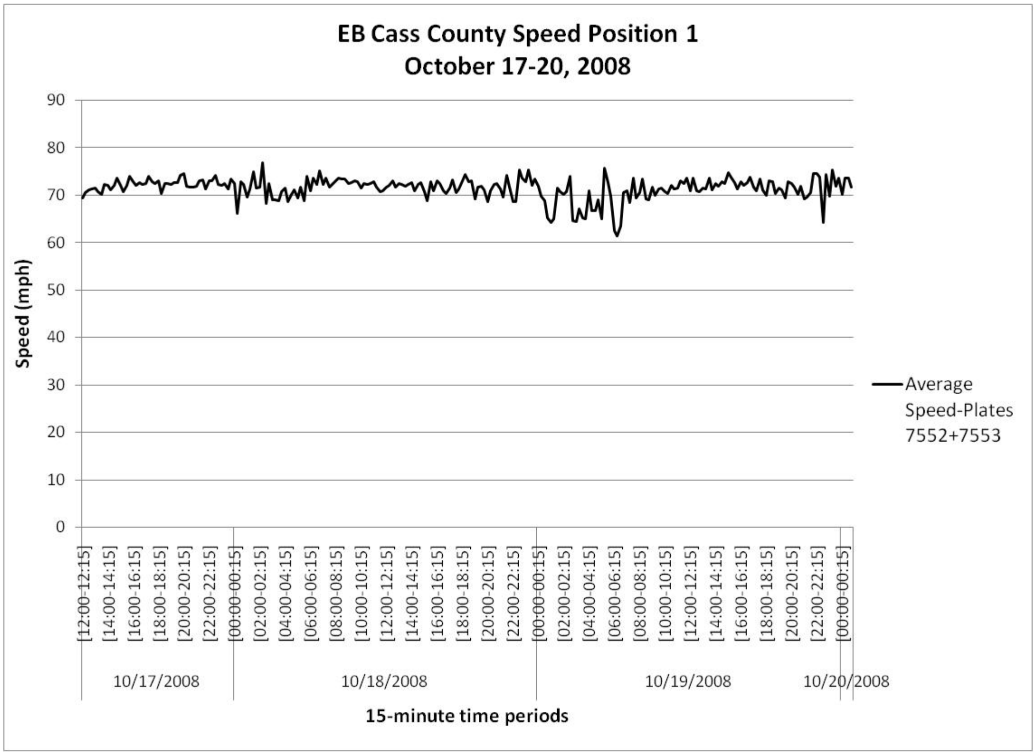


Figure A.22. Average vehicle speed (both lanes) at Position 1–October 16–20, 2008

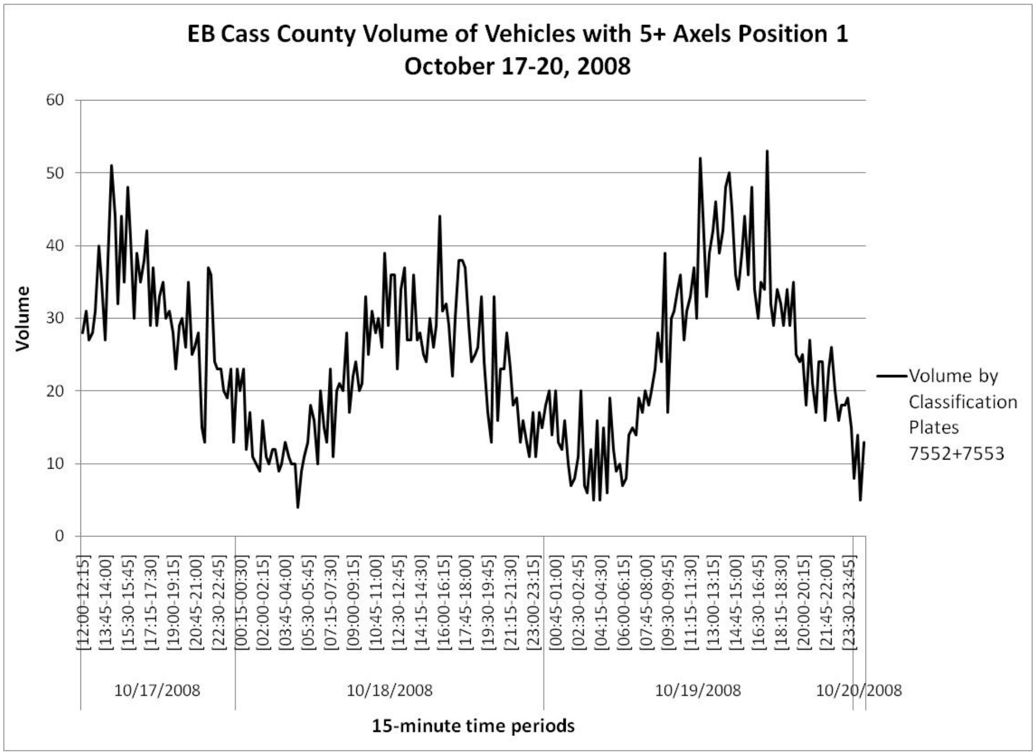


Figure A.23. Volume of heavy truck traffic at position 1 (both lanes)–October 16–20, 2008

Table A.17. Volume counter locations for WB Cass County

Volume count source	Distance east of point of closure (in miles)
Sensor A–EB–1 #10	0.3
Sensor A–EB–1 #6	0.5
Jamar Counter location P1	1.2
DOT ATR # 11530	1.6

(Note– ATR locations are beyond limits of the map.)

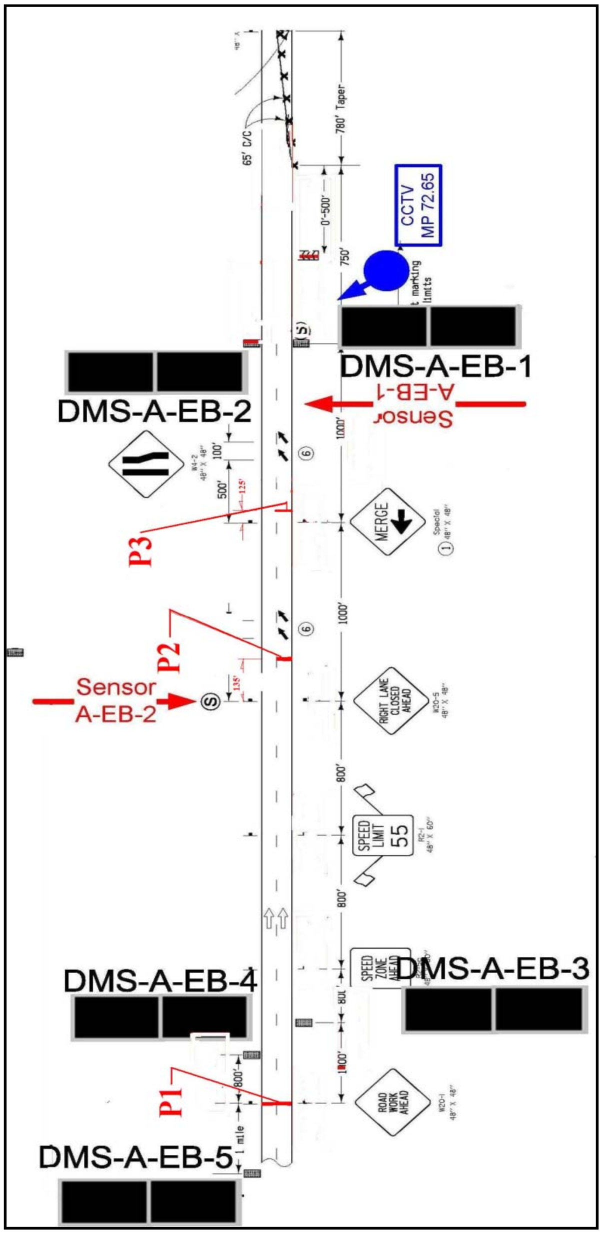


Figure A.24. Relative locations of volume counters listed in Table A.20

Table A.18. Comparison of hourly counter information from sensors, ATR, and Jamar counters

Hourly Traffic Volumes at WB Cass County Location

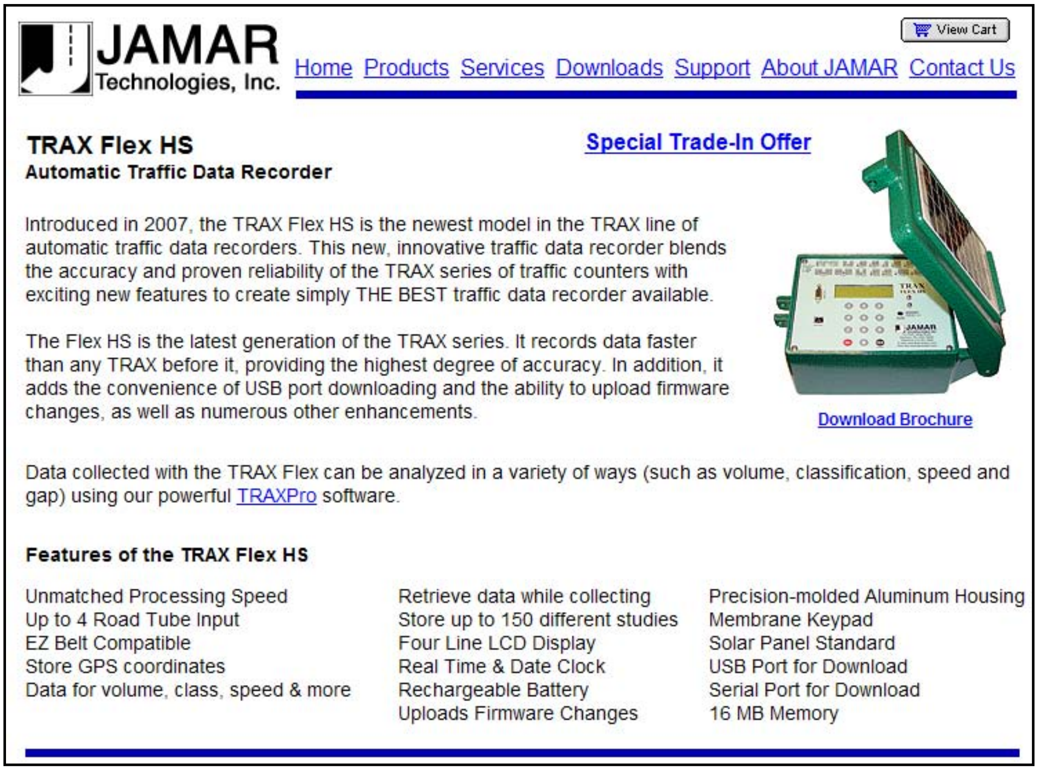
August 3 Data

		Sensor	DOT ATR	Difference	Jamar	Difference	Jamar/Recorder	
	#			(Pos if Sens. is high)		Pos if Jamar high	Per Cent	
8/3/2008 @ 12	q06	222	348	-126	341	-7	98%	
8/3/2008 @ 1:	q06	231	213	18	334	121	157%	
8/3/2008 @ 2:	q06	242	221	21	250	29	113%	
8/3/2008 @ 3:	q06	178	162	16	177	15	109%	
8/3/2008 @ 4:	q06	91	103	-12	155	52	150%	
8/3/2008 @ 5:	q06	95	98	-3	206	108	210%	
8/3/2008 @ 6:	q06	94	119	-25	290	171	244%	
@7			180	-180	496	316	276%	
@8	Sensor		316	-316	695	379	220%	
@9	Skiped?		448	-448	950	502	212%	
@10			638	-638	1,242	604	195%	
8/3/2008 @ 11	q06	48	853	-805	1,388	535	163%	
8/3/2008 @ 12	q06	309	921	-612	1,357	436	147%	
8/3/2008 @ 1:	q06	849	919	-70	1,460	541	159%	
8/3/2008 @ 2:	q06	940	1,007	-67	1,575	568	156%	
8/3/2008 @ 3:	q06	994	1,116	-122	1,665	549	149%	
8/3/2008 @ 4:	q06	1,038	1,170	-132	1,646	476	141%	
8/3/2008 @ 5:	q06	1,041	1,176	-135	1,630	454	139%	
8/3/2008 @ 6:	q06	1,025	1,136	-111	1,372	236	121%	
8/3/2008 @ 7:	q06	847	947	-100	1,209	262	128%	
8/3/2008 @ 8:	q06	778	823	-45	968	145	118%	
8/3/2008 @ 9:	q06	601	640	-39	819	179	128%	
8/3/2008 @ 10	q06	552	553	-1	642	89	116%	
8/3/2008 @ 11	q06	346	431	-85	501	70	116%	
				-4,017		6,830		
	Sum=	10,521	14,538	-4,017	21,368	6,830	Avg.	147%

August 4 Data

			Sensors		DOT ATR	Difference		Jamar	Difference	Jamar/Recorder
	#		#			(Pos if Sens. is high)		AT P1	Pos if Jamar high	Per Cent
8/4/2008 @ 12	q10	275	q06	193		q10	q06	344		
8/4/2008 @ 1:	q10	80	q06	235	240	-160	-5	276	36	115%
8/4/2008 @ 2:	q10	63	q06	194	187	-124	7	182	-5	97%
8/4/2008 @ 3:	q10	47	q06	123	123	-76	0	202	79	164%
8/4/2008 @ 4:	q10	45	q06	133	138	-93	-5	265	127	192%
8/4/2008 @ 5:	q10	57	q06	166	170	-113	-4	366	196	215%
8/4/2008 @ 6:	q10	69	q06	235	234	-165	1	539	305	230%
8/4/2008 @ 7:	q10	106	q06	342	348	-242	-6	682	334	196%
8/4/2008 @ 8:	q10	85	q06	295	428	-343	-133			
8/4/2008 @ 9:	q10	127	q06	506	514	-387	-8			
8/4/2008 @ 10	q10	129	q06	595	596	-467	-1			
8/4/2008 @ 11	q10	186	q06	684	728	-542	-44			
8/4/2008 @ 12	q10	158	q06	632	691	-533	-59			
8/4/2008 @ 1:	q10	142	q06	573	693	-551	-120			
8/4/2008 @ 2:	q10	119	q06	590	718	-599	-128			
8/4/2008 @ 3:	q10	133	q06	706	745	-612	-39			
8/4/2008 @ 4:	q10	201	q06	804	776	-575	28			
8/4/2008 @ 5:	q10	197	q06	814	827	-630	-13			
8/4/2008 @ 6:	q10	166	q06	636	627	-461	9			
8/4/2008 @ 7:	q10	211	q06	706	696	-485	10			
8/4/2008 @ 8:	q10	198	q06	643	580	-382	63			
8/4/2008 @ 9:	q10	188	q06	581	513	-325	68			
8/4/2008 @ 10	q10	134	q06	457	433	-299	24			
8/4/2008 @ 11	q10	85	q06	289	331	-246	-42			
	Sum =	3,201		11,132	11,336	-8,410	-397	2,856	1,072	

APPENDIX B. EQUIPMENT SPECIFICATIONS



TRAX Flex HS

Automatic Traffic Data Recorder

Introduced in 2007, the TRAX Flex HS is the newest model in the TRAX line of automatic traffic data recorders. This new, innovative traffic data recorder blends the accuracy and proven reliability of the TRAX series of traffic counters with exciting new features to create simply THE BEST traffic data recorder available.

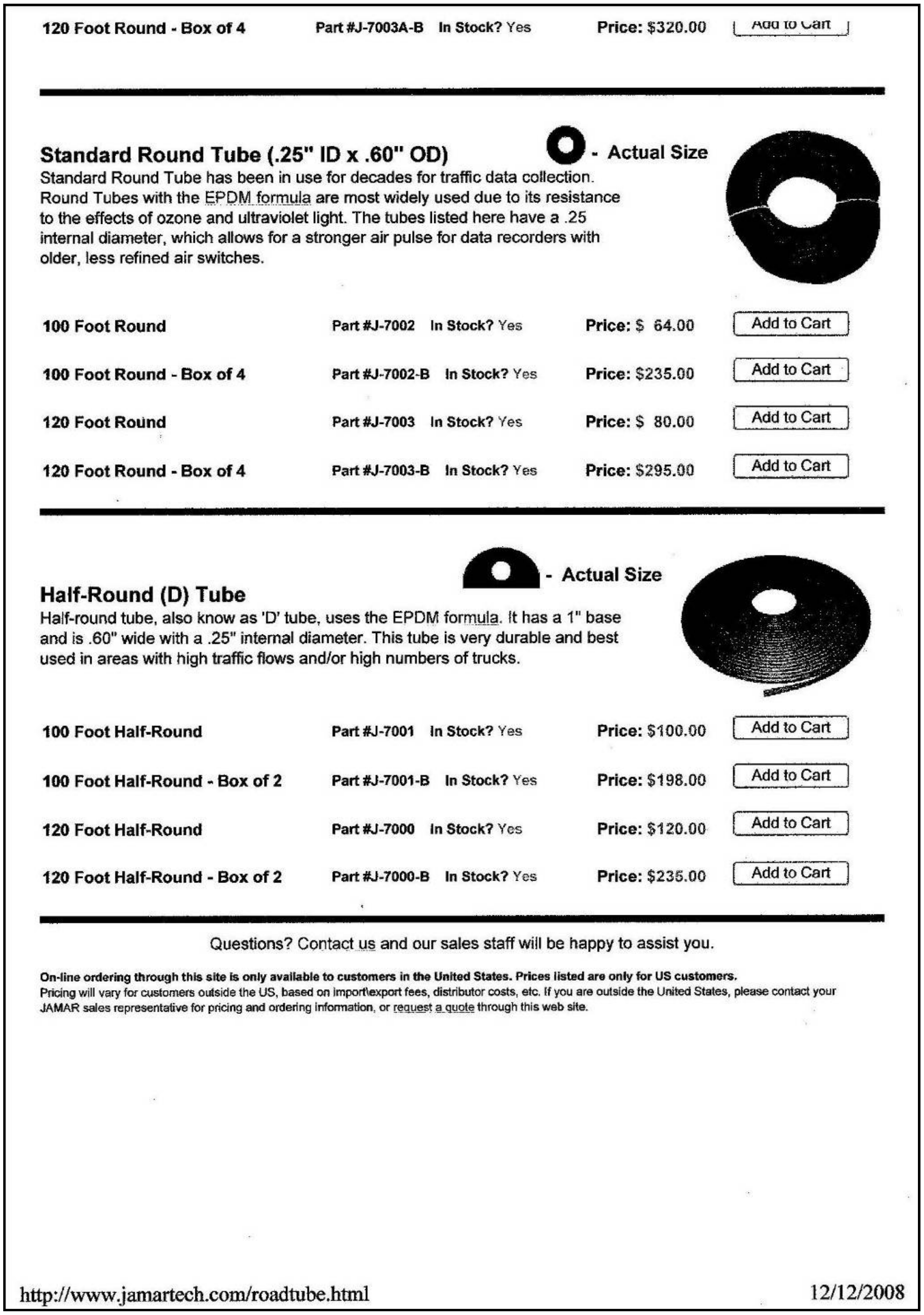
The Flex HS is the latest generation of the TRAX series. It records data faster than any TRAX before it, providing the highest degree of accuracy. In addition, it adds the convenience of USB port downloading and the ability to upload firmware changes, as well as numerous other enhancements.

Data collected with the TRAX Flex can be analyzed in a variety of ways (such as volume, classification, speed and gap) using our powerful TRAXPro software.

Features of the TRAX Flex HS

Unmatched Processing Speed
Up to 4 Road Tube Input
EZ Belt Compatible
Store GPS coordinates
Data for volume, class, speed & more
Retrieve data while collecting
Store up to 150 different studies
Four Line LCD Display
Real Time & Date Clock
Rechargeable Battery
Uploads Firmware Changes
Precision-molded Aluminum Housing
Membrane Keypad
Solar Panel Standard
USB Port for Download
Serial Port for Download
16 MB Memory

Figure B.1. Jamar TRAX Flex HS



120 Foot Round - Box of 4	**Part #J-7003A-B**	**In Stock?** Yes	**Price:** $320.00	Add to Cart

Standard Round Tube (.25" ID x .60" OD)

- Actual Size

Standard Round Tube has been in use for decades for traffic data collection. Round Tubes with the EPDM formula are most widely used due to its resistance to the effects of ozone and ultraviolet light. The tubes listed here have a .25 internal diameter, which allows for a stronger air pulse for data recorders with older, less refined air switches.

100 Foot Round	**Part #J-7002**	**In Stock?** Yes	**Price:** $ 64.00	Add to Cart
100 Foot Round - Box of 4	**Part #J-7002-B**	**In Stock?** Yes	**Price:** $235.00	Add to Cart
120 Foot Round	**Part #J-7003**	**In Stock?** Yes	**Price:** $ 80.00	Add to Cart
120 Foot Round - Box of 4	**Part #J-7003-B**	**In Stock?** Yes	**Price:** $295.00	Add to Cart

Half-Round (D) Tube

- Actual Size

Half-round tube, also know as 'D' tube, uses the EPDM formula. It has a 1" base and is .60" wide with a .25" internal diameter. This tube is very durable and best used in areas with high traffic flows and/or high numbers of trucks.

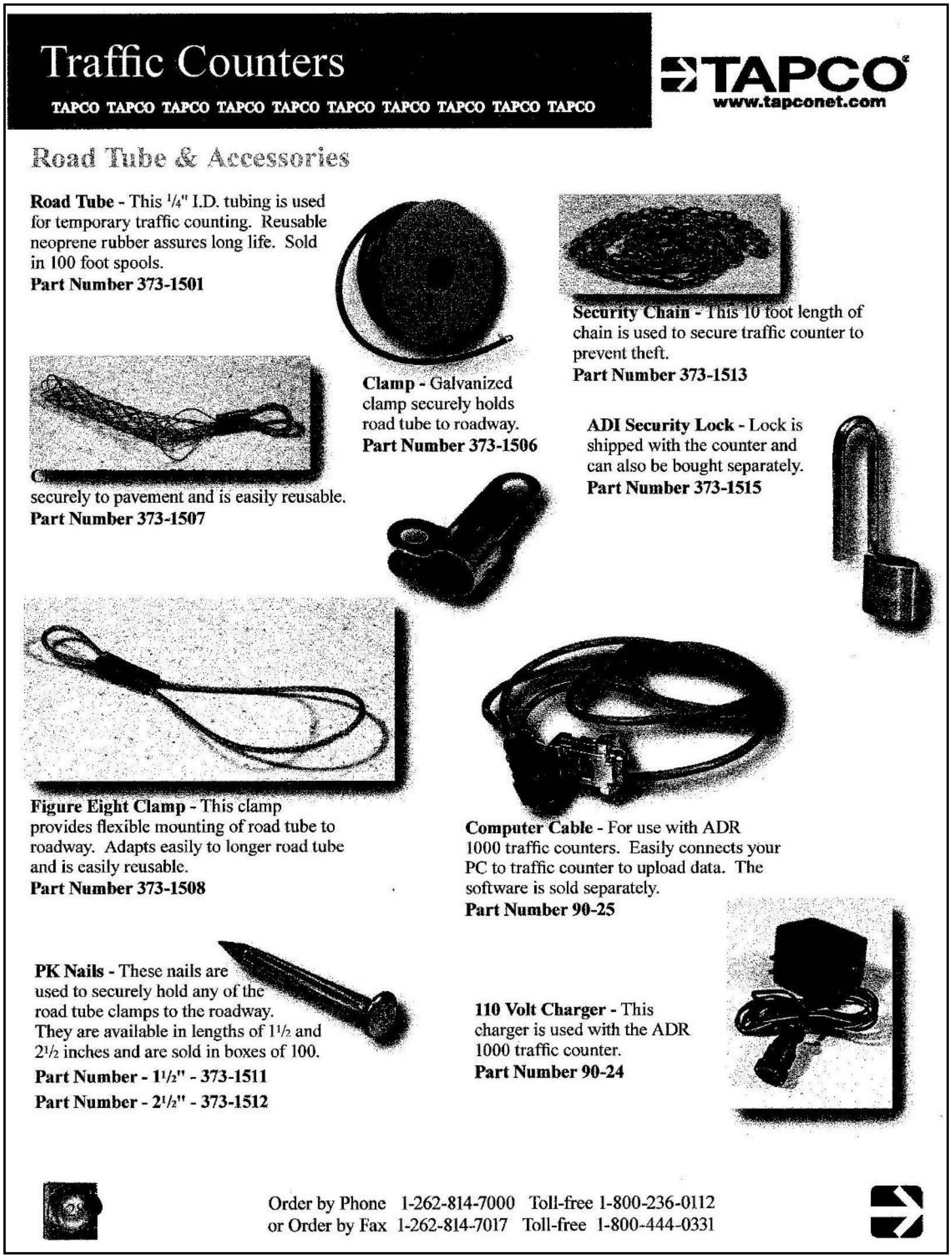
100 Foot Half-Round	**Part #J-7001**	**In Stock?** Yes	**Price:** $100.00	Add to Cart
100 Foot Half-Round - Box of 2	**Part #J-7001-B**	**In Stock?** Yes	**Price:** $198.00	Add to Cart
120 Foot Half-Round	**Part #J-7000**	**In Stock?** Yes	**Price:** $120.00	Add to Cart
120 Foot Half-Round - Box of 2	**Part #J-7000-B**	**In Stock?** Yes	**Price:** $235.00	Add to Cart

Questions? Contact us and our sales staff will be happy to assist you.

On-line ordering through this site is only available to customers in the United States. Prices listed are only for US customers.
Pricing will vary for customers outside the US, based on import\export fees, distributor costs, etc. If you are outside the United States, please contact your JAMAR sales representative for pricing and ordering information, or request a quote through this web site.

http://www.jamartech.com/roadtube.html 12/12/2008

Figure B.2. Jamar Half Round (D) Tube



Traffic Counters

TAPCO TAPCO TAPCO TAPCO TAPCO TAPCO TAPCO TAPCO TAPCO TAPCO

TAPCO
www.tapconet.com

Road Tube & Accessories

Road Tube - This $\frac{1}{4}$" I.D. tubing is used for temporary traffic counting. Reusable neoprene rubber assures long life. Sold in 100 foot spools.
Part Number 373-1501

Security Chain - This 10 foot length of chain is used to secure traffic counter to prevent theft.
Part Number 373-1513

Clamp - Galvanized clamp securely holds road tube to roadway.
Part Number 373-1506

securely to pavement and is easily reusable.
Part Number 373-1507

ADI Security Lock - Lock is shipped with the counter and can also be bought separately.
Part Number 373-1515

Figure Eight Clamp - This clamp provides flexible mounting of road tube to roadway. Adapts easily to longer road tube and is easily reusable.
Part Number 373-1508

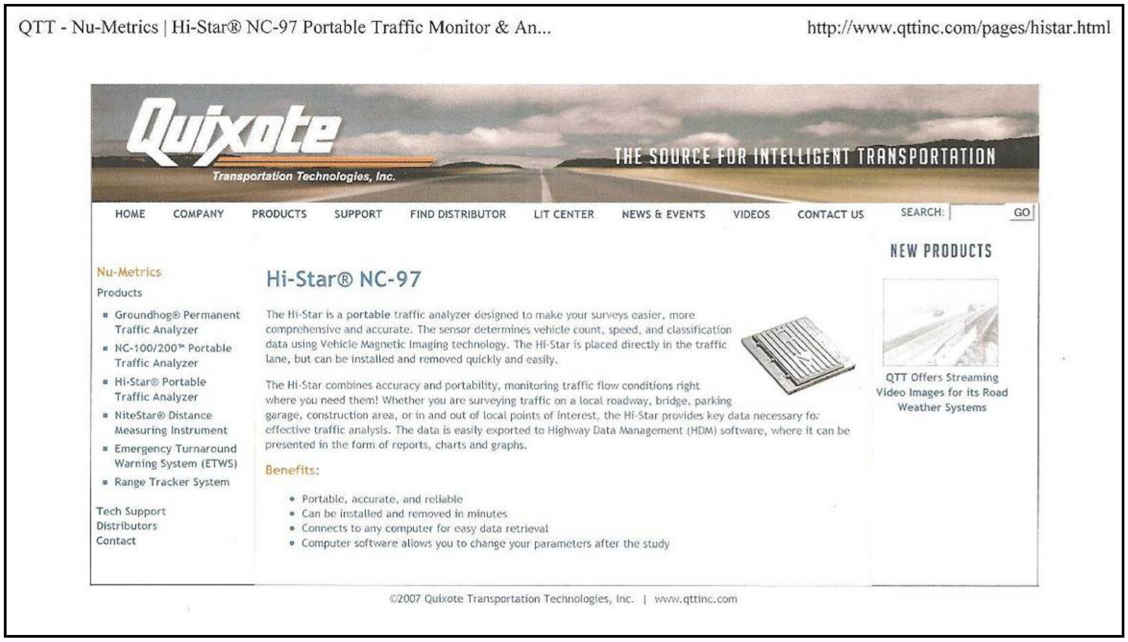
Computer Cable - For use with ADR 1000 traffic counters. Easily connects your PC to traffic counter to upload data. The software is sold separately.
Part Number 90-25

PK Nails - These nails are used to securely hold any of the road tube clamps to the roadway. They are available in lengths of $1\frac{1}{2}$ and $2\frac{1}{2}$ inches and are sold in boxes of 100.
Part Number - $1\frac{1}{2}$" - 373-1511
Part Number - $2\frac{1}{2}$" - 373-1512

110 Volt Charger - This charger is used with the ADR 1000 traffic counter.
Part Number 90-24

Order by Phone 1-262-814-7000 Toll-free 1-800-236-0112
or Order by Fax 1-262-814-7017 Toll-free 1-800-444-0331

Figure B.3. TAPCO Traffic Counting Accessories



Hi-Star® NC-97

The Hi-Star is a **portable** traffic analyzer designed to make your surveys easier, more comprehensive and accurate. The sensor determines vehicle count, speed, and classification data using Vehicle Magnetic Imaging technology. The Hi-Star is placed directly in the traffic lane, but can be installed and removed quickly and easily.

The Hi-Star combines accuracy and portability, monitoring traffic flow conditions right where you need them! Whether you are surveying traffic on a local roadway, bridge, parking garage, construction area, or in and out of local points of interest, the Hi-Star provides key data necessary for effective traffic analysis. The data is easily exported to Highway Data Management (HDM) software, where it can be presented in the form of reports, charts and graphs.

Benefits:

- Portable, accurate, and reliable
- Can be installed and removed in minutes
- Connects to any computer for easy data retrieval
- Computer software allows you to change your parameters after the study

QTT Offers Streaming Video Images for its Road Weather Systems

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Figure B.4. Quixote–NuMetrics Hi Star NC-97

NC-100/200™

Portable Traffic Analyzer

Overview

The NC-100/200 is a portable traffic analyzer designed to provide accurate count, speed, and classification data. The sensor is placed directly in the traffic lane to measure data, and can be installed and removed quickly and easily. The NC-100 model provides count only, while the NC-200 model provides count, speed and classification of vehicles.

The sensor combines accuracy and portability, monitoring traffic flow conditions right where you need them. Whether you are surveying traffic on a local roadway, bridge, parking garage, construction area, or in and out of local points of interest, the NC-100/200 provides key data necessary for effective traffic analysis.

The NC-100/200 utilizes Vehicle Magnetic Imaging (VMI) technology to detect vehicle count, speed and classification. The data is easily exported to Highway Data Management (HDM) software, where it can be presented in the form of reports, charts and graphs.

Benefits

- Portable sensor detects vehicle count, speed and classification
- Can be installed and removed in minutes
- Less noticeable to traffic, which results in more accurate information

Applications

- Traffic studies
- Parking lots, garages, and shopping centers
- Temporary studies for roadway planning
- Construction zones
- Airports, stadiums, and casinos
- Military bases and border crossings
- Parks or recreational areas
- Police departments (for speed studies)
- Stop signs, traffic lights, or posted speeds

www.qttinc.com

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The Source For Intelligent Transportation

Figure B.5. Quixote–NuMetrics NC-100/200 (p.1)

NC-100/200™

Portable Traffic Analyzer

Features

- Accurately measures vehicle count, speed, and classification
- Categorizes traffic into bins or by individual vehicle
- 15 speed bins and 13 length classification bins (configurable)
- Durable extruded aluminum housing
- Long life, rechargeable, Lithium-ion battery
- Connects to any computer for easy data retrieval
- Easy to use software for viewing data
- Software allows you to change your parameters after the study

Key Specifications

Housing Material	Extruded/anodized aluminum
Ultimate Bearing Strength	88,000 psi (607 Mpa)
Dimensions	7.125 x 4.625 x 0.5 inches (181 x 118 x 12.7 millimeters)
Weight	1.3 pounds (0.59 kilograms)
Operating Temperature	-4°F to +140°F (-20°C to +60°C)
Sensor	GMR magnetic chip for Vehicle Magnetic Imaging
Memory	Micro Serial Flash: 3MB
Battery/Power	Lithium-ion rechargeable (up to 21 days before recharge)
Computed Values	Imperial or Metric
*Capacity	Up to 300,000 vehicles or 21 days per study, whichever occurs first
*Length Classification (% of Volume)	13 bins (user selectable length range)
*Speed Class (% of Volume)	15 bins (user selectable speed range)
Vehicle Detection	Detects vehicles between 8 and 120 mph (13 to 193 kph)

*Applies to model NC-200

Specifications subject to change without notice.

Quixote Transportation Technologies, Inc.

nu-metrics®

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Figure B.6. Quixote–NuMetrics NC 100/200 (p.2)

APPENDIX C. DAMAGE TO EQUIPMENT DURING TESTING

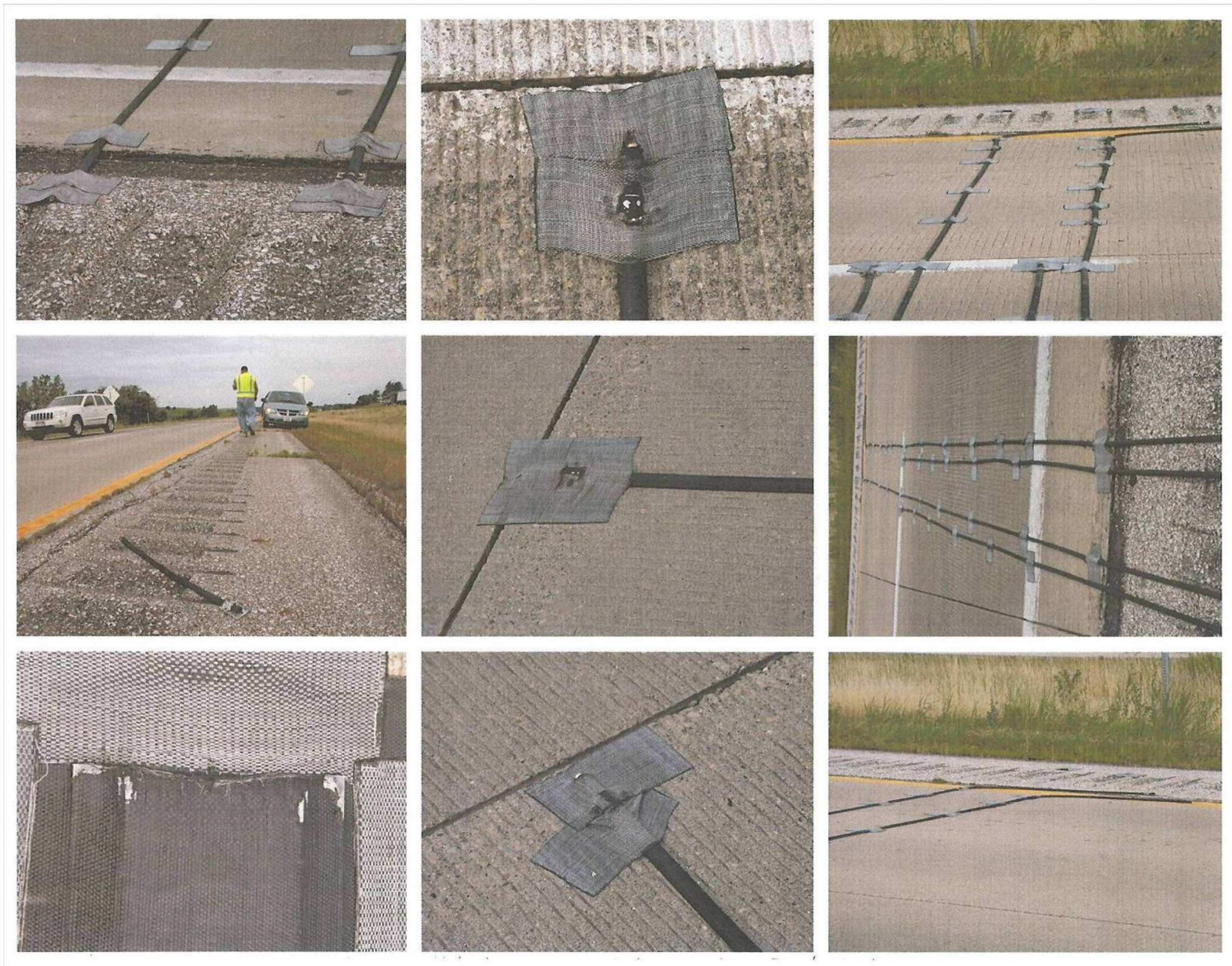

Figure C.1. Photos of damaged tubes, tape, and hold-down devices (photos by Brad Grefe)

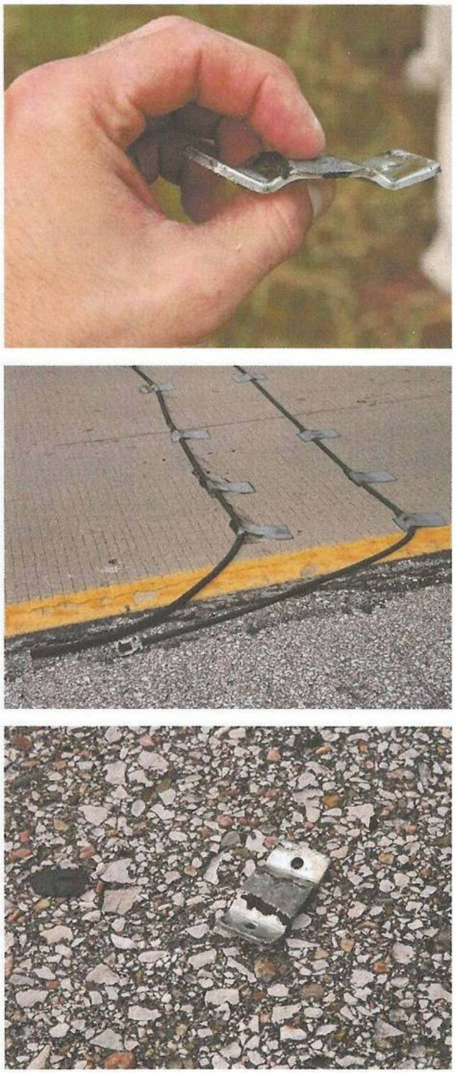

Figure C.2. Photos of damaged tubes, tape, and hold-down devices (continued) (photos by Brad Grefe)