MIDWEST SMART WORK ZONE DEPLOYMENT INITIATIVE

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Intellizone

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Abstract

Improving freeway work zone traffic control could lead to more efficient traffic flow and greater safety to workers and the driving public. Newer technologies are being developed for improving work zone traffic control as in the case of dynamic speed advisory systems. Such systems have the potential to warn drivers of slow downs near work zones and streamline traffic approaching the work zone. An evaluation of a particular speed advisory system was conducted using multiple performance measures on I-70 in St. Louis, Missouri. The use of mean speed, speed variance, and driver surveys show that the system helped to improve the safety of the work zone. Data also show that static and dynamic operations of the system produced different effects on the traffic pattern. Time headways and conflict video were collected but were not useful in this particular evaluation.

Evaluation of a Freeway Work-zone Advance Speed Advisory System

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Executive Summary

The Quixote IntelliZone is a work zone speed advisory system. Three mobile count units (which can measure flow, speed, and density) are placed in each lane where queues could form due to the construction zone. Two variable message signs (VMS units) are placed approximately two miles and five miles upstream from the detectors. One mobile command unit is placed between the detectors and the VMS units. The command units take information from the sensors on average speed and send signals to the VMS units to indicate an appropriate message, using either line-of-sight or cellular communication. Under free flow conditions the message would provide a standard warning of the construction zone. When queues cause significant speed reductions the VMS units can warn of the reduced speed ahead by displaying the downstream speed, based upon a rolling 3- to 5-minute average. The study site for the evaluation of the IntelliZone system was Eastbound I-70 near Wentzville Pkwy. and Pearce Blvd. which is just west of St. Louis, Missouri.

The objectives of the evaluation are to determine whether the system:

1. Performs as described.
2. Affects the speed pattern positively.
3. Reduces traffic conflicts.
4. Is understood and accepted by the driving public.

The deployment objective of driver understanding and acceptance of the system was measured by driver surveys downstream of deployment. The objectives of reduced speeds, reduced speed variances, and increased headways were measured by detectors

upstream from the work zone. The objective of fewer conflicts was not assessed as the video footage of the back of queues was inconclusive.

The data collected for evaluation included the following:

- eighteen days of temporary magnetic detector data collected at 15 minute intervals
- video detector data from two separate days (before and after conditions)
- video for conflict analysis from seven different days
- over 100 driver surveys (interview and mailback) of drivers who have experienced the IntelliZone system most of whom experienced dynamic operation (i.e. congested condition)

During the course of the evaluation, several challenges were presented. The primary one being the difficulty in obtaining highly congested traffic data that would trigger the dynamic capabilities of the IntelliZone system. Due to MoDOT's commitment to mobility and the desire to maintain the same number of lanes open on I-70 during daytime, most of the data collected did not result in conditions of extreme congestion. However, some data during congestion were obtained using temporary detectors, video, conflict, and driver surveys. The difficulty in obtaining congested data during the evaluation of a Smart Work Zone technology is not new. In an evaluation of another work zone traffic control system, there were no periods of congested flow collected during the before and after studies (MATC, 2000). Another related issue involved the growth of queues past the furthest VMS sign from the work zone. This is an issue because under such conditions, drivers react to the back of the queue instead VMS signs. Another issue involves large trucks occluding the inner lane of the two-lane freeway. This led to some difficulties in obtaining useful inner lane data from video footages for our data collection.

One important conclusion from the study was that there was some evidence that the IntelliZone system did positively affect speeds of vehicles during congested periods. During approximately one hour and thirty-five minutes of dynamic IntelliZone operation, it was shown that IntelliZone was effective in slowing vehicles as they approached the work zone. The headways did not show any consistent trends between the 7-mile and the 1.5-mile locations. During IntelliZone implementation, a high percentage of drivers (66.3%) indicated that the IntelliZone signs caused them to slow down while over 95% of the drivers indicated that they understood the messages.

Regarding IntelliZone operation during uncongested times (static operation), the IntelliZone system still seemed to affect traffic patterns. A comparison between before and after speeds shows that the traffic patterns changed consistently. The desirability of such changes; however, is not clear. In addition, speeds were more similar between the two lanes in the after case than in the before case. This result would seem to be desirable since a smaller speed variance could mean safer conditions.

Technology

The project undertaken by the University of Missouri-Columbia and the Missouri Department of Transportation served to evaluate the effectiveness of a new technology that attempts to improve traffic conditions in a freeway work zone. This new technology, IntelliZone, makes use of Variable Message Signs (VMSs) and multiple detectors in the roadway so that messages to drivers via the VMSs can be changed with varying traffic conditions. The system was developed by Quixote (Key-hoh-tee) Transportation Safety and HCI Enterprises, Inc.

In this IntelliZone application, two VMS units were placed 2 and 5 miles upstream from the work zone. In the work zone, a set of detectors was placed in the pavement to determine the traffic conditions (speed, flow, density) and, in turn, transmit this data to a Mobile Command Unit on the roadside. It was at this point that a message was created on the VMSs according to the rolling 5-minute average speed that was provided from the six detectors in the roadway. VMSs received transmissions from the Mobile Command Unit via cellular technology. When there were free flow conditions, a standard message was shown. However, when a certain average speed was reached, the message would change to illustrate the fact that there was a significant speed drop at the work zone. The messages and the speed thresholds are shown in Figure 7.

Study Site

The site at which this evaluation took place is located along Interstate 70 northwest of St. Louis in the city of Wentzville. The work zone involved the reconstruction of the freeway interchange. Appendices B-D shows the static signage for this work zone section. Appendix E and F contain aerial and driver's field-of-view photographs of the study site. Most of the land west of the work zone is rural as Wentzville could be considered the beginning of the St. Louis Metropolitan area for drivers traveling eastbound on I-70. There has been considerable growth in the area, however, as people move outward from the city. This segment of freeway does not experience a severely congested morning or evening rush. In fact, the highest hourly volume occurs on Friday afternoons at about 3pm. The AADT value for the count station closest to the work zone in the year 2000 is 48901. Figure 27 shows a typical 24 hour volume plot on a weekday.

The arrangement of the work zone included concrete barriers directly next to travel lanes, creating a very narrow corridor for vehicles to travel through. It was believed this layout would allow for significant congestion when there was ample traffic demand. Lanes were closed only at times when it was absolutely necessary since it is MoDOT's policy to keep freeway work zones operating within capacity limits. Congested data presented later in this report was collected only at times when there was a lane closure, since this was the only time when speeds were low enough to trigger a change in the VMSs messages. Drawings showing the layout of the work zone and placement of IntelliZone components are attached in the appendices and Figure 8.

The goal of the IntelliZone system was to improve the safety of work zones on freeways. This gave rise to the question of how to quantify an improvement in safety. In the opinion of many, a safer work zone has the following vehicle characteristics: slower speeds, more consistent speeds, fewer conflicts, and an overall acceptance and compliance from drivers. The methods by which these characteristics were evaluated are explained in a later section. Hypotheses that were tested included the following:

1. There was a significant decrease in speeds as vehicles approached the work zone after IntelliZone was implemented.
2. There was a significant decrease in the number and severity of conflicts after IntelliZone was implemented.
3. There were a significant percentage of drivers interviewed who accepted the message of the signs and adhered to its warning.

Other Evaluations

The concept of an advance speed warning system is not a brand new idea in the transportation industry. Static signage and non-dynamic message boards have been used for many years to inform motorists of upcoming work zone activity. Past field studies on interstates in states such as Texas (Richards 1985) or South Dakota (McCoy 1995) have shown that changeable message signs (CMS) are effective as a speed control method in work zones. The range of speed reduction reported in Texas range from 3-9 mph with CMS displaying speed only, and speed with informational message.

The message content of variable message signs has significant influence on driver behavior. Studies by Dudek (1999) have shown that drivers traveling at 55mph have only about 8 s to read a CMS message. Studies conducted in Indiana along the Borman Expressway have shown that drivers react differently to passive and active messages (Peeta 2000).

Sometimes roadside surveys have been used to study driver response to VMS. Studies have used a laboratory approach (Wardman 1998) or field approach by surveying drivers at rest stops downstream from the VMS (Peeta 2000).

A relatively new way of employing variable or changeable message signs is to advise drivers to slow down and beware of a reduction in speed within a certain distance from their current location. There is little previous research on these new dynamic speed warning systems. One prior study, though, stated that VMSs using radar actuation caused a significant drop in speed on several different study sites. It included the use of automatic traffic data recorders and video to collect vehicle characteristics as they traversed the site. Pneumatic tubes were placed at locations just before the VMS, just after the VMS and at the exit of the work zone. In addition, video cameras were placed after the VMS at two locations a relatively long distance apart. The camera's sole purpose was to record speeding drivers as they moved through the work zone to determine the effect of the VMS on that group separate from the rest of the sampled drivers. Conclusions drawn from the study were that VMSs using radar were more effective than static MUTCD signs in altering driver behavior in work zones. Average speeds and speed variances were significantly reduced and, thus, a safer work zone was produced (Garber, 1995).

In another study, this one completed along I-80 in Nebraska, a system (ADAPTIR) placed three dynamic VMSs and one static VMS upstream of the work zone, each with different purposes. The VMS on I-80 furthest from the work zone was used to display speed warnings and diversion information when delay was over 30 minutes. Another VMS was placed on the Route 6 approach to I-80. Its purpose was to advise drivers on Route 6 to not join I-80 when delay was over 30 minutes and instead stay on the current route. The second VMS encountered by drivers aimed to slow them down by giving specific speed information of the vehicles ahead. Finally, the VMS closest to the work zone displayed a static message telling drivers to merge left. Results of the study showed that the ADAPTIR system was not effective in slowing down vehicles when there was uncongested conditions since the VMSs would often remain blank until congested flow began. When conditions approached congested flow, however, the system did significantly slow vehicles approaching the work zone, except for the VMS furthest from the work zone. The reason given for this VMS not slowing vehicles was that its spacing from the next closest VMS was too great and drivers would not see the need to slow down. Another interesting result dealt with the diversion of vehicles from the route they were currently on. About 3 percent of the drivers on I-80 diverted to another route, while it was shown that the diversion information on Route 6 was not effective since about 80% of the drivers surveyed were not from Nebraska and therefore had little knowledge of alternate routes. (MATC, 2000).

Some reports dealing with conflict analysis were also reviewed. Most gave a basic overview of how a conflict analysis should be conducted and the errors associated with different methodologies. One report, noted that when using a qualitative method, it is best to count conflicts with personnel set up in the field in order to make use of the third dimension perspective, which is not included in video recordings. This method, however, will not allow for verification like video recording will. The report also suggests the use of the reciprocal of time-to-collision as a method for a quantitative analysis; with the reciprocal being used since it increase with increasing conflict severity. Plotting the frequency of the reciprocal of time-to collision versus the frequency could yield good results as a method of quantitatively counting conflicts (Chin, 1997). A prior report by the same authors gives more detailed explanation of how to use this methodology for expressway merging (Chin, 1991).

A study on the conflicts occurring at several intersections in Kentucky found that collecting conflict data only during peak hours was advantageous because other periods yielded less desirable results. It also explained that variation of qualitative conflict counts can occur due to differences of observer alertness, experience, and driving attitude, showing that is would be necessary to thoroughly train observers before formally beginning a qualitative conflict analysis (Zegeer, 1978).

Data Collection

As noted previously, three characteristics were studied in order to compare traffic flow before and after the implementation of IntelliZone. The methodology to study each characteristic is described individually in the following sections.

Speed and Headway Data

With the assistance of MoDOT personnel, temporary traffic data recorders were placed on the roadway in order to collect the volume, average speed, and surface conditions. Data were grouped into intervals of fifteen minutes due to a limit in the detector's memory that was available. Using these longer intervals meant data could be recorded for at worst 2.6 days, possibly longer. In the course of the study, however, it was found that several detectors experienced problems, which led to little or no data for some detectors. It is unclear what caused the detection problems to occur, but possibilities include destruction of the detectors by vehicles, improper installation, memory limitations, and battery failure.

The detectors were placed at three locations approaching the work zone. The first location was 7 miles upstream from the work zone and, therefore, 2 miles before the first VMS. This detector was to give vehicle speeds and headways before drivers observed any indication of a work zone. The second location was 4.5 miles from the work zone, or just after the first VMS. Speeds and headways at this location would tell the reaction of the drivers with regards to speed after viewing the first VMS. Lastly, the third location was 1.5 miles from the work zone, or just after the second VMS. Data from this location and the 4.5-mile location were then used to determine if there was a speed or headway change resulting from the second VMS. Detectors were placed on the roadway at these locations on 5 separate occasions, 2 during the before condition and 3 during the after condition.

Due to a lack of congested traffic data in both conditions, it was necessary to use video cameras to collect data at times when it was estimated there would be significant congestion in the work zone (average speeds less than 45 mph). Video collection for the after condition was conducted using high quality digital camcorders on tripods that, when fully extended, stood approximately 7 feet above the ground. Data for the modified before condition were collected using portable video surveillance trailers with thirty foot telescoping masts. It is a modified before condition because data were collected after IntelliZone was removed so some drivers had experienced the IntelliZone system previously. A video processing unit from *Iteris* called Vantage Edge was employed for speed, headway, and volume data to be obtained from the videotape previously gathered. According to the manufacturer, the desired location of the camera was approximately 30 feet above the traffic and as much above the center of the roadway as possible. In this project, the cameras were placed as close to the roadway as possible, while keeping the safety of the crew and drivers in mind. While some video image processing units require the cameras used to point either upstream or downstream, *Iteris* did not limit its system to one direction. Rather, in the process of processing the data with the Vantage Edge unit, the technician simply specified the direction of vehicle travel, either "up" or "down". *Iteris* notes in its manual that pointing the cameras downstream was desirable, but not absolutely necessary. Video data using the camcorders on tripods was collected before the *Iteris* unit was purchased, and therefore is facing upstream. Conversely, the video data using the modified trailers was collected after the purchase of the *Iteris* unit and is pointed downstream, recording vehicles as they drive away from the cameras. A diagram of the location of all speed data collection devices is given as Figure 8.

Another important point about the video trailer data is that video collection points for that day (August 7th) were shifted approximately 7 miles west of the work zone. The original work zone was located at mile marker 208, while in this case the work zone was located at about mile marker 201. The shift in collection points was necessary as a result of there being few chances to collect data when there was a lane drop and therefore few chances for a queue to form. The sites were comparable in that both served relatively the same population of drivers. There were no major exits between mile markers 201 and 208, thus it can be reasonably estimated that drivers passing the work zone at mile marker 201 would also eventually pass through the original work zone at mile marker 208. Another reason the data can be considered comparable is that the sites had very similar geometry and surroundings, as both segments of the freeway were two lanes with grass medians on both sides of the roadway.

For the last step in video data processing, it was necessary to extract the information from the Vantage Edge unit to a spreadsheet format. Software provided by *Iteris* was utilized in completing this step.

Survey Data

In order to gauge user acceptance and understanding of the system, a driver survey was conducted at a number of downstream locations. The surveys were collected in two ways. The first method was to have student employees interview drivers face-to-face as they stopped various locations around exit 208 (the exit under construction). The most common locations were gas stations, as they provided the best opportunity for drivers to have time to answer the questions posed by the interviewer. Some survey interviews were conducted as drivers stopped at signals on both sides of the overpass. 62 surveys were collected using the interview method.

After several days of conducting interviews, it became apparent that another method would be necessary in order to gain a larger sample of drivers due to a low volume of drivers stopping at businesses near the exit. A very busy gas station on the north side of the overpass would not allow surveys to be conducted on its property as it was against company policy. This led to the distribution of surveys with stamped, addressed envelopes with the hope that drivers would take the time to fill out and return the surveys later. Almost all surveys handed out in this manner were given to drivers as they stopped at the signal on the south side of the overpass. About 120 drivers accepted the survey with 39 returning them through the mail. A very high percentage was received within a week after they were distributed.

The objectives the survey included determining if the VMSs were being seen, read, and understood. Also, it was important to gauge the response of drivers to the signs. This would aid in supporting or disproving the conclusions drawn from the speed and conflict data. As far as the design of the survey, several aspects were deemed necessary in order to obtain the best possible results.

1. Keep survey as short as possible to facilitate maximum participation.
2. Make questions easy to understand to minimize confusion.
3. Use closed answers to allow for quantification during analysis.
4. Place demographic information last so driver does not become defensive at the start of the survey.
5. Place easier questions early in the survey to avoid discouraging the respondent.
6. Try to make the sample as broad-based as possible by collecting at several locations.

A summary of the results from the survey data and discussion of those results follows in later sections.

Conflict Data

It is most common in safety studies to use accident data as a main indicator of the level of safety of a segment of roadway or a point along the roadway. However, it is often found that there is little recorded accident occurrence if the range of time studied is not sufficient. Also, there is a distinct chance that many accidents are not reported, especially Property Damage Only collisions where there are no injuries or fatalities. Furthermore, there is a responsibility to the public to not wait for a number of accidents to occur so that evaluation of the road's safety can be completed. These reasons, along with time limitations of a safety study, have led many transportation engineers to look at the safety of a roadway using different methods of evaluation.

One such method gaining much popularity is known as the traffic conflict technique, in which vehicles are observed in order to document the number of evasive measures taken by motorists to avoid a collision. On freeways, identification of conflicts can be in the form of vehicle brake lights or sudden lane changes caused by a difference in vehicle speeds. At the First Workshop on Traffic Conflict, a definition was agreed upon. It defined a traffic conflict as "an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remained unchanged." This definition is helpful in that it provides the base from which a conflict can be determined.

Gathering video data that was usable in analysis of conflicts was a major difficulty in the process. In past studies, conflicts analyses have predominantly been conducted for intersections. Some have been conducted for freeway, but have been limited to the merging area of the freeway. In both cases, the area of concern was fixed and, therefore, it was simple to obtain usable data. For this study, however, the area of concern was the end of the queue of vehicles extending upstream from the work zone, something that is in constant motion. In some cases, the queue would move at such a rate that it was very challenging to get in position quick enough to videotape vehicles approaching the end of the queue. The vehicles would back up to, or even past, the camera, thus vehicles would be slowed down or already reacting to the queue.

Conflict data was recorded on 7 separate days, 3 in the before condition and 4 in the after condition. In some cases two cameras were used in a leapfrogging manner in order to better keep up with the backward moving queue. While there were many hours of data on record, very little of the video was of vehicles approaching the end of a queue. Also, the video that did show vehicles approaching the end of a queue was not consistent with regards to quality, lighting, and distance from the focal point. For that reason, it was decided that it would be best not to attempt a conflict analysis that would be inherently flawed. Instead, lessons were learned as to how to best conduct a conflict analysis on a freeway. Suggestions are discussed in a later section.

Data Analysis

Summary of Data Collection

Table 1 summarizes the complete data collection effort involved in this evaluation. Speed, flow, and headway data are obtained by using temporary magnetic detectors and video detectors (video image processing). The traffic conflict data is obtained through the use of end-of-the-queue video. Driver surveys are conducted using interview and mail-back formats.

Speed Data

As noted in the methodology section, there was drastically more uncongested data than congested data collected. This is reflected in this section by the fact that there were approximately 2 to 3 entire days of usable data for both the before and after conditions in the uncongested case. On the other hand, there were only 2 to 3 hours of usable congested data in both the before and after conditions. The "congested after data" that were considered usable were in the form of 2 hours of data averaged over 15-minute intervals and 1.5 hours of data averaged over 20-second intervals. The 15-minute interval data were collected using temporary detectors and the 20-second interval data was found using video methodology.

All usable uncongested data was in the form of 15-minute intervals. This data was broken into groups by time of day – morning, mid-day, evening, and night. Table 2 shows uncongested data for the before condition, while Table 3 shows uncongested data for the after condition.

The congested data for the after condition (shown in Table 4b) summarizes driver behavior while reacting to the dynamically operating IntelliZone system over a 1.5-hour period. The message shown by both the 5 and 2-mile sign is given as well as the average speed at the 7, 4.5, and 2-mile locations. It should be noted, however, that this data is for the right lane only because obtaining correct left lane data would have been difficult due to the camera positioning causing some occlusion of vehicles in the left lane. Also, some vehicles in the right lane (e.g. tractor-trailers) would most likely be double counted in the left lane in addition to the right lane.

Congested data for the before condition was processed using the *Iteris* unit, and is compiled into Table 4a. Vehicle speeds and time headways are shown for each location in order to display the typical speed and headway pattern as vehicles approached the work zone. Graphically, the speed profiles are shown in Figure 5 with each line representing a certain 10-minute average of the 20-second mean data obtained from the *Iteris* processor. This figure can be compared to Figure 6, the graphical representation of the speed patterns for the congested after condition. In the case of Figure 6, each line represents a time period where the messages on the VMS were the same for a varying amount of time. The after congested data used to make Figure 6 was tabulated in the same manner as the figure and is shown as Table 4b. Average speeds and time headways are once again shown to numerically show the speed and headway pattern.

Congested data on June 27th (after condition) has data – which was acquired with the temporary detectors - for both the left and right lane, but only for locations 3 and 2 (7 and 4.5 mile locations). Both temporary detectors malfunctioned at location 1 (1.5 mile location) and thus there was no data available for that time of day on June 27th when there was congestion. In addition, the temporary detectors were placed in the roadway while congestion had already caused a queue to develop past the 5 mi detector and also past the 7 mi detector at several times. Speeds shown for June 27th in Table 5 reflect the fact that there were forced flow conditions for the entire 2-hour period. This was the most usable congested data collected using the temporary detectors.

Survey Data

Once all surveys had been received via mail, they were analyzed with the aid of a spreadsheet. Each survey was entered into the spreadsheet, one row per survey. The answers to questions 2 through 12, the form of the survey (interview or mail-back) and a description of traffic conditions at the time of the survey formed the columns. Each possible answer for each question was given a number. For example, answer "a" for each question represented in the spreadsheet with the number 1, "b" with the number 2, and so on. With all survey answers entered into the spreadsheet, the percentage of each answer for each question was calculated using the histogram function. These percentages are summarized in Table 6.

Conflict Data

As mentioned in the methodology section above, results from the conflict study would have been inconsistent, so no results were found for this study. However, some suggestions for future conflict studies were formulated based on the experience of this work zone. If possible, the video data should be analyzed quantitatively, thus reducing the bias of a qualitative analysis and the errors that rise from such an analysis. One study that quantified conflicts on a freeway did so at a merging point. It used an equation consisting of the upstream vehicle's speed, the downstream vehicle's speed, and the distance between them. The goal was to determine the time to collision if vehicles did not change behavior. This would give a number that could be used in a comparison of the before and after cases.

More than likely, the conflict data will often be analyzed qualitatively. This would require a conflict to be defined in order for conflicts to be counted by a group of observers. More than one observer would be used in order to reduce bias and therefore error. One complaint with qualitative analysis is that it is very difficult to categorize conflicts by severity, as there is a fine line between minor and major conflicts in many cases. A quantitative analysis with numerical values makes it much easier to classify conflicts by severity.

One way to possibly collect better freeway conflict data would be to set up multiple cameras at several locations upstream of the reduction in capacity, in an attempt to avert the problem of not being able to keep up with the fast-forming queue. A similar camera angle with similar distances should be used in order to obtain more comparable data. If a quantitative analysis is to be used, one could use video processing. This would require a high camera angle with a distance known on the freeway.

Results for a quantitative analysis would be comprised of a table and plot showing the number of conflicts at various levels for both the before and after condition. Possibly, these would show a difference in the number and severity of conflicts after the implementation of a traffic control device. If a qualitative analysis is used, results will take a similar form.

Results

The purpose of this section is to identify and interpret the most important results and to describe factors that may have affected the outcome. Also, the validity of the hypotheses proposed will be judged according to the results.

Table 2 summarizes the uncongested data in the before condition. It aids in understanding how drivers react to the VMS operating in static mode preceding the work zone. Location 1 is closest to the work zone (1.5 miles) and location 3 is 7 miles from the work zone, or in other words, upstream of the first VMS. Examination of the average speed for all time periods – morning, mid-day, evening, and night – shows that there is a definite trend from location to location, especially for vehicles traveling in the right lane. Speeds for the right lane tend to increase by 1-2 miles per hour from location 3 to location 2. On the other hand vehicles tended to decrease by 1-2 miles per hour from location 2 to location 1. For the left lane, there was not a definite trend showing an increase or decrease in speeds between any of the locations. Essentially, speeds remained the same for vehicles in the left lane, showing that there was little, if any, reaction to static VMS. Tables 8b and 9b are statistical test summaries of the speed data and support the suggested tendencies of speed patterns. T-tests were conducted to determine if the average speeds were significantly different at a confidence level of 95%.

A possible reason why the vehicles in the right lane did not slow down until 2 miles before the work zone is because there was no visual evidence of the work zone until that point. In the same way, there were not signs informing drivers of the work zone at points more than 5 miles from the work zone. The increase in speed from location 3 to 2 in the right lane could be evidence of the normal speeds found at those points on the freeway. Geometry of the freeway at location 2 may be such that speeds are normally higher than at location 3. In any case, Table 2 shows that vehicles usually will not increase or decrease speeds if they are in the left lane, but have a slight increase followed by a decrease if they are traveling in the right lane. This is further supported by Figures 1 and 3, the speed profiles of vehicles in the right and left lanes for the uncongested case, respectively.

Table 2 also shows the headway trends as vehicles approached the work zone before IntelliZone was implemented. For most cases, there were higher values of time headway at the 4.5-mile location as compared to the 7 and 1.5-mile locations. This trend held for both the right and left lane. With regards to the right lane, one would not expect the 4.5-mile location to have the highest time headway since it also had the highest average speed most of the time. High speeds correspond to short time headways if the distance headway is constant.

Table 3 summarizes the speeds and headways of vehicles as they approached the work zone with the VMSs in place. It aids in determining driver's reactions to the VMSs when there was no congestion and the IntelliZone system was not functioning dynamically. Examination of 20-second average vehicle speeds in the right lane at locations 3 and 2 show that vehicles tend to slow down by 3 or 4 miles per hour as they react to the first VMS. Conversely, vehicles dramatically increase in speed as they approach the work zone, from location 2 to 1. Drivers in the right lane might be slowing down after they see the first VMS, but then possibly increasing in speed from location 2 to 1 because they recognize that there is not a queue of vehicles and, therefore, can begin to travel at a faster pace. It should also be noted that, in the before condition, there was a speed increase from location 3 to 2, but decrease from location 2 to location 1. This would be evidence that the first VMS is effective in slowing down vehicles. The trends shown for vehicles in the left lane were very much the opposite of those for the right lane. Drivers tended to increase in speed by about 2 miles per hour from location 3 to 2 and then decrease by about the same amount from location 2 to 1. The trends described here for the left and right lanes are shown graphically in Figures 2 and 4 for the right and left lanes, respectively.

It is not understood why vehicles in the right and left lanes behave in an opposite manner. It should be mentioned, however, that when looking at the difference in speeds between the two lanes, there was not much of a difference at locations 3 and 1 in the after case (Table 3). Location 2 average speeds had a significant difference between the two lanes (about 7 mph). Similar speeds between the two lanes at location 1 is encouraging as vehicles traveling at the same speed would experience fewer conflicts because they would not be adjusting to slower moving vehicles. In the before condition, there was a significant difference between the left and right lane at all locations, showing that there would be many times where vehicles would be adjusting to slower moving vehicles.

Therefore, it is possible that the signs produce a more streamlined flow of traffic as one moves closer to the work zone from location 2 to 1.

An important note concerning the uncongested, 15-minute average speed data is that it did show signs of being statistically autocorralated when a Minitab test was ran to investigate this matter. Autocorrelation of data would mean that the p-value for the statistical tests could be higher than if there were no autocorrelation present. Since in this case p-values were very small, it is suspected autocorrelation did not significantly affect the results of the statistical tests on the speed data, but one should be aware of the possible error caused by autocorrelation of data.

Regarding headways in the uncongested after condition, there was no pattern in the right lane as headways remained about constant. In the left lane, however, there was an ever so slight increase in time headway, which is encouraging. These longer time headways allow for an increase in reaction time for vehicles following each other.

One very important point for discussion prior to this point is that the IntelliZone system was not functioning dynamically at the time when uncongested data was collected. Thus, the system was, in effect, was operating in a static mode.

Tables 4a, 4b, and 5 summarize data for times when there were congestion in the work zone and the VMSs were displaying a dynamic message. All three tables provide measures of the system's effectiveness in speed reduction. Table 4a is a summary of data obtained over a 1.5 hour time period on August 7th. Times are given sequentially to give a realtime sense of how traffic behaved when there was congestion. Each row is a 10-minute average of the 20-second averages obtained from the *Iteris* video image processor. Inspection of the table and Figure 5 shows that generally drivers will decrease their speed, and then increase their speed as they approach the work zone when IntelliZone is not in place. Patterns concerning time headways of vehicles were mixed. Table 4b is a representation of vehicle speeds over a 1.5-hour time period on July 17th (congested after condition). Inspection of the table and Figure 6 shows that most of the time there was a decrease in speeds from location 3 to location 2, ranging from 1 to 7 miles per hour. This was then followed by another decrease in speeds most of the time. This could be considered evidence of IntelliZone positively affecting speeds of vehicles during congested conditions. Both messages corresponding to the lowest speed thresholds for changing the messages on VMS A or the VMS closest to the work zone ("Slow traffic 5 miles ahead" and "Be prepared to stop within next 5 miles") seem to effectively slow down vehicles passing the VMSs. Statistical tests were conducted on these trends, with the results of those tests supporting the suggested trends. The statistical evidence presented in Table 7b shows that the decrease in speed between the average of the 7 mile and 5 mile, and between the average of the 5 mile and 2 mile are statistically significant at a confident level of 95%

Table 5 shows data for a two-hour period on June 27th. Unfortunately, collection did not begin until the queue had grown past the 7-mile detection point. For that reason, it is difficult to draw any significant conclusions from the data. Collecting speeds of vehicles within the queue is not productive since it is the end of queue conditions that are of interest. Also, since the data is averaged into 15-minute intervals, it is difficult to analyze how vehicles reacted to each message the VMS displayed since they could change several times within 15 minutes. For that reason, Tables 3a and 3b give a better idea of the effectiveness of a dynamically functioning system.

Table 6 is a summary of the driver survey conducted at several locations around the work zone. 60 of the surveys collected were acquired during congested flow conditions, while 41 were collected during free-flow condition. For each possible answer, the percent of drivers who selected that answer was calculated. Questions pertaining to a driver's age and sex as well as questions about the vehicle they were driving and how long they had been traveling before their stop were included to gauge the breadth of the sample. There was a poor distribution with regard to vehicle type as there were no tractor-trailer drivers interviewed. This was due to the fact that they rarely stopped at fuel stations and climbing up to interview them in their truck at an intersection was difficult. Also, the weigh station was located upstream of the work zone, thus it was rare for a tractor-trailer to be in a position for the driver to be interviewed properly. Except for this case, there were no apparent problems with the distribution of the demographic information of the drivers interviewed. For that reason, it is expected the population, except for tractor-trailer drivers, is reasonably well represented in this survey. One should note that if the entire population was interviewed, the results could vary from the sample used in this project. The methodology of the survey collection was one of convenience since more complicated methods for collecting the surveys were not feasible or practical. Also, due to the fact that the survey was self-reporting, the results that follow may not be exactly what the drivers did on the freeway in that they might say they slowed down but in actuality might have just been telling the interviewer what they thought the right answer should be. In any case, this method of survey collection has been used for years and for many transportation studies.

An interesting observation of the survey answers was that the percentage of drivers who could read the entire message was less than the percentage who could understand the entire message. Almost all drivers could understand the message, but 22.4% could not read the entire message. This could be due to vehicles in the right lane interfering with left lane vehicles or it could be due to the VMS display not changing fast enough to read the entire message. It was observed several times in the field that tractor-trailers in the right lane moving at relatively the same speed as a vehicle in the left lane would block the VMS from view.

Possibly the most important question asked to drivers addresses the effect of the VMS signs on the drivers behavior ("What did the message signs cause you to do?"). A very large percentage (66.3%) said the signs caused them to slow down, while only 16.9% said they did not affect the driver's behavior. Only 3.6% of drivers surveyed said they changed their route, but it is suspected that the actual percentage for the entire population would be higher since drivers who did alter their route would often avoid the work zone entirely and would, therefore, not be able to be interviewed. The hypothesis stating that there was a significant number of drivers who understood the VMSs and adhered to its warning was shown to be true since two out of every three drivers said they slowed down as a result of the IntelliZone system.

Beyond finding the simple percentages of how each question was answered, creative use of the data yielded some possibly helpful information. There are several questions that are of interest that could be answered by cross tabulation of the survey data gained from the public using the work zone. The results of the cross tabulations are shown as Appendix F.

One such question is the effect of the signs vs. the age of the driver. Are younger drivers less likely to slow down due to the signs? Due to a lack of experience, they are often seen as more reckless than middle age and senior citizen drivers. The results showed that there was a lower percentage of drivers in the "under 25" group who slowed down as a result of the signs as compared to the older age groups. Also, no other age group said they diverted their route except for the youngest age group. However, the 22 to 55 year old drivers had the highest percentage who said the signs did not affect their driving. So one could not say for certain that young drivers had less respect for the warning since there is not a clear difference between the youngest drivers and the older age groups.

Another question is the age of the driver vs. the perception of safety in the work zone. Does age matter as to how a driver identifies with a work zone or is an unsafe work zone identified as such by all age groups? The results of this question were mixed as each group had the highest percentage for a certain answer. The young driver group had the highest percentage that thought the work zone was of the same hazard level as other parts of the highway, while the 22 to 55 year old group had the highest percentage that believed the work zone was more hazardous. The oldest drivers had the highest percentage (20.8%) that actually thought the work zone was less hazardous than other parts of the freeway. Possibly since the speeds were so low during the collection of several surveys, it made those drivers feel more safe than traveling at normal freeway speeds of 65 to 70 mph. In any case, it does not seem a driver's age will affect their perception of the work zone's hazard level.

Keeping with the same thought of demographics vs. certain questions, does the sex of the driver make a difference as far as perception of safety and the effect of the signs on the behavior? It is a common theory that male drivers are more reckless than their female counterparts. This is supported by the higher cost of auto insurance for males, especially at younger ages. So do the males who answered the survey behave stereotypically by saying that the signs did not affect their driving instead of causing them to slow down? The results illustrated that this was not the case as there were a higher percentage of males (76.6%) that said they slowed down as compared to females who slowed down (51.4%). Also, there were more women (20.0%) than men (14.9%) who said they were unaffected by the VMSs warnings.

An interesting thing that was noticed in the compilation of the surveys was that some drivers said they could not read the whole message but understood what the message said. This question was investigated to get an exact number of drivers who answered in this fashion. While almost all drivers said they could read and understand the messages (90.4%), there was a small percentage (4.1%) that could not read the entire message, but could understand what it was conveying.

The survey included a question as to how often the drivers used the segment of the interstate on which the work zone was located. This was intended to help determine if drivers who see the work zone and the VMS's often will behave differently because they know of the work zone and might expect there will be congestion anyway and will slow down regardless of the signs. If significant results were found, it may help in future deployment of IntelliZone as far as if the signs are in an area that has high percentages of daily users or if they are in an area where the drivers use the freeway less often. The results showed that the daily users of the work zone segment of the freeway were less likely to slow down as a result of the VMSs than any other group (weekly, monthly, or seldom). So it could be concluded that if the system was put in an area known to have a high ratio of daily users, one could expect the system to have less effect than if it were placed on a segment that does not have many drivers who see the work zone often.

It should be noted that there is a certain amount of error interval associated with this survey, just as any other survey of a subgroup of a population. Using a 95% confidence, a maximum standard deviation of 50.0% (the most one answer could change), and the sample size of the survey (101 drivers), the margin of error for each question was +- 10%. For the cross-tabulation results, the sample sizes varied and were significantly smaller. The margin of error for each comparison is included with the results in Appendix F.

Using the information provided by statistical tests, the hypotheses presented in the introduction can now be discussed. The student's t-test was used to determine if there was a significant difference in average speeds for several different comparisons. As noted above, when IntelliZone was functioning dynamically, there was a significant reduction in vehicle speeds as one approached the work zone. Also, the F-test was used to determine if there was a significant difference in the variance of average speeds for several comparisons. Inspection of Table 7b shows that there was a significant decrease in variance of 20-second average speeds after IntelliZone was implemented during congested periods. In the same way, Table 8b shows that there was a significant decrease in the variance of 15-minute average speeds in the right lane during uncongested conditions after IntelliZone was implemented. Table 9b shows that there was not a significant decrease in variance for vehicles in the left lane during uncongested conditions. An F test p-value of less than 0.05 is used to determine if a statistical difference existed. Graphically, the smaller dispersion of vehicle speeds can be seen in the speed distribution plots shown in Figures 9 to 26. The plots are grouped by location and condition (Before Uncongested 7 mile is grouped with After Uncongested 7 mile) in order to best visually display this reduction in speed dispersion.

The conflict hypothesis could not be tested due the lack of quality data described previously.

Conclusions

According to the uncongested speed data, the IntelliZone system does not gradually slow vehicles as they approach the work zone, but the speed patterns were significantly affected. It would be desirable for the speeds to gradually decrease after each VMS so that vehicles are moving at a slower pace and therefore would be better suited to adjust to congestion in the work zone. As shown in Tables 1 and 2, the traffic speed pattern was a speed decrease followed by a speed increase. Consequently, drivers may have adjusted their speeds in response to the VMSs and possibly they may have been more alert. However, the purpose of IntelliZone is to dynamically present drivers upstream of a work zone with information about slow moving vehicles present in the work zone. To effectively determine if IntelliZone was able to affect vehicle speed when there was congestion in the work zone, the congested speed data was most useful. Tables 4a and 4b summarize the data for congested periods in the before and after condition respectively. They are evidence that IntelliZone, when operating dynamically, can be successful in slowing vehicles as they approach the work zone. Further evidence was produced by the driver survey that over 66% of drivers interviewed said they slowed down as a result of reading the VMSs contrast with only 16.9% that said that the VMSs did not affect their driving.

Observed issues with the system included the following:

1. Large vehicles in the right lane would often block the VMSs from vehicles in the left lane. This could be avoided if the VMSs were placed at a higher position or in the median. This would raise issues with structural stability and mobility of the trailers.
2. Often during lane closures, the queue resulting from a reduction in capacity would extend past the first VMS and would make the system ineffective as drivers would see the end of the queue before any warning was given through the VMSs. This shows that the agency deploying the system needs to space the VMSs effectively so that the queue does not grow past the furthest VMS.

Solutions to these issues would help in making IntelliZone a more effective tool in giving drivers advance warning of traffic conditions in the work zone.

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Tables

Table 1 Data Collection Summary					
Data Type	Date (2002)	Method of Collection	Traffic Behavior	Before/ After Condition	Samples
Speed	5/14 to 5/21	Temp Magnetic	Uncongested	Before	3312 15-MinutePeriods 498795 Actuations
Speed	6/14 to 6/17	Temp Magnetic	Uncongested	After	
Speed	6/19 to 6/21	Temp Magnetic	Uncongested	After	
Speed	6/27 to 7/1	Temp Magnetic	Uncongested	After	
Speed	7/17	Video Image Processing	Congested	After	1421 20-Second Periods 2802 Actuations
Speed	8/7	Video Image Processing	Congested	Before	
Conflict	5/14	Video	Uncongested	Before	NA
Conflict	5/17	Video	Uncongested	Before	
Conflict	6/14	Video	Uncongested	After	
Conflict	6/19	Video	Uncongested	After	
Conflict	6/26	Video	Congested	After	
Conflict	7/17	Video	Congested	After	
Conflict	8/7	Video	Congested	Before	
Survey	6/19	Interview	Uncongested	After	101 Surveys
Survey	6/26	Interview/Mail-back	Congested	After	

Table 2 Uncongested Before Data													
		Right Lane			Left Lane			Right Lane			Left Lane		
Date	Time of Day	Avg. Speed at 7mi (mph)	Avg. Speed at 4.5mi (mph)	Avg. Speed at 1.5mi (mph)	Avg. Speed at 7mi (mph)	Avg. Speed at 4.5mi (mph)	Avg. Speed at 1.5mi (mph)	Avg. Hdwy 7mi (sec)	Avg Hdwy. 4.5mi (sec)	Avg. Hdwy 1.5mi (sec)	Avg. Hdwy 7mi (sec)	Avg Hdwy. 4.5mi (sec)	Avg. Hdwy 1.5mi (sec)
May 16	Morning	62.09	64.53	62.43	66.75	67.18	67.51	4.97	6.73	4.93	6.81	6.95	5.17
May 16	Mid-day	61.59	62.94	60.26	66.80	66.53	65.56	4.43	5.38	4.69	5.80	5.89	5.13
May 16	Evening	64.59	65.27	63.90	68.29	67.83	68.34	4.87	11.55	4.94	6.97	7.01	6.15
May 16	Night	63.59	62.79	62.51	66.62	66.46	66.72	12.17	77.37	12.74	49.82	55.33	41.47
May 17	Morning	62.33	63.76	62.27	66.97	67.05	67.27	5.04	6.75	4.89	6.38	6.54	5.12
May 17	Mid-day	58.35	59.92	58.33	63.67	63.78	64.62	4.40	4.61	4.56	4.92	4.97	4.53
May 17	Evening	61.57	62.86	61.69	66.28	66.34	66.21	4.12	4.27	4.21	4.10	4.10	3.74
May 17	Night	64.10	64.95	63.13	66.75	67.58	68.03	12.10	10.12	12.13	46.47	69.03	41.75
May 18	Morning	64.54	64.84	63.50	68.74	68.37	68.02	5.87	6.14	6.14	13.81	13.51	10.63
May 18	Mid-day	64.37	64.20inc	63.93	69.13	67.54	67.95	3.87	3.89 inc	3.87	3.87	3.87	3.87
May 18	Evening	inc	inc	64.10	68.65	67.90	67.80	inc	inc	4.01	4.27	4.23	3.48

*May 16 – Thursday May 17 – Friday May 18 – Saturday
**Headway data found using the inverse of flow for each 15-minute interval
***inc = incomplete data for time period

Table 3 Uncongested After Data													
		Right Lane			Left Lane			Right Lane			Left Lane		
Date	Time of Day	Avg. Speed at 7mi (mph)	Avg. Speed at 4.5mi (mph)	Avg. Speed at 1.5mi (mph)	Avg. Speed at 7mi (mph)	Avg. Speed at 4.5mi (mph)	Avg. Speed at 1.5mi (mph)	Avg. Hdwy 7mi (sec)	Avg Hdwy. 4.5mi (sec)	Avg. Hdwy 1.5mi (sec)	Avg. Hdwy 7mi (sec)	Avg Hdwy. 4.5mi (sec)	Avg. Hdwy 1.5mi (sec)
June 14	Morning	66.81	63.55	69.83	68.52	71.21	69.35	4.63	4.57	4.64	4.99	6.17	6.42
June 14	Mid-day	66.23	63.07	68.74	68.74	70.73	68.16	4.00	3.90	3.91	3.92	3.99	4.27
June 14	Evening	67.00	64.11	69.34	69.07	70.84	68.95	4.02	4.04	4.05	3.85	3.90	4.16
June 14	Night	66.40	62.56	69.78	68.05	70.32	67.86	9.25	9.12	9.11	14.25	15.20	16.33
June 15	Morning	67.50	63.91	70.27	68.95	71.15	68.93	5.61	5.61	5.51	7.91	8.85	9.48
June 15	Mid-day	66.17	63.66	68.77	67.70	70.87	68.51	4.12	3.82	3.82	3.63	3.64	3.83
June 15	Evening	66.94	63.65	68.78	69.32 inc	71.22	69.00	4.30	4.45	4.31	4.28 inc	4.88	5.42

*June 14th - Friday June 15th - Saturday

** Headway data found directly from detector data files

Table 4a Before Congested Data - Video						
Time of Day	Avg. Speed at 7 mi (mph)	Avg. Speed at 4.5 mi (mph)	Avg. Speed at 1.5 mi (mph)	Avg. Headway at 7mi (sec)	Avg. Headway at 5mi (sec)	Avg. Headway at 1.5 mi (sec)
6:46:00pm - 6:56:00pm	68.98	64.46	63.53	5.61	5.66	7.27
6:56:00pm - 7:06:00pm	68.33	62.38	65.68	5.26	5.90	7.55
7:06:00pm - 7:16:00pm	63.68	60.38	64.83	7.23	2.86	6.16
7:16:00pm - 7:26:00pm	67.73	63.88	63.72	5.73	6.24	7.25
7:26:00pm - 7:36:00pm	69.05	61.6	64.54	5.26	7.73	7.72
7:36:00pm - 7:46:00pm	63.07	60.24	61.89	7.64	6.50	7.84
7:46:00pm - 7:56:00pm	62.21	60.97	65.45	7.94	6.86	8.02
7:56:00pm - 8:06:00pm	61.82	61.03	60.43	6.21	7.57	8.65
8:06:00pm - 8:16:00pm	60.95	56.74	65.95	6.11	7.46	8.83

10 minute averages of 20 second intervals

Note: Data collected on Wednesday, August 7, 2002

Table 5 After Congested Data – Temporary Detectors

Time of day	Right Lane 7mi Avg. speed (mph)	Right Lane 4.5mi Avg. speed (mph)	Left Lane 7mi Avg. speed (mph)	Left Lane 4.5mi Avg. speed (mph)	Right Lane Volume (7mi/4.5mi)	Left Lane Volume (7mi/4.5mi)
1:30 PM	15	24	19	26	134/189	166/213
1:45 PM	10	16	17	20	111/189	138/234
2:00 PM	10	26	18	28	72/143	102/175
2:15 PM	10	42	14	40	112/120	77/143
2:30 PM	15	25	20	30	116/225	143/238
2:45 PM	15	22	23	19	169/96	157/133
3:00 PM	15	39	25	44	207/240	215/273
3:15 PM	49	38	29	42	248/216	242/298
3:30 PM	55	63	54	67	211/220	395/242

Table 6 Survey Summary

How long were you driving before this stop?	Less than 15 minutes 37.2%	15 to 30 minutes 29.8%	More Than 30 Minutes 33.0%	
Did you notice the changeable message signs 2 and 5 miles before the work zone?	Yes 83.5%	No (if no, skip to question 7) 10.3%	Vaguely remember 6.2%	
What did the message signs cause you to do?	Slow Down 66.3%	Change Your Route 3.6%	Did Not Affect Your Driving 16.9%	Other 13.3%
Were you able to read the entire message?	Yes 77.6%	No 22.4%		
Did you understand the message?	Yes 95.3%	No 4.7%		
How often do you use I-70 between the Foristell and Pearce Blvd exits?	Most Days 39.6%	Once A Week 24.0%	Once A Month 11.5%	Seldom 25.0%
How safe is this work zone compared to other parts of the interstate?	Same 35.8%	More Hazardous 52.6%	Less Hazardous 11.6%	
What type of vehicle were you driving?	Tractor Trailer 0.0%	Truck/SUV 35.7%	Passenger Car 40.8%	Other 23.5%
Which of the following is closest to describing the flow of traffic in the work zone?	Free Flowing 16.1%	Congested, But Not Stopping 24.1%	Stop And Go 59.8%	
Is your age:	Less Than 25 16.0%	Between 25 And 55 58.0%	Over 55 26.0%	N/A 0.0%
Are you:	Male 57.0%	Female 43.0%		

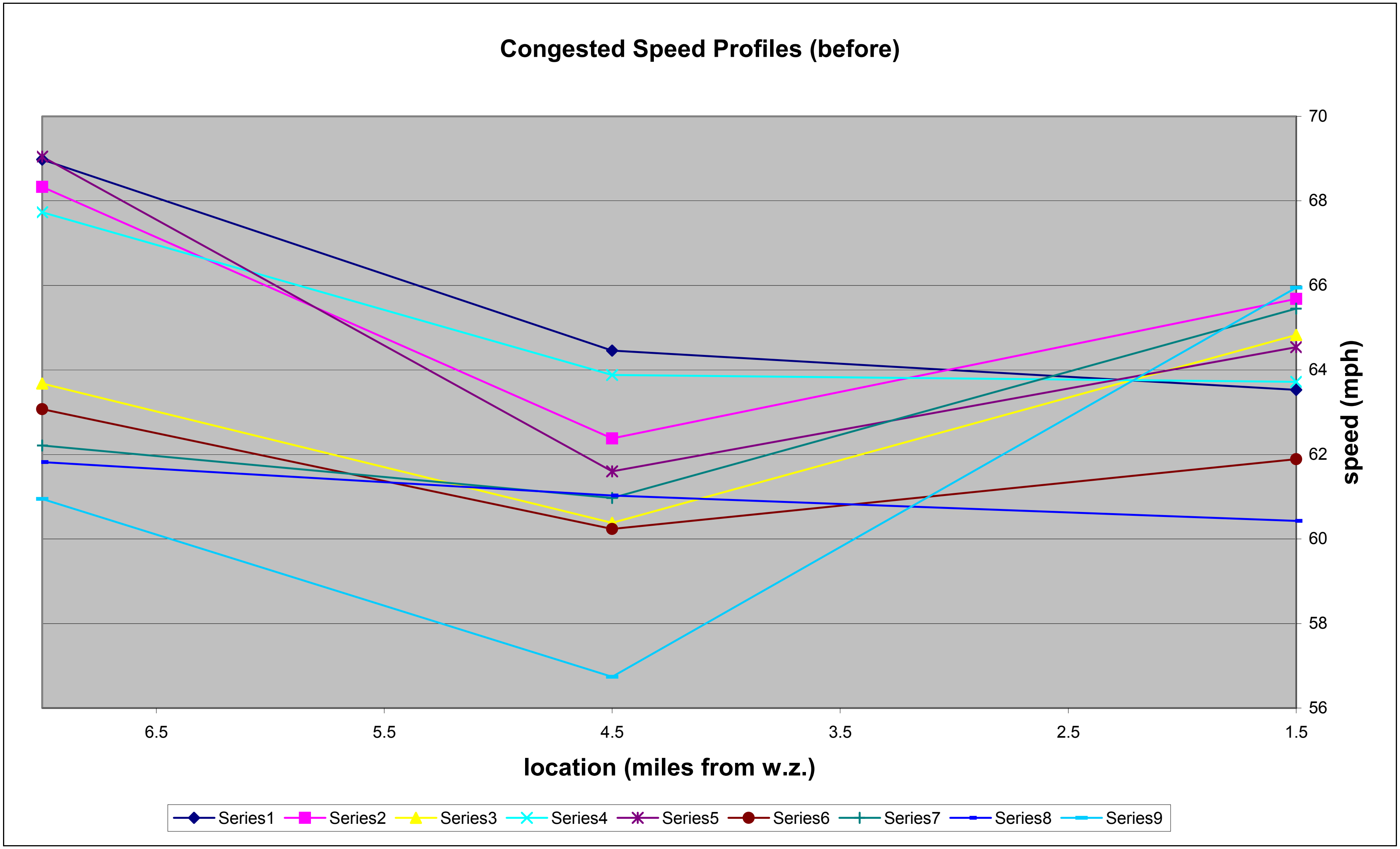


Figure 5 Speed Profiles for congested before condition.

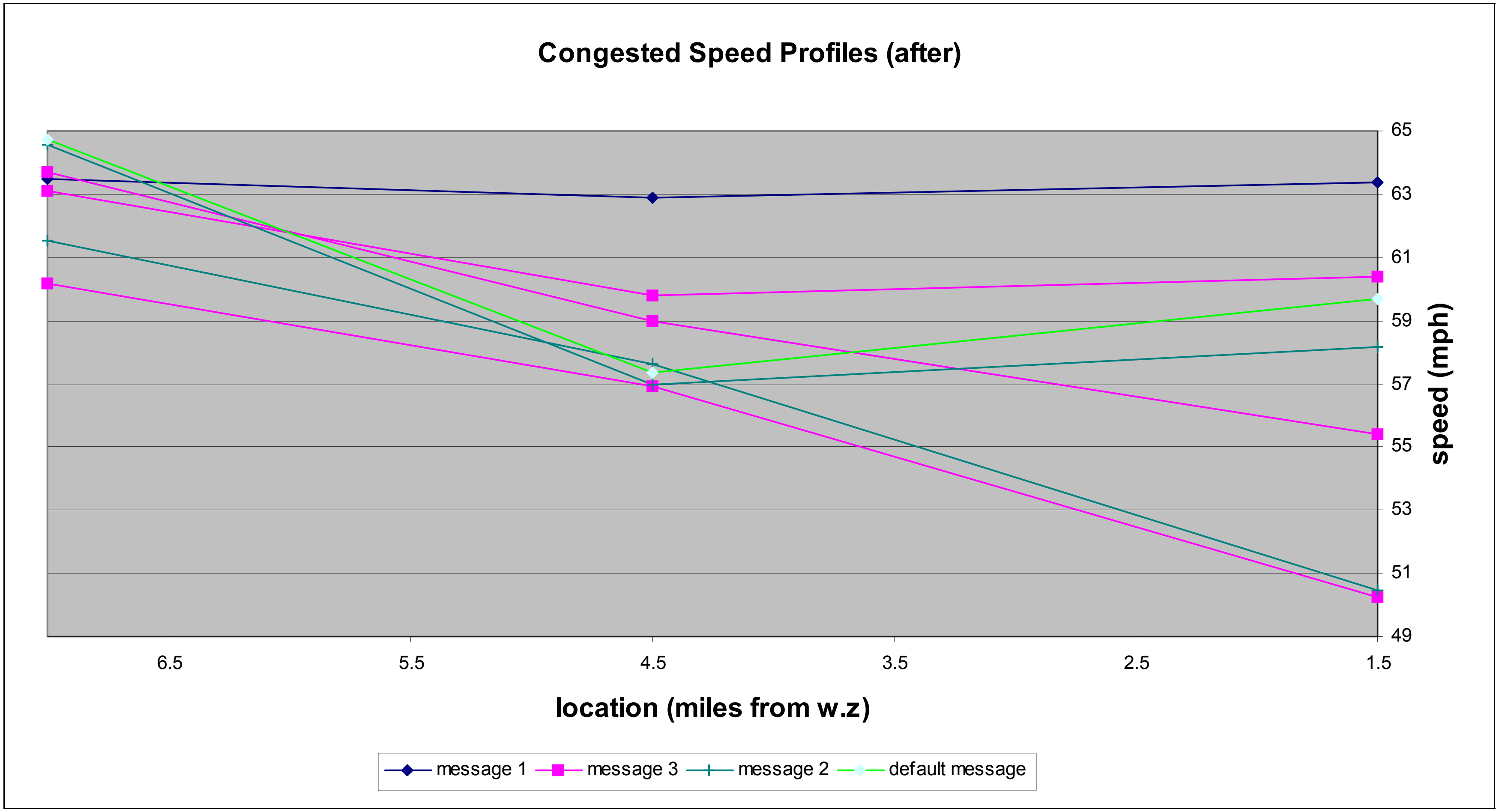


Figure 6 Speed profiles for congested after condition.

THRESHOLD		VMS B	VMS A
0-19 MPH	PAGE 1	STOPPED TRAFFIC AHEAD	BE PREPARED TO STOP
	PAGE 2		WITHIN NEXT 5 MILES
20-34 MPH	PAGE 1	ACTUAL SPEEDS AHEAD	SLOW TRAFFIC
	PAGE 2	25 MPH	5 MILES AHEAD
35-45 MPH	PAGE 1	ACTUAL SPEEDS AHEAD	SLOW TRAFFIC
	PAGE 2	40 MPH	5 MILES AHEAD
>46 MPH	PAGE 1	WORK ZONE AHEAD	WORK ZONE
	PAGE 2	SPEED LIMIT 55 MPH	5 MILES AHEAD

Figure 7 VMS Messages and Speed Thresholds

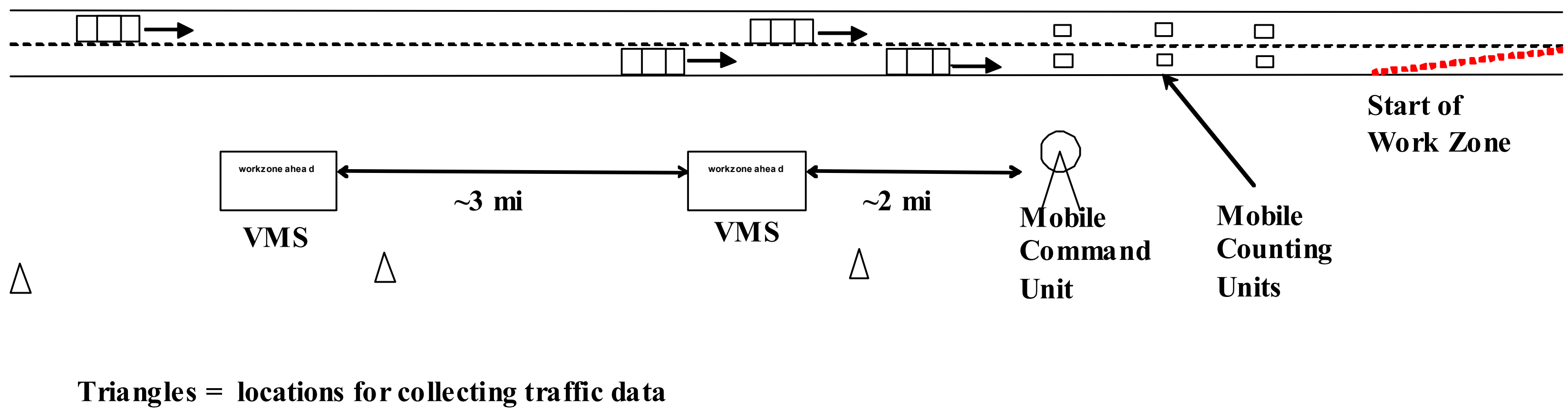


Figure 8 Conceptual diagram of IntelliZone evaluation

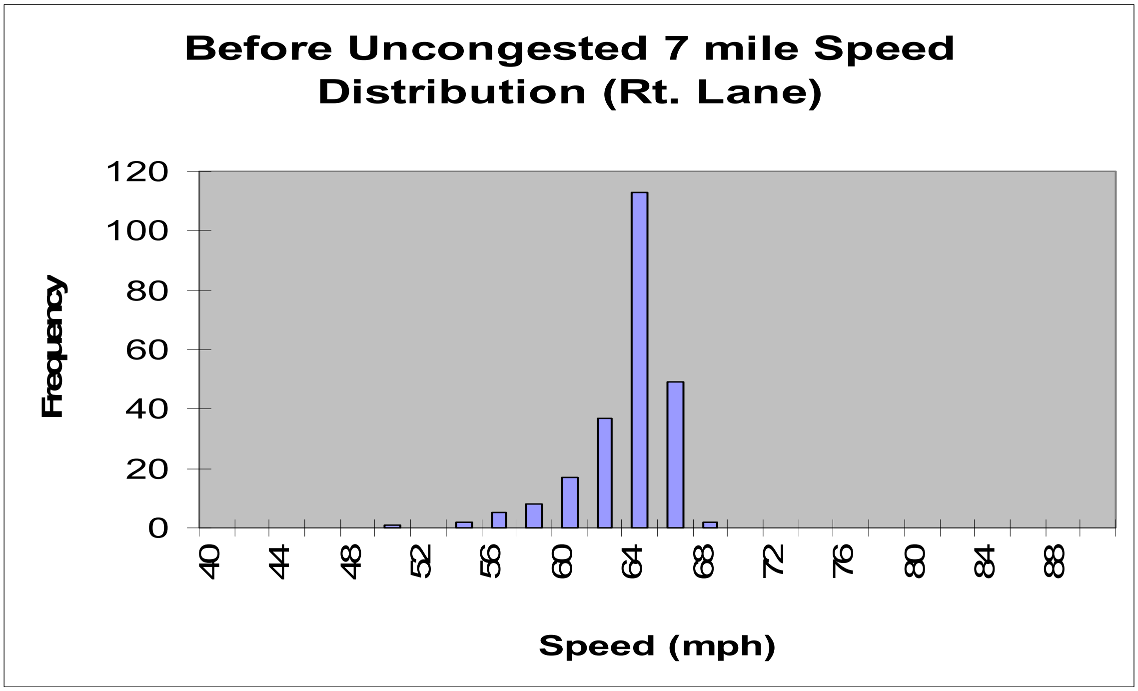


Figure9

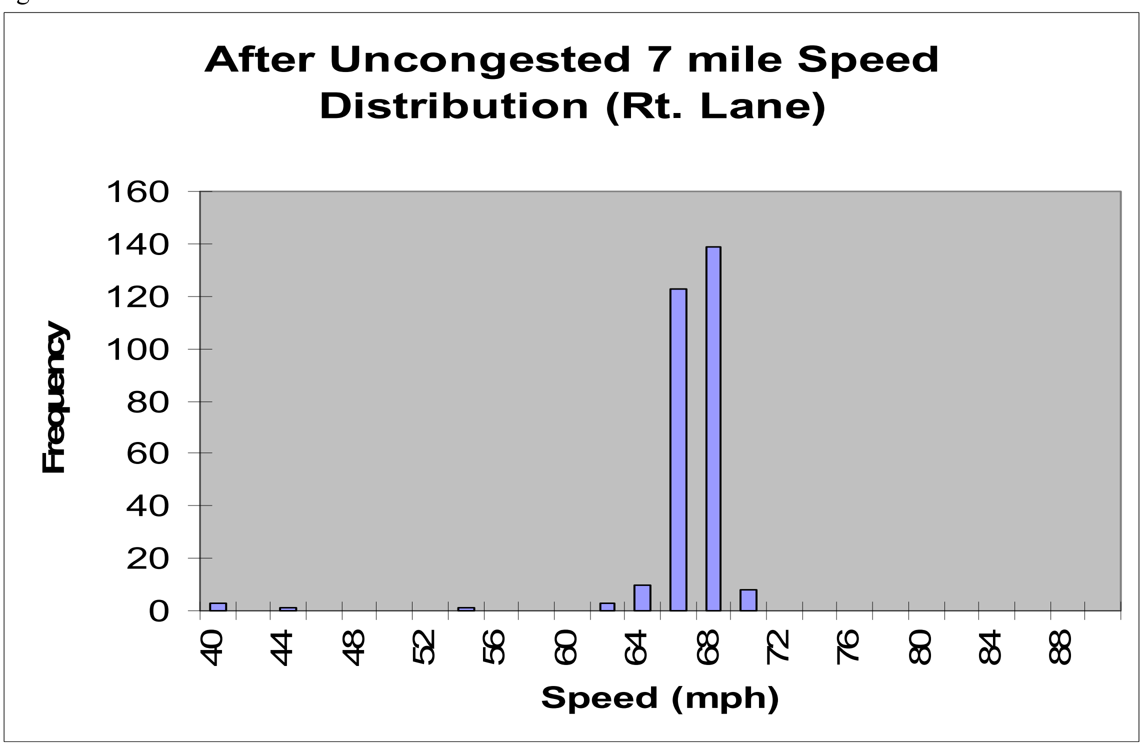


Figure 10

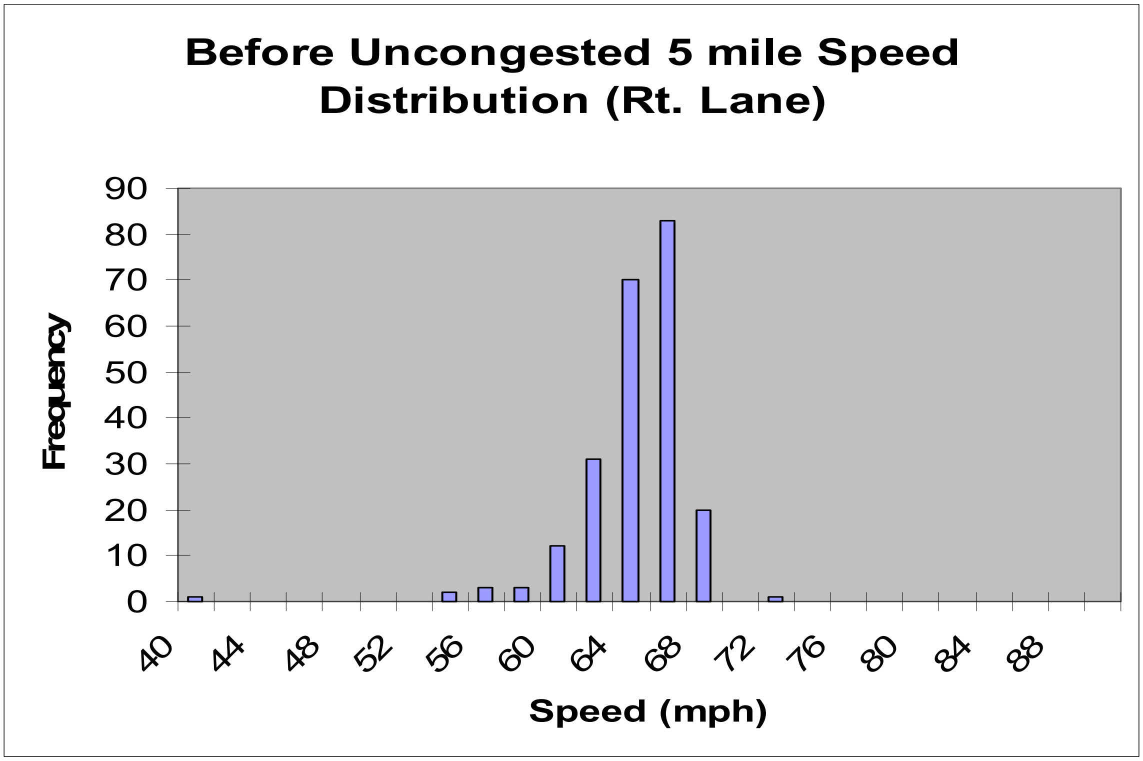


Figure 11

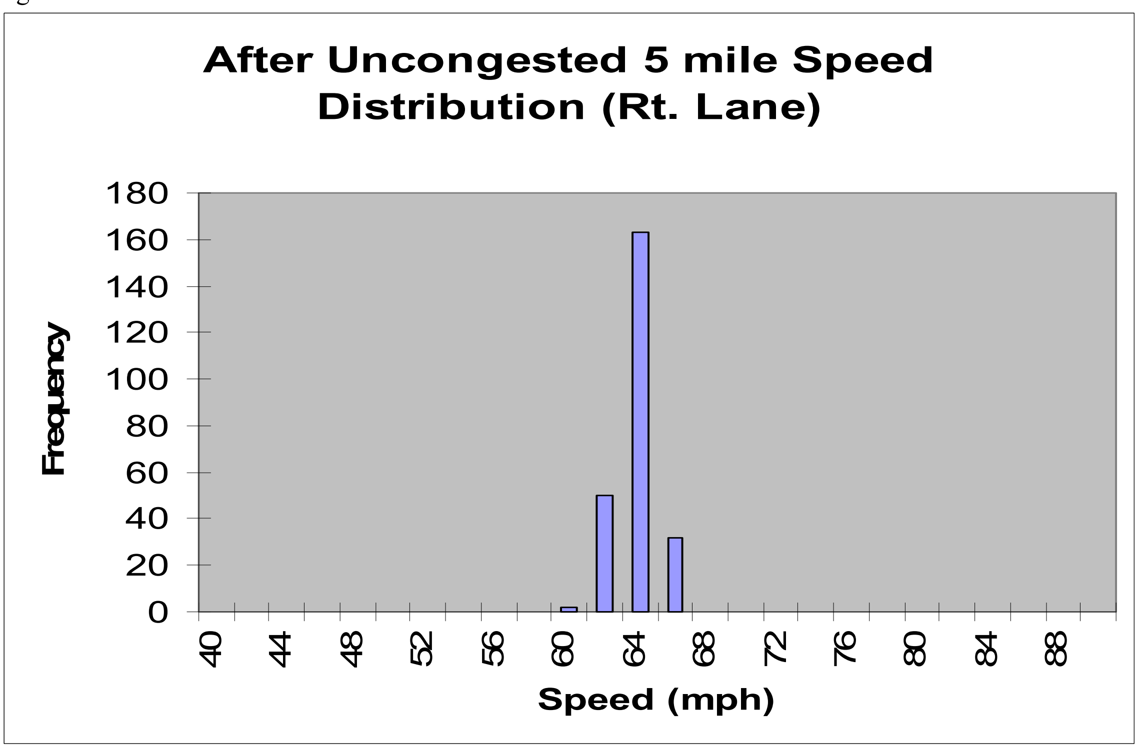


Figure 12

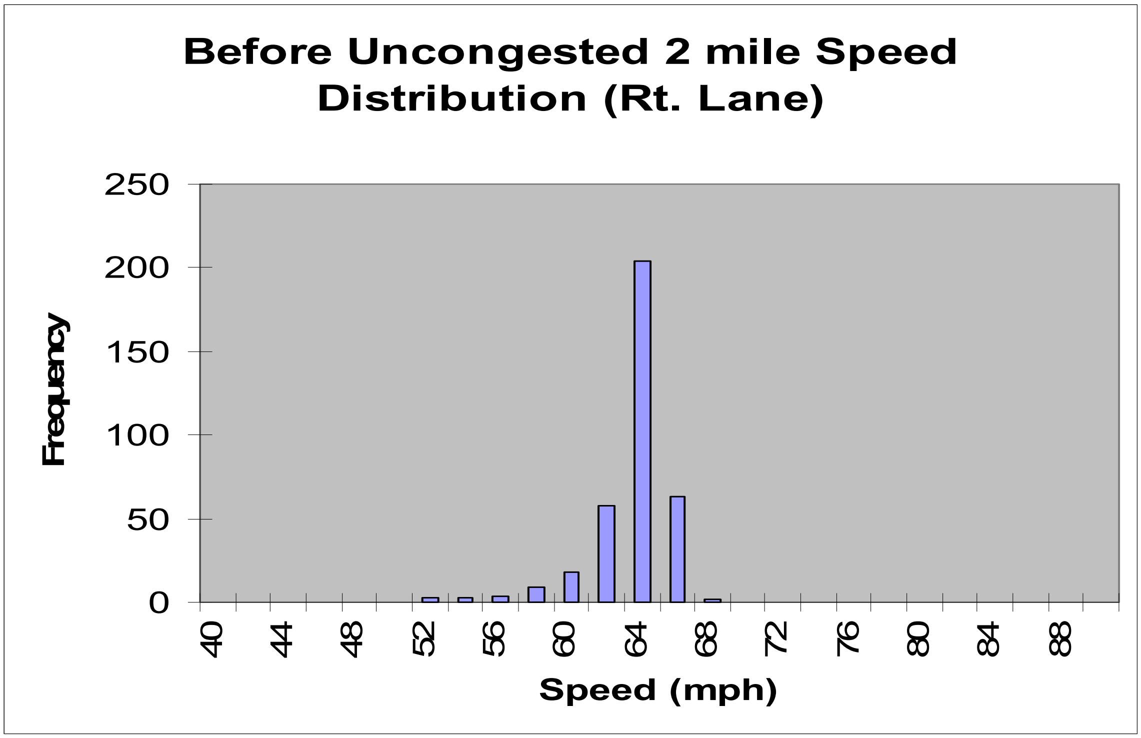


Figure 13

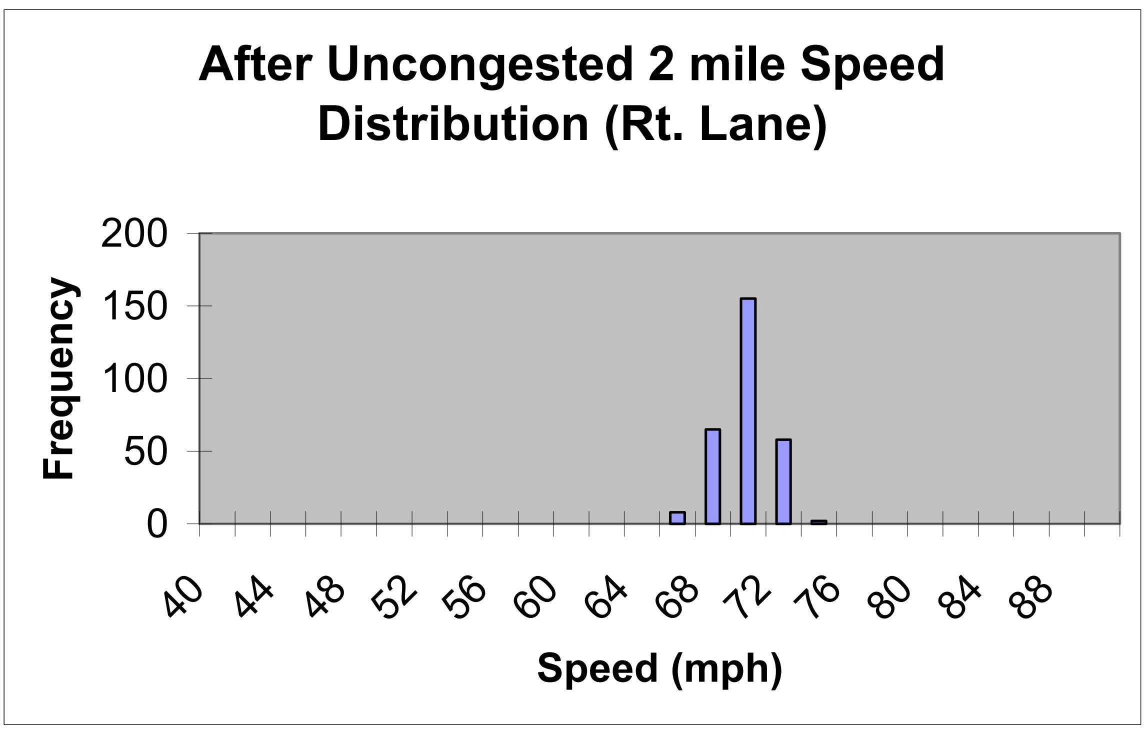


Figure 14

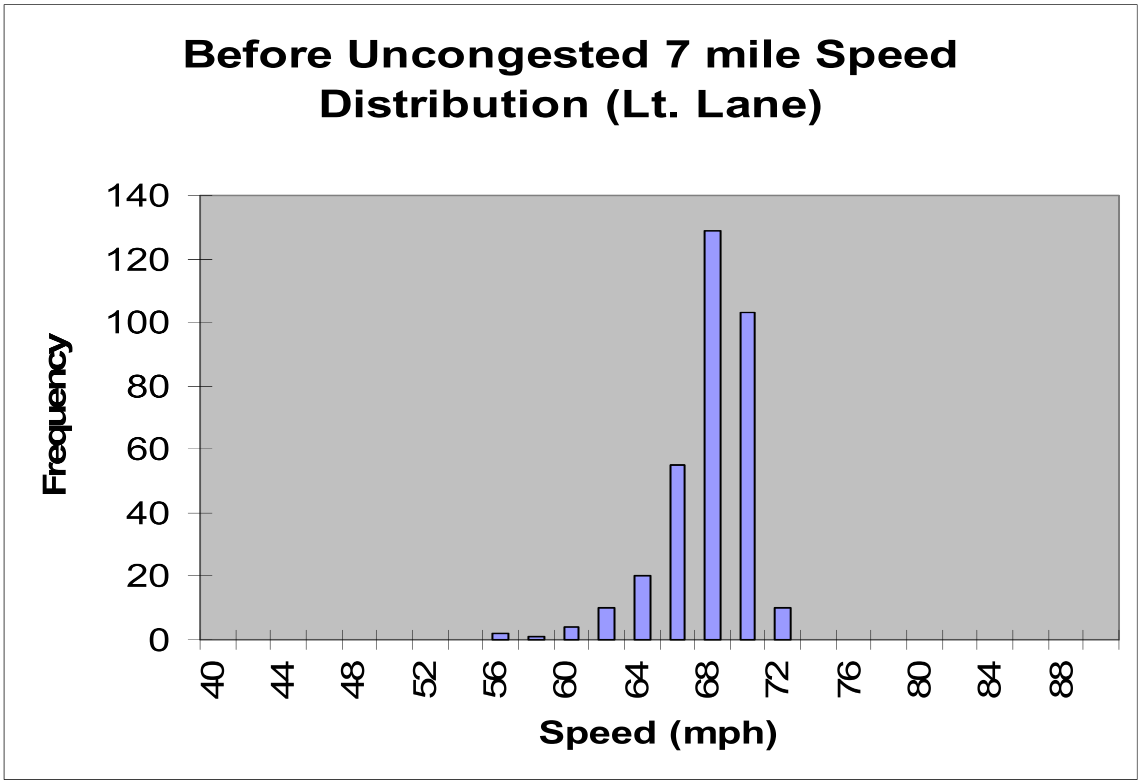


Figure 15

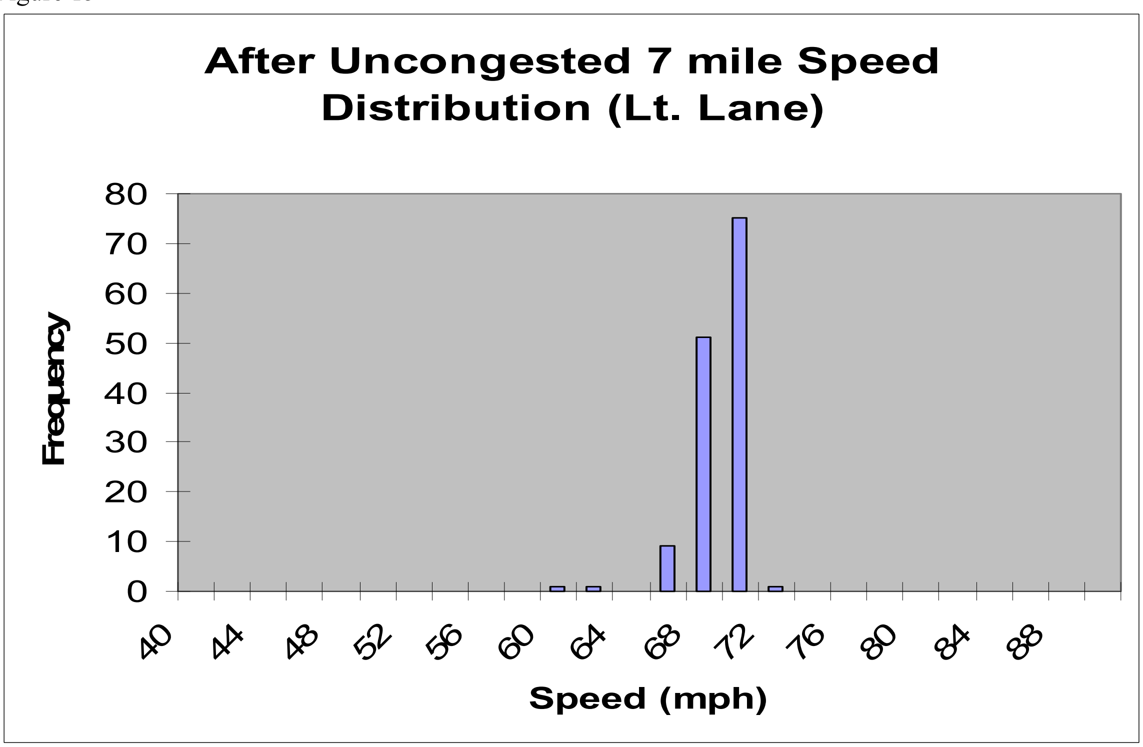


Figure 16

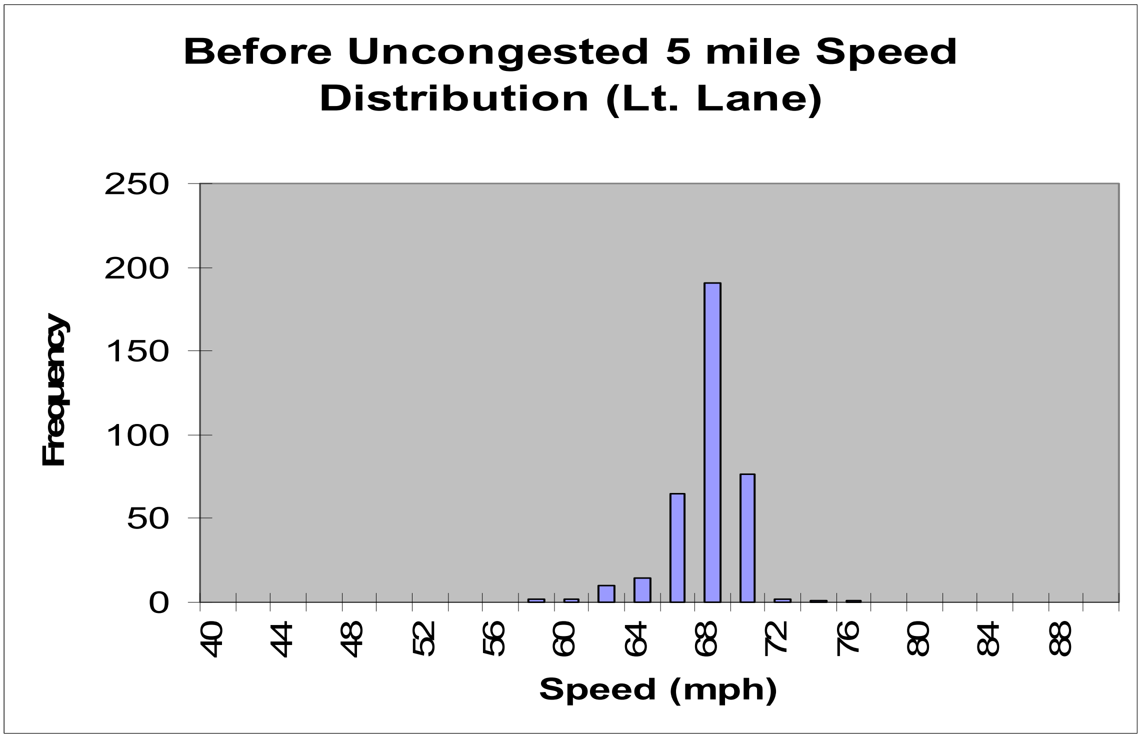


Figure 17

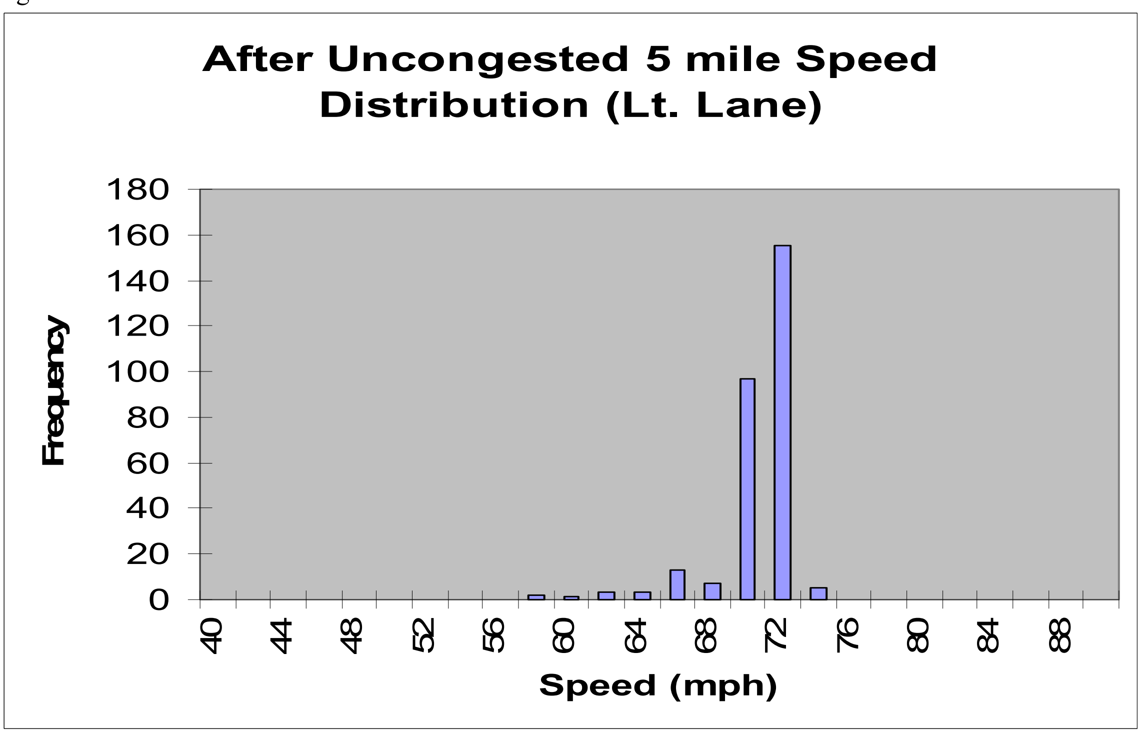
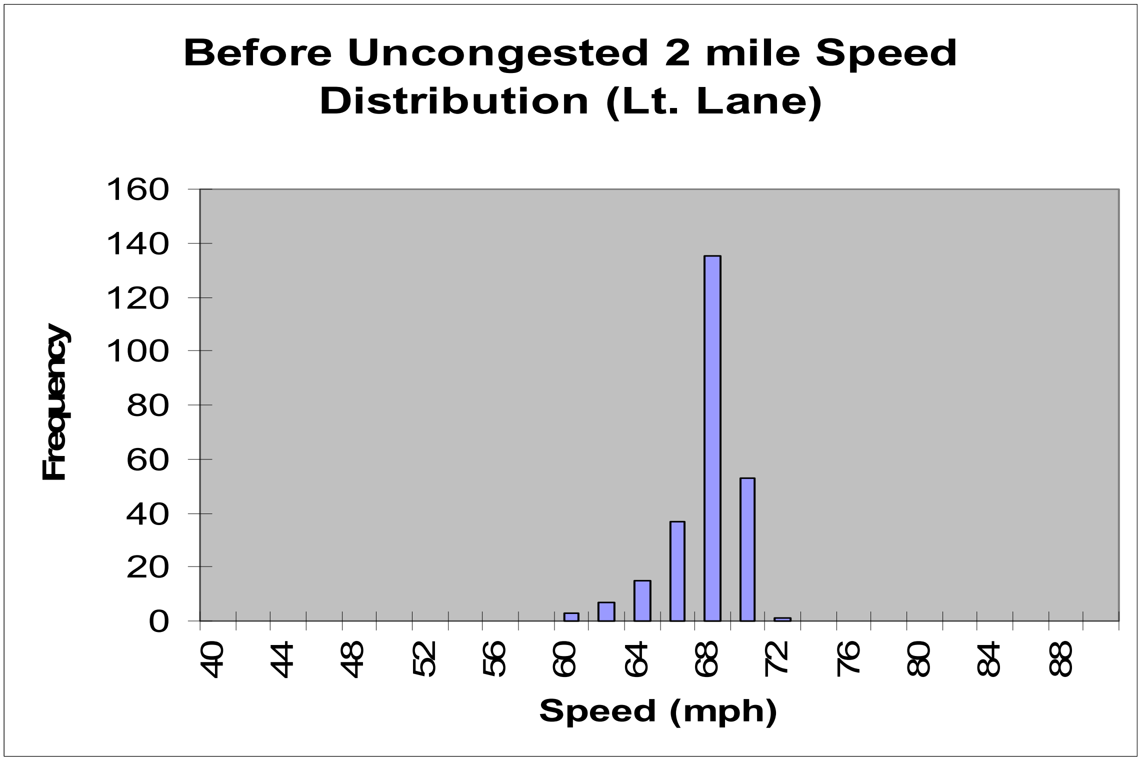


Figure 18



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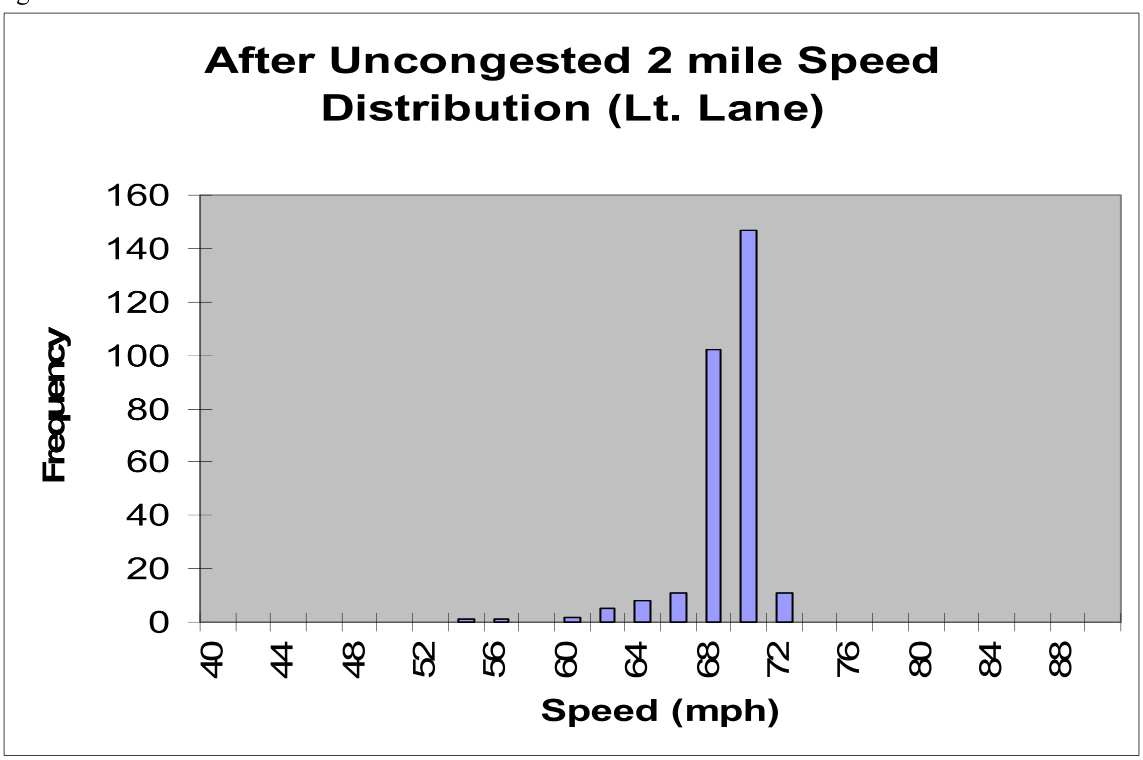

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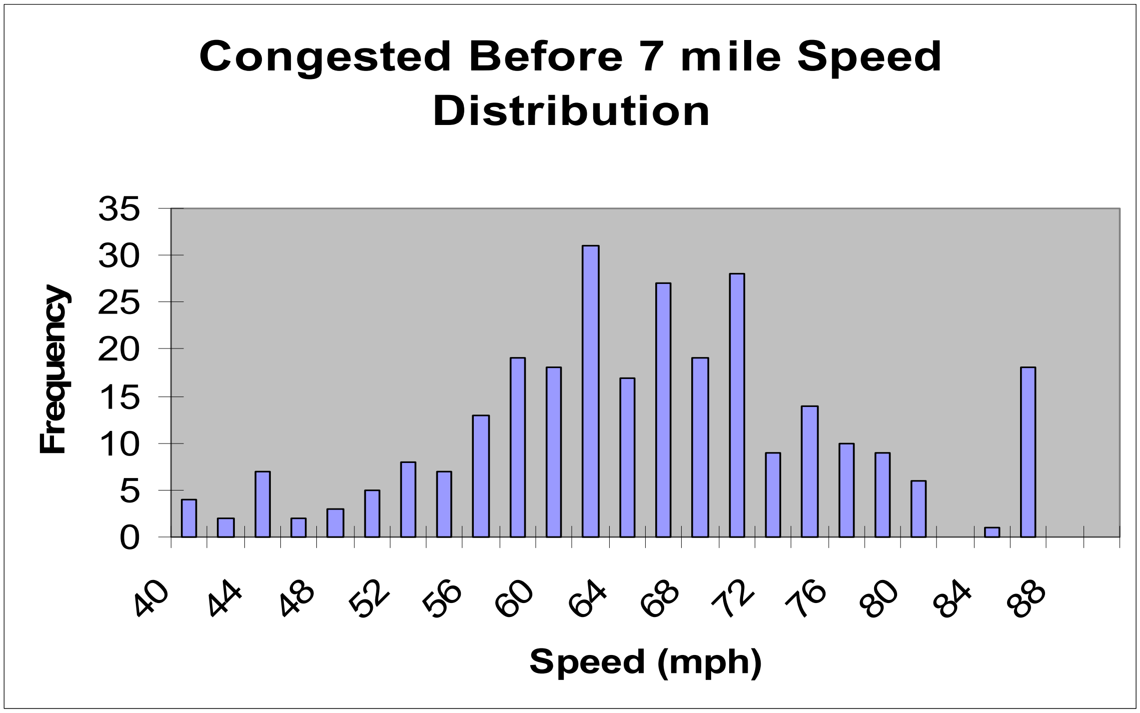

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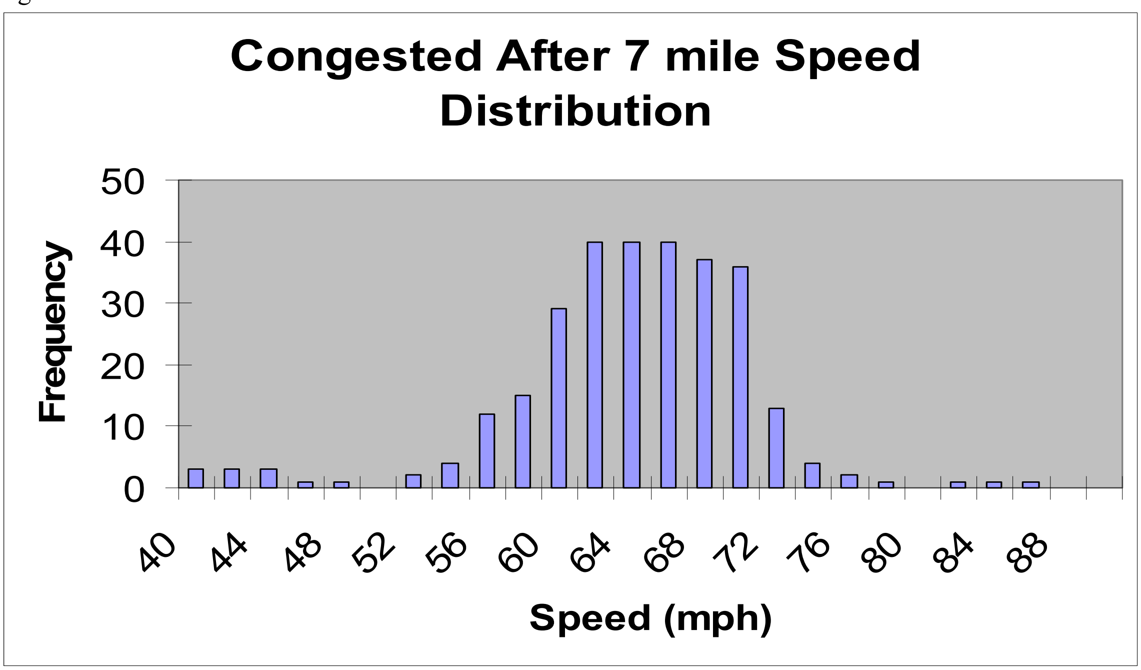

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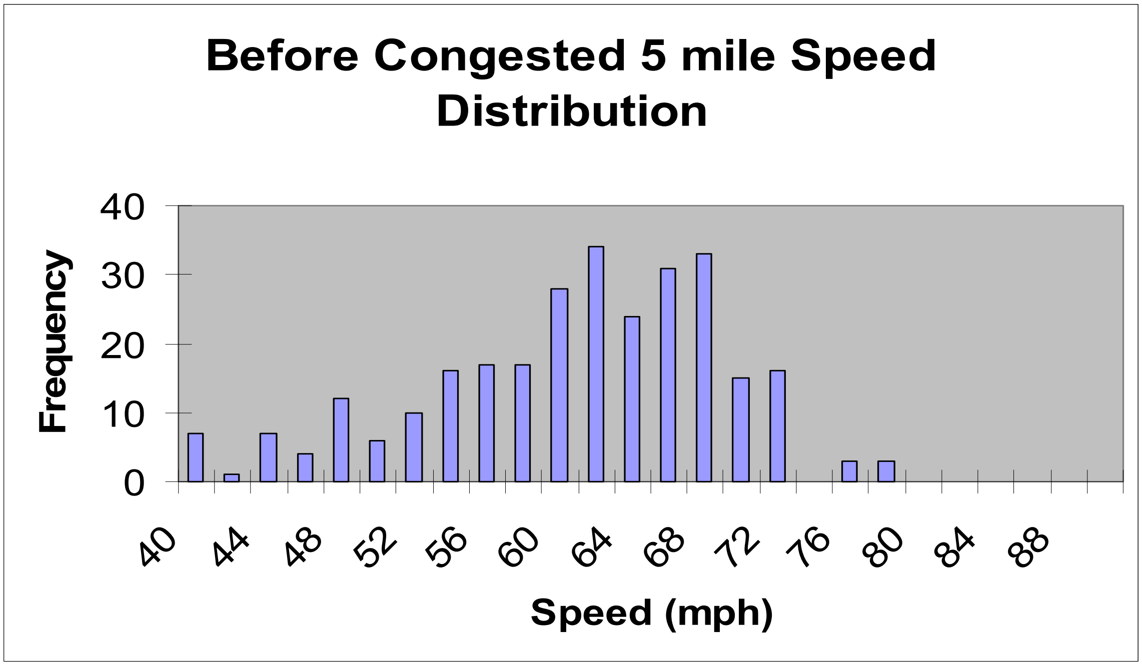

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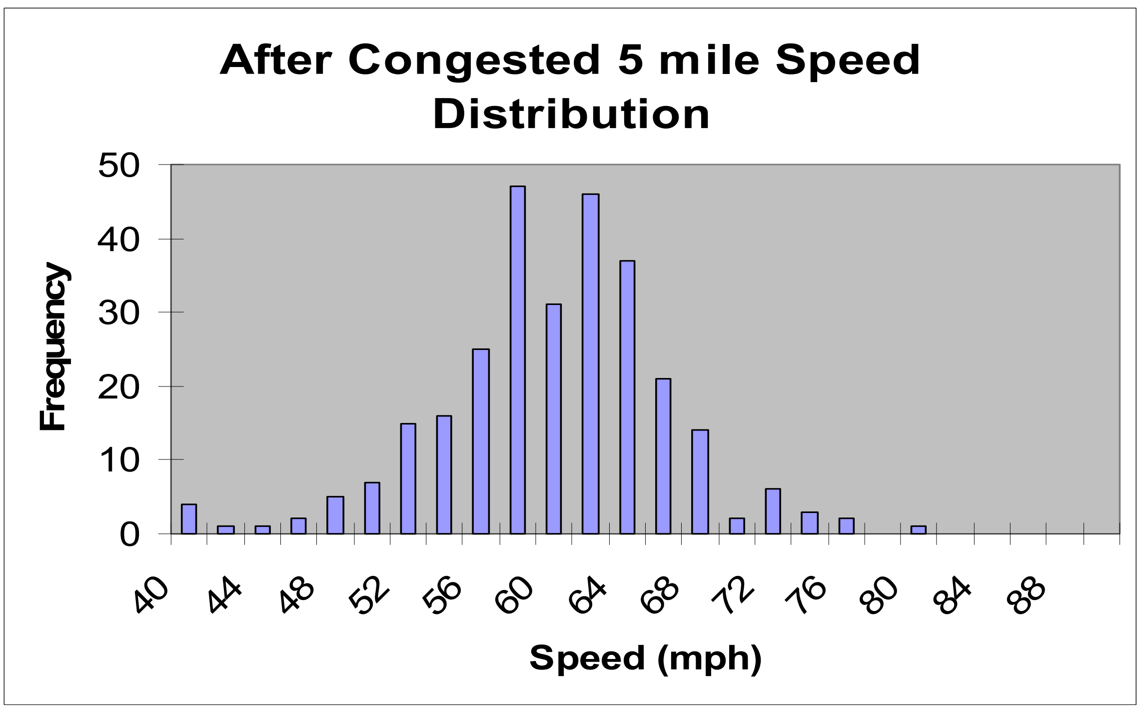

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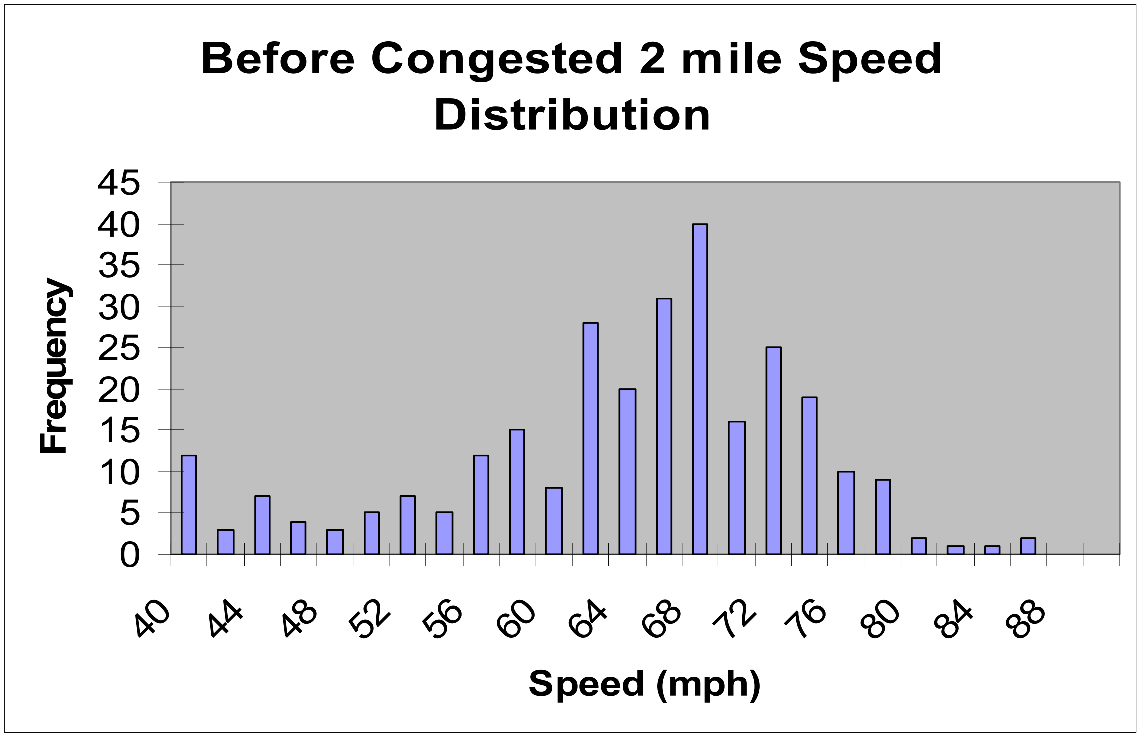

Figure 25

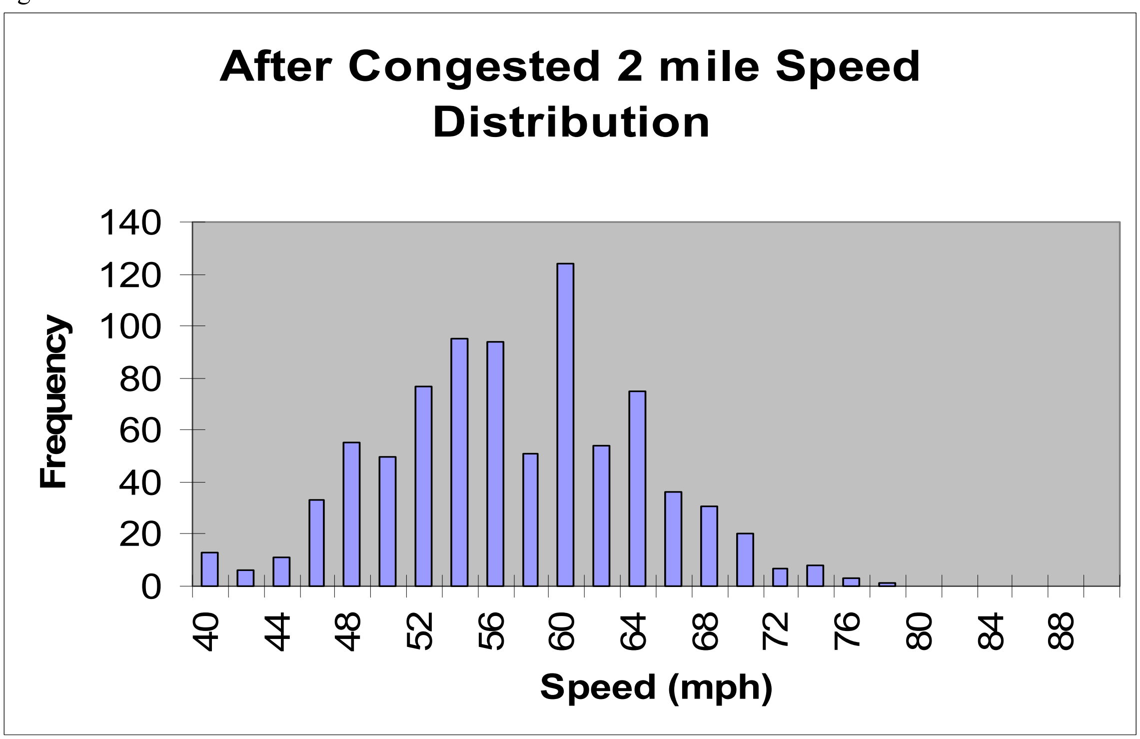

Figure 26

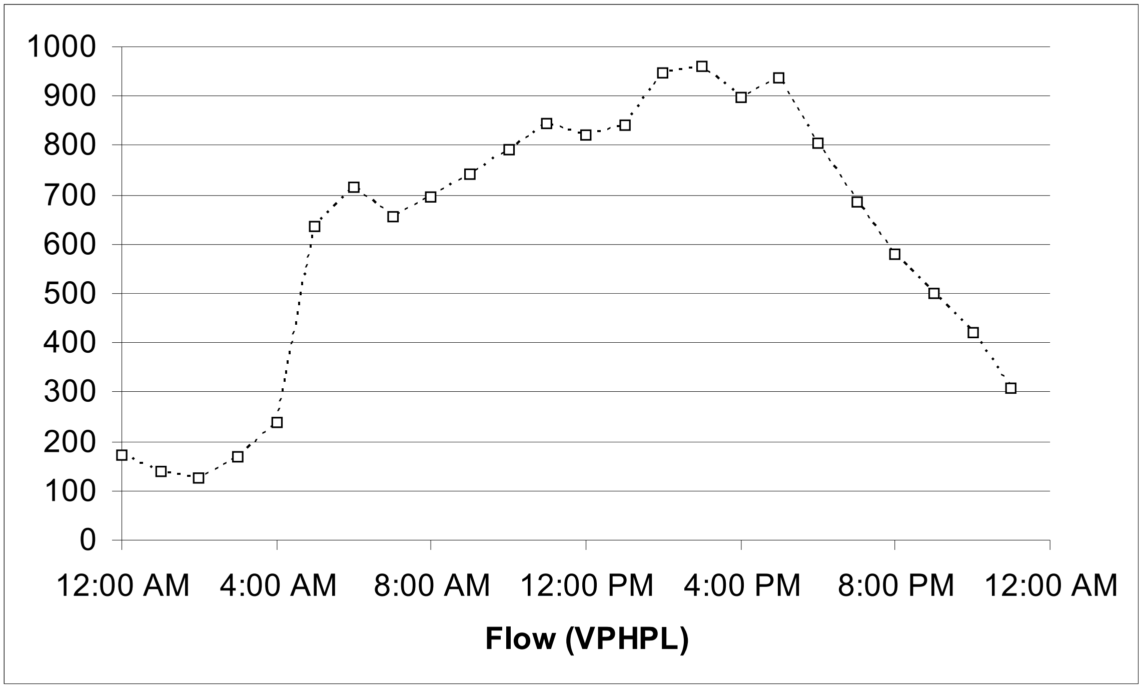

Figure 27 Typical Weekday 24 Hour Volumes

Appendix D

Aerial Photograph from the I-70 at Wentzville Study Site

Appendix E

Pictures from the I-70 at Wentzville Study Site

I-70 EB @ Pearce Blvd.
1 1/2 Mile Exit Sign and
First Construction Sign

I-70 EB @ 207 1/4 Mile Marker

I-70 EB @ Exit 208 Food Info Sign
Begin Lane Drop

I-70 EB @ EB Temporary
Exit Ramp to Pearce Blvd.


I-70 EB @ Bridge

Appendix F

Cross Tabulation of Driver Survey

<u>Length of Trip vs. Reaction to Signs</u>

less than 15 minute trip who slowed down = 62.07%
less than 15 minute trip who changed route = 3.45% n=29
less than 15 minute trip who did not affect = 17.24% margin +- 18.2%
less than 15 minute trip who chose "other" = 17.24%

15 to 30 minute trip who slowed down = 64.00%
15 to 30 minute trip who changed route = 4.00% n= 25
15 to 30 minute trip who did not affect = 16.00% margin +-19.6%
15 to 30 minute trip who chose "other" = 16.00%

over 30 minute trip who slowed down = 76.92%
over 30 minute trip who changed route = 3.85% n=26
over 30 minute trip who did not affect = 11.54% margin +- 19.2%
over 30 minute trip who chose "other" = 7.69%

<u>Familiarity of Work Zone vs. Reaction to Signs</u>

Daily users who slowed down = 52.80%
Daily users who changed route = 2.80% n=36
Daily users who were not affected = 30.60% margin +- 16.3%
Daily users who chose "other" = 13.90%

Weekly users who slowed down = 73.70%
Weekly users who changed route = 5.30% n=22
Weekly users who were not affected = 10.60% margin +- 20.9%
Weekly users who chose "other" = 10.60%

Monthly users who slowed down = 71.40%
Monthly users who changed route = 0.00% n=7
Monthly users who were not affected = 14.30% margin +- 37.0%
Monthly users who chose "other" = 14.30%

Seldom users who slowed down = 80.00%
Seldom users who changed route = 5.00% n=20
Seldom users who were not affected = 0.00% margin +- 21.9%
Seldom users who chose "other" = 15.00%

<u>Sex of Driver vs. Perception of Work Zone</u>

Men who think w.z. same hazardousness = 26.40%
Men who think w.z. more hazardous = 58.50% n=53
Men who think w.z. less hazardous = 15.10% margin +- 13.5%

Women who think w.z. same hazardousness = 48.80%
Women who think w.z. more hazardous = 43.90% n=47
Women who think w.z. less hazardous =7.30% margin +- 14.3%

Sex of Driver vs. Reaction to Signs

Men who slowed down = 76.60%	
Men who changed route = 0.00%	n=47
Men who were not affected = 14.90%	margin +- 14.3%
Men who chose "other" = 8.50%	
Women who slowed down = 51.40%	
Women who changed route = 8.60%	n=35
Women who were not affected = 20.00%	margin +- 16.6%
Women who chose "other" = 20.00%	

Age of Driver vs. Perception of Work Zone

Under 25 who think w.z. same hazardousness = 50.00%	
Under 25 who think w.z. more hazardous = 37.50%	n=16
Under 25 who think w.z. less hazardous = 12.50%	margin +- 24.5%
22 to 55 who think w.z. same hazardousness = 32.70%	
22 to 55 who think w.z. more hazardous = 60.00%	n=55
22 to 55 who think w.z. less hazardous =7.30%	margin +- 13.2%
Over 55 who think w.z. same hazardousness = 33.30%	
Over 55 who think w.z. more hazardous = 45.80%	n=24
Over 55 who think w.z. less hazardous =20.80%	margin +- 20.0%

Age of Driver vs. Reaction to Signs

Under 25 who slowed down = 57.10%	
Under 25 who changed route = 21.40%	n=14
Under 25 who were not affected = 7.10%	margin +- 26.2%
Under 25 who chose "other" = 14.20%	
22 to 55 who slowed down = 65.20%	
22 to 55 who changed route = 0.00%	n=46
22 to 55 who were not affected = 21.70%	margin +- 14.4%
22 to 55 who chose "other" = 13.00%	
Over 55 who slowed down = 73.90%	
Over 55 who changed route = 0.00%	n=23
Over 55 who were not affected = 13.00%	margin +- 20.4%
Over 55 who chose "other" = 13.00%	

Signs Read vs. Signs Understood

Drivers who could read signs and could understand them = 90.40%	
Drivers who could read signs but could not understand them = 0.00%	n=73
Drivers who could not read signs but could understand them = 4.10%	margin +-
Drivers who could not read signs and could not understand them = 5.50%	11.5%