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EFFICACY OF SPEED MONITORING DISPLAYS IN INCREASING SPEED LIMIT COMPLIANCE IN HIGHWAY WORK ZONES

Final Report

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16. Abstract
Safety in highway work zones has become a concern at UDOT as the highway network has begun to age and more maintenance and construction work has been necessary. Researchers are looking at several mechanisms for improving safety in highway work zones. This study focuses on the goal of reducing speed in work zones. First, research on methods of speed reduction used by state DOTs throughout the country is identified and summarized. Next, the methodology and results of a field study that tests the efficacy of the Speed Monitoring Display (SMD) are described in detail. Finally, the results of a survey that was conducted to ascertain drivers' opinions of the SMD are presented.
For the field study, three main conditions were analyzed: a no-treatment case, with the MUTCD signs and barriers; a treatment case using the SMD; and a treatment case using a police vehicle. In the no-treatment case, average vehicle speed was reduced about 3 mph as vehicles entered the work area of the work zone. With the SMD, average vehicle speed was reduced 7 mph. With the police vehicle, average vehicle speed was reduced about 9 mph. (These conclusions are valid at a 95 percent confidence level.) The results of the study suggest that the SMD is a promising option for state DOTs.

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CHAPTER 1. INTRODUCTION

Safety in highway construction and maintenance work zones has become an important issue in the field of transportation engineering. As the nation's highway system has begun to deteriorate and the number of vehicle-miles-traveled per year has increased, it has become more and more common to perform construction and maintenance work while the roadway is in use. In highway work zones, narrower roadways and a prevalence of roadside objects compromise the safety of motorists and highway workers. The challenge for the transportation engineer in designing work zones is to find a way to balance three goals: the accomplishment of the construction or maintenance work itself, the preservation of the capacity of the roadway, and the safety of the highway workers and the motorists.

As transportation engineers seek to increase safety in highway work zones, they have examined several different techniques. These include keeping drivers alert, aware, and awake; making workers and the work zone more visible; improving the control of traffic in merging areas to make lane changes more predictable; developing better safety devices; and reducing traffic speed and speed variance in the work zone. This research focuses on the last of these techniques, reducing traffic speeds, but it should be noted that techniques for reducing traffic speed sometimes play a role in supporting the other goals as well.

This report is divided into three major parts. The first is a literature review of devices that have been studied with the goal of reducing traffic speed within work zones.

The second part describes an empirical study of one of these devices, the Speed Monitoring Display (SMD). The Utah Department of Transportation (UDOT) chose this device because the research surrounding it is promising. The final part describes a survey of drivers' opinions regarding the SMD.

CHAPTER 2. GOALS AND OBJECTIVES

This study was commissioned by UDOT to gain more information about traffic control techniques that are useful for reducing the speeds of vehicles traveling through highway work zones. The end goal of the research was to provide information to help UDOT and the departments of transportation in other states to improve safety in highway work zones. Four main objectives contributed to the attainment of this goal.

The first objective was to evaluate the effectiveness of current work zone speed control measures used by UDOT contractors and other state agencies. The second objective was to determine the effectiveness of SMDs and law enforcement alone or in conjunction with each other in increasing speed compliance and reducing speed variation in work zones. The third objective was to determine drivers' opinions regarding the effectiveness of traffic control measures, especially SMDs, in work zones. The fourth objective was to provide training to UDOT and contractor employees regarding the information learned in obtaining the first three objectives.

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CHAPTER 3. METHODOLOGY

The research was divided into four parts, each designed to meet one of the four objectives described in Chapter 2. The first part was a literature review of speed control techniques. The second part was a field study of the effectiveness of the SMD and/or police presence for speed control in highway work zones. The third part was a survey of drivers' opinions. The final part consisted of conveying the information to others through oral presentations and written reports such as this one.

3.1. Literature Review

The literature review examined published studies and reports regarding safety in work zones especially as it relates to vehicle speed. Six methods for reducing speed were identified, including setting appropriate work zone speed limits, staging flaggers or police officers at the work zone, making drivers believe a police officer is stationed at the work zone, using feedback devices so that drivers are made aware of their speed, using drivers' communication devices to warn of the upcoming work zone, and changing the roadway. The literature review describes each of these techniques and related devices and summarizes the studies that have been performed on them.

3.2. Field Study

The effectiveness of both the SMD and police presence at reducing speed was tested at seven highway work zone locations in Utah during the summer and fall of 2002.

At each work zone location, speed and vehicle type information were taken for both the no-treatment condition and for one or more of the treatment conditions. The treatment conditions applied were: one or more SMDs, a stationary police vehicle with radar on, a stationary police vehicle without radar on, a cruising police vehicle, and a combination of the SMD and each of the police treatments. The treatments were not applied randomly.

For each study site, a minimum of three data collectors were used. In each case, the first data collector was set up within the work zone but before the treatment could be detected by the driver. The second data collector was set up near where the treatment was applied (except in the case of a cruising police vehicle, where this was impossible). The final data collector was located in the work zone, usually near the end of the work zone. Where the work zone was long enough, as many as seven data collectors were set up to collect data throughout the entire study area.

The data were compiled to create a table of average speed and standard deviation of speeds for each condition at each study location and at each data collector. This compiled data were analyzed using general linear models to determine if there were statistically significant differences between the treatments.

3.3. Survey of Drivers' Opinions

A one-page questionnaire was administered to 622 drivers. The questions covered three general areas: demographic information, drivers' tendencies, and drivers' opinions of the SMD. The information about drivers' tendencies was analyzed using a chi-square statistical test.

3.4. Communication of Results

The results of this research were communicated to UDOT through oral presentations and a formal report. The oral presentations allowed UDOT employees to gain knowledge about the research and to discuss how UDOT should use the knowledge gained through this research without reading a lengthy report. Those who were interested in learning more details were able to read the full report.

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CHAPTER 4. LITERATURE REVIEW

Papers cited in this review were for the most part found using the TRIS Online database search (*1*). TRIS Online contains an index of transportation research from 1968 to the present. Other research was found by reviewing the reference lists from articles that were found on TRIS Online and by conducting web searches of key authors. Key words that were used in the TRIS Online search include combinations of various terms such as “speed monitoring display,” “work zone,” “speed,” “police,” “construction zone,” “radar,” “optical speed bar,” and “rumble strips.”

The following sections summarize the current research for each of the six methods of reducing vehicle speed described in Chapter 3. These include setting appropriate work zone speed limits, staging flaggers or police officers at the work zone, making drivers believe a police officer is stationed at the work zone, using feedback devices so that drivers are made aware of their speed, using drivers’ communication devices to warn of the upcoming work zone, and changing the roadway.

4.1. Recommended Work Zone Speeds

Before discussing methods or treatments for reducing speed in highway work zones, it is necessary to determine the desired speed. That is, how can the engineer determine the desired speed, one that balances the goals of preserving capacity and increasing safety? Studies providing recommendations for setting work zone speed limits suggest that speed limits in work zones should be reduced only where geometry necessitates a reduction and that the necessary speed reductions should be apparent to the driver (*2*, *3*).

Research on this topic performed by Graham-Migletz Enterprises, Inc. for National Cooperative Highway Research Program (NCHRP) Project 3-41 and 3-41(2) are published in the NCHRP's Research Results Digest (*4*) and in the Transportation Research Record (*5*), respectively. The researchers performed an in-depth study including conducting a literature review; surveying highway agency officials, motorists, construction contractors, and construction liability insurance carriers; developing a procedure to use when determining speed limits in work zones; and verifying the efficacy of the procedure. The procedure is described in detail in the paper in the Research Results Digest (*4*) mentioned above. This procedure was tested at 30 sites in seven states, with the result that mean speeds were reduced in work zones with or without speed limit reductions and the high variance that is typically seen within work zones was significantly reduced when the procedure was followed (*5*).

In response to the findings of Graham-Migletz's study, the Manual on Uniform Traffic Control Devices (MUTCD) was revised. Section 6B of the Millennium edition of the MUTCD (*6*) states:

> Reduced speed limits should be used only in the specific portion of the temporary traffic control zone where conditions or restrictive features are present. However, frequent changes in the speed limit should be avoided. A temporary traffic control plan should be designed so that vehicles can safely travel through the temporary traffic control zone with a speed limit reduction of no more than 16 km/h (10 mph).
>
> A reduction of more than 16 km/h (10 mph) in the speed limit should be used only when required by restrictive features in the temporary traffic control zone. Where restrictive features justify a speed reduction of more than 16 km/h (10 mph), additional driver notification should be provided. The speed limit should be stepped

> down in advance of the location requiring the lowest speed, and additional temporary traffic control warning devices should be used.
>
> Reduced speed zoning (lowering the regulatory speed limit) should be avoided as much as practical because drivers will reduce their speeds only if they clearly perceive a need to do so.

Establishing work zone speed limits that are based on engineering studies or principles and that are not overly restrictive can reduce mean speed and speed variability. However, because this method does not ensure speed limit compliance, additional devices or treatments may be beneficial to further reduce speed in highway work zones and thereby increase safety.

4.2. Traffic Control/Enforcement

It is commonly accepted that the most effective method of reducing mean traffic speed is through the use of law enforcement. This can take the form of traffic controllers (where an officer stands at the side of the road and motions for traffic to slow down), stationary police vehicles (where the officer sits in a parked police vehicle at the side of the road), or moving police vehicles (where the officer cruises the area in question). Unfortunately, police presence is not always feasible due to cost or availability of police officers.

A recent study reported on a survey of law enforcement personnel (*7*). Schrock and his colleagues state that probably the greatest deterrent to using law enforcement is the high labor cost. All of the 20 states surveyed use off-duty officers and pay them overtime to work shifts in work zones. Only four of the 20 states indicated that patrolling work zones is part of an officer's normal duty shift. Indeed, most officers are too busy with other duties to patrol work zones during the normal duty shift. The authors suggest that this difficulty is nearly impossible to overcome. Emphasis should therefore be placed on maximizing the effectiveness of the officers when they are present. Related to this problem is the chronic shortage of officers available to patrol work zones. The survey described a program being used in South Dakota called DOTCOP. Any sworn or retired officer with a firearm license can be hired as a DOTCOP. These officers are given a uniform and patrol vehicles that show their designation as work zone enforcement. The officers have jurisdiction only in and around the work zone. The DOTCOP must remain at the work zone for the entire shift and cannot be called away to other duty during the time they are assigned to patrol the work zone.

Another deterrent to using law enforcement noted by Schrock and his colleagues is the lack of space for maneuvering and for apprehending speeders without hindering the rest of the traffic stream (*7*). To overcome this problem, the researchers suggest creating pullout areas within the work zone.

Another possible method of overcoming this difficulty was described by Fontaine et al. in 2002 (*8*). A photo-radar located within the work zone could snap a picture (or provide a video image) of a vehicle traveling faster than a given threshold. The picture could be transmitted downstream to a police officer waiting in a vehicle at the end of the work zone. The police officer could then apprehend the speeder at a safer location.

Another issue that is addressed in the study by Schrock et al. (7) is an apparent discrepancy between the activities that law enforcement officers consider to be effective and those considered effective by engineers. Thirteen of the 20 states use stationary police vehicles for enforcement, five use police as traffic controllers, and nine use circulating vehicles. For two of these states, circulating vehicles are used exclusively.

The officers in states that use circulating methods indicated that they feel circulating methods are more effective. However, the researchers note that engineering studies have indicated that stationary police vehicles are more effective than cruising vehicles.

Numerous studies have shown that mean traffic speeds are more likely to be reduced when a stationary police vehicle is present than when the police vehicle is cruising the area (*2*, *3*, *4*). One such study was performed by Richards et al. at work zones in Texas in 1986 (*9*). The law enforcement treatments that were studied included a police traffic controller, a stationary police car with and without lights and radar, and a circulating police car. The study found the police traffic controller to be most effective, reducing mean speeds by about 10 mph. (Note that this treatment was not tested on an urban freeway because officers were reluctant to stand unprotected on this type of facility). Stationary police vehicles were next most effective, reducing mean speeds by around 7 mph. Circulating police vehicles reduced speeds by only 2 to 3 mph. It should be noted that this study found flaggers to be slightly more effective than enforcement, especially when an innovative flagging method was used which involved waving the flag with the left hand as directed in the MUTCD while at the same time using the free hand to either motion to vehicles to slow down or to point to a speed limit sign. Other studies have found police traffic controllers and flaggers to be slightly less effective than stationary police vehicles (*2*).

In a paper that appeared in a 1986 issue of Human Factors, Shinar and Stiebel seek to reconcile the concept of perceived risk of apprehension (PRA), which postulates that cruising police vehicles should be more effective than stationary police vehicles at reducing traffic speed, with the results of previous studies, such as those presented in the last paragraph (*10*). According to the theories surrounding the PRA concept, drivers are more likely to modify their behavior if they can see the police vehicle and it is ready to apprehend them. The PRA concept postulates that for individual vehicles the circulating police vehicle would be more effective at reducing speeds because it is more visible and it is in a better position to apprehend speeders. To test their theory, the researchers examined the speed behaviors of individual military vehicles in the presence of military police. All of the subjects were speeding at the time that they were first detected and were subsequently subjected to the treatment of either a stationary police vehicle or a moving police vehicle. Speed data were taken at three locations: when the vehicle first entered the study area, near the treatment, and after the treatment. The authors determined that speed reduction for a vehicle approaching a police vehicle was the same regardless of whether the police vehicle was stationary or moving. However, once the subject vehicle had passed the police vehicle (moving or stationary), the moving police vehicle treatment was more effective at maintaining reduced speeds than was the stationary police vehicle treatment. This was most likely because the moving police vehicle posed more of a perceived risk to these drivers than did the stationary police vehicle.

The apparent discrepancy in the results of the studies described in the last two paragraphs can be explained by noting that although a moving vehicle may have more impact on an individual vehicle, it is seen by far fewer drivers. The stationary police vehicle may not have as large an impact on individual vehicles, but it is more likely to have an effect on the traffic stream as a whole. This also may help to account for the perception of police officers that they are more effective in a moving vehicle, since the vehicles near the police officer are likely to slow down more if the police vehicle is in motion than if it is stationary.

Another issue surrounding speed enforcement is that although mean speed decreases dramatically near a stationary police vehicle, the effect does not continue downstream. This phenomenon was observed in the study by Shinar and Stiebel (*10*). Dart et al. also observed this phenomenon (*11*). These researchers studied the speed profile of vehicles passing a stationary police vehicle on a two-lane rural road. Whereas mean speed and speed variance were both reduced at the location of the police vehicle, the speed reduction began to disappear 1000 feet downstream of the police vehicle and had completely disappeared by a point 2 miles downstream.

In summary, although law enforcement has been shown to be very effective at reducing mean speeds of vehicles in work zones, there are a number of difficulties associated with this treatment. A more ideal treatment would be less costly, would result in speed reductions of the same magnitude as those resulting from police enforcement, and would maintain these speed reductions throughout the work zone. The following chapters describe treatments that have been studied with the hope that they will provide one or more of these benefits.

4.3. Mimicking Enforcement

In addition to the visual stimulus that influences all drivers when they are approaching a police vehicle, drivers with radar detectors have an additional stimulus, the chirp of their radar detector. Drone radar (radar that is emitted continuously) has been tested for reducing speed in work zones based on the premise that drivers with radar detectors will slow down when drone radar is encountered. Because drivers with radar detectors typically drive faster than the speed limit, this would reduce the percentage of vehicles exceeding the speed limit and reduce the speed variance.

The measures of effectiveness (MOEs) that have been studied with regard to drone radar include mean speed, speed variation, the percentage of cars speeding, the number of conflicts due to severe braking, and the percentage of vehicles using radar detectors. In general, drone radar has been found to reduce the mean speed of vehicles by small amounts (0 to 2 mph) (*12, 13, 14, 15, 16*). Studies that identified vehicles equipped with radar detectors found greater decreases in mean speed among these drivers than were found in the driver population in general (*17*, *18*). Often, the drone radar had a greater effect on mean truck speeds, possibly because of a greater percentage of radar use among trucks than among cars (*13*, *15*). A simulation using the data on vehicle trajectories from one experiment showed that drone radar would change overall speeds if 13 percent of vehicles were equipped with radar detectors (*17*).

Any beneficial effect of drone radar depends to some extent on the driver's belief that the radar is emanating from a police vehicle. To maintain this belief, it is important that the drone device is hidden and that more than one drone is used so that it is difficult for drivers to pin-point the source of the radar. This is especially important in the case of truck drivers, who communicate with each other over CB radio. CB radio communications are one method of determining driver's reactions to the radar (*13*).

One variation of drone radar is known as the Safety Warning System (SWS). With this system, an SWS radar-emitting device is placed in a work zone, on an emergency vehicle, or in some other suitable place. When an SWS radar detector receives the SWS message, it gives off a warning beep and then displays a text message or uses a voice synthesizer to relay the message audibly. Radar detectors that are not SWS-compliant simply sound the normal warning that there is radar in the area. Thus, all drivers with radar detectors are alerted to radar in the area, and drivers with SWS-compliant detectors can be given a more specific message such as, “Workers Ahead” or “Right Lane Closed Ahead.” Studies of this technology have found decreases that are comparable to or greater than the speed decreases when traditional drone radar is used (*19*, *20*).

Results for drone radar have been mixed, with a few researchers finding significant benefits in terms of speed reductions for the overall driver population, but most researchers finding small but statistically significant speed reductions in only those vehicles equipped with radar detectors. The SWS is slightly more effective than drone radar alone in decreasing mean vehicle speeds (*19*, *20*). Further research could clarify how the percentage of radar-detector-equipped vehicles in the traffic stream affects these results, investigate methods for convincing drivers that drone radar is actually police enforcement, and determine the types of SWS messages that are most effective.

4.4. Feedback Devices

Transportation engineers have studied feedback devices under the premise that if drivers were made more aware of their behavior they might make adjustments toward desired behaviors. Some of these devices may also derive efficacy from the use of radar to determine vehicle speeds.

Using feedback on speeding behavior as a means of encouraging speed limit compliance is not a new idea. A study published in the Journal of Applied Behavior Analysis in 1980 (*21*) found that speeding was significantly reduced when a road sign gave an indication of the percentage of cars not speeding the day or the week before and the highest percentage yet recorded (see Figure 1). The percentage of cars speeding and the percentage of cars going 5, 10, and 15 mph over the speed limit were reduced when the feedback sign was in use. The speed limit reduction continued even after the sign was in place for more than 25 weeks. However, the sign had no effect when no numbers were posted. A second set of researchers validated Van Houten et al.'s results in 1987 (*22*). Cars passing a similar feedback sign showed similar reductions in speed. These speed reductions continued at least 4 weeks after the sign was removed. In each case, the researchers concluded that providing feedback to drivers regarding their speeding behavior was an effective and inexpensive way to increase speed limit compliance.

Figure 1. Speed Compliance Feedback Sign

The SMD is a more modern version of the feedback sign, giving immediate feedback regarding each motorist's individual speed. The SMD is a device attached to a portable trailer that uses radar to measure the speed of passing cars and displays the speed to the driver of the car. Often, an advisory or regulatory speed limit sign and a sign that reads "Your Speed" are attached to the display (see Figure 2). In this way, the drivers receive immediate feedback as to how fast they are driving and how the speed relates to the posted speed limit. Over the past few years, a number of research projects have studied the SMD as a possible cost-effective method of increasing safety in construction and maintenance work zones by increasing speed limit compliance.

Figure 2. Speed Monitoring Display

Recent studies of the SMD have considered short-term and long-term effectiveness on various types of roads, at a variety of different speeds, and in several locations throughout the work zone. The MOEs that have been studied include mean speed, speed variation, and the percentage of cars speeding. In the short term, the SMD has been found to reduce mean speed by 4 to 5 mph and increase speed limit compliance by 10 to 20 percentage points. Studies have not found consistent results regarding changes in speed variation.

Carlson, Fontaine, and Hawkins studied the SMD in the summers of 1999 and 2000. In the first year (*15*), the SMD was tested on two four-lane divided highways with lane closures. Data were collected for the condition with no SMD in the morning and with the SMD in the afternoon. The SMD was positioned after the initial work zone warning signs, but prior to the roadway taper. The MOEs were speed, percent of vehicles speeding, speed variability, and the number of conflicts (due to slow moving vehicles or lane changes) for conditions with and without the SMD. The results were promising. Upstream of the work zone, car and truck speeds were reduced once the SMD display was legible, and speeds were also reduced at the SMD by between 2 and 7.5 mph. The speed reductions continued as the cars approached the taper and continued through the work zone. In the work zone, the speed reductions ranged between 3 and 6 mph. For cars, the standard deviation decreased when the SMD was present. For trucks, the standard deviation increased. The authors reported an increase in conflicts when the SMD was present, but the conflict analysis was only performed at one site, and very few conflicts were detected in both the before and after period.

In the second year (*23, 24*), the SMD was used at two locations on a rural two-lane road where all of the traffic was diverted onto the shoulders. Once again, the SMD was placed along the road after the initial work zone warning signs, but prior to the taper; however, the distance of the SMD from the taper was different at each location studied. Once again, speed and volume data for conditions with and without the SMD were taken in one day at each site. The SMD was found to be effective in reducing the percentage of vehicles speeding in the taper; however, there were no vehicles speeding in the work zone under any condition. The SMD was more effective at reducing average speed for trucks than for passenger cars. There was a difference in the amount of reduction depending upon the location of the SMD, but the best placement for the SMD could not be conclusively determined from this study. The final summary for the two-year study concluded that the SMD was easy to operate and set up and that it resulted in speed reductions of 5 mph before the taper and 3.5 mph in the work zone (corresponding to a 13 percent reduction in speeding vehicles in the taper and a 6 percent reduction in the work zone). Construction workers at the sites gave positive feedback on the SMD. Of all of the devices tested, the SMD had the largest impact.

A study undertaken by Kamyab et al. in Iowa gave less promising results (*19*). The group used the SMD at a work zone on I-35 where the posted speed was 55 mph. The SMD was located 2250 feet upstream of the taper, and speed data were taken at 1500 feet and 500 feet upstream of the taper. Data were collected for two days before and two days after the SMD was in place. Although the results showed a positive trend (reduction in mean speed, reduction in percentage of high-speed vehicles, increase in number of vehicles in the pace, and decrease in pace speed), these changes were not statistically significant. The researchers concluded that the character size used for the SMD (18 inches) was not large enough for a 55 mph roadway.

Another study presented in 2000 at the Mid-Continent Transportation Symposium Proceedings examined the use of the SMD in Kansas (*20*, *25*). The SMD was used in a construction zone on a rural section of I-70. It was placed within the work zone at a median crossing. Data were collected for one week without the SMD, for one week with the SMD, and for one more week without the SMD but with police enforcement. The SMD significantly (95 percent confidence) decreased mean speed (by about 3 mph), 85th percentile speed, percent of vehicles speeding (from 67 percent to 36 percent), and standard deviation of speed for both cars and trucks. One-half mile downstream of the speed display, the changes in the MOEs were not as pronounced (mean speed was only 1 mph lower, for example), but the reductions were still statistically significantly different from the no-treatment condition. The speeds were also decreased when police enforcement was present, but the speeds returned to normal downstream of the police enforcement. Once police enforcement left, speeds increased to higher than the baseline speed.

Lyles et al. in Michigan evaluated SMDs and other speed control measures in 1998 (*26*). The data were taken in a work zone involving a lane closure on an 11-mile stretch of I-69. Speed data were taken at three locations in the work zone, one of them prior to the taper. Police presence just before the taper was the most effective method of reducing vehicle speeds, but the SMD was also effective at reducing speed. Unfortunately, it was difficult to directly compare the results for different methods of speed control used in this study because the work zone speed limit varied from 35 mph to

50 mph on different days. As a result, although the SMD was qualitatively found to be less effective than police presence at reducing vehicle speeds, the amount of the difference could not be determined.

A study performed in New Mexico (*16*) found that the SMD reduced mean speed in work zones on two urban arterials by 4 to 5 mph. The percentages of cars exceeding the posted speed limit and the percentage of cars traveling at 10 mph above the posted limit were also reduced. There was a statistically significant reduction in speed variance at one site, but not at the other site. The letters on the SMD were 12 inches high. A larger SMD was also used at a work zone on I-40 after a publicity campaign and an intensive speed enforcement program. In this case, there were few vehicle speeds greater than 5 mph above the speed limit.

One of the few studies with an SMD where advisory rather than regulatory speed limit signs were used in the work zone took place in South Dakota in 1993 (*27*). The study took place at a bridge-replacement work zone on an urban section of I-90. At the work zone, the Average Annual Daily Traffic (AADT) was 9000 vehicles per day. The normal speed limit was 55 mph and the advisory speed limit was 45 mph. The characters on the SMDs were only 9 inches high. SMDs were placed at a position downstream of the construction warning signs and about 310 feet upstream of the lane-change taper, one on each side of the road. The work zone activity was not visible to motorists from this location. Tape switches were installed at three locations: downstream of the initial construction warning signs, just downstream of the SMDs and upstream of the taper, and at the end of the taper. Only those vehicles with 4-second headways were analyzed. An analysis of variance of the speed data showed that mean speeds were reduced by 4 to

5 mph when the SMDs were present. The percentage of vehicles exceeding the speed limit by 10 mph was reduced by 40 percentage points. These results are generally comparable with the results of other studies. However, the researchers noted that the SMD could have been more effective if the numbers were larger and if there were fewer signs nearby to distract the driver.

In the same issue of the Transportation Research Record, Garber and Patel (*28*) published their study of a changeable message sign (CMS) used to provide immediate feedback to the driver in a way similar to the feedback provided by an SMD. A radar speed detector was attached to the CMS in such a way that when a speeding vehicle approached the CMS, it displayed one of four messages, “Excessive Speed Slow Down,” “High Speed Slow Down,” “Reduce Speed in Work Zone,” or “You Are Speeding Slow Down.” The device was tested at seven locations on I-81 and I-64 in Virginia during 1992 and 1993. The AADTs for these sites varied from a low of 8400 to a high of 33,000. The normal speed limit was 65 mph at each site and the regulatory work zone speed limit was 55 mph at every site except for one (where the work zone speed limit was 45 mph). In each case, the CMS was placed in the work zone just after the taper. Speed data were collected at three sites: just before the transition area, halfway through the activity area, and just before the end of the work zone. Speed and volume data were collected only for those vehicles going fast enough to trigger the CMS message. The researchers found that all four signs were effective in reducing both the mean speeds and the 85th percentile speeds of high-speed vehicles in the work zone. Additionally, speeds tended to converge as the drivers approached the end of the work zone, indicating that speed variance was reduced. The authors recommended the use of the message, “You Are Speeding Slow Down,” as this message reduced speeds more than the other messages.

In addition to the studies presented above that examined the short-term (less than one week) effectiveness of immediate feedback on reducing speeds in work zones, there are three studies that examined the long-term effectiveness of SMDs or feedback CMSs. Two of the studies (*29*, *30*) found that the effects of the feedback devices lasted over a 5- to 7-week period. The most recent study (*31*) found that speed limit compliance degraded rapidly during the second week.

Garber continued his study of the feedback CMS in the summer of 1995 (*30*). This time, he used only the “You Are Speeding Slow Down” message. Data were collected at three sites (two interstate sites and one primary route site) where the CMS was used for a period of 7 weeks (except at one of the interstate sites, where data could only be collected for 3 weeks). Sixty-five percent of the drivers traveling the interstate sites said they used the highway at least once a day. On the primary route, 80 percent used the highway at least once a day. As with the previous study, the researcher found that the feedback CMS effectively reduced speeds in the short term. Additionally, the effectiveness continued throughout the 7-week study period. The speed reductions were between 5 and 10 mph at the interstate sites and 8 to 12 mph at the primary route site. Garber also indicated that the probability of speeding was reduced and the speed variance was reduced. These results held true for all classes of vehicles.

Pesti and McCoy carried out two studies on the effectiveness of the SMD over the long term (longer than one week) (*31*). In the first of these studies, three SMDs were placed along a section of I-80 in Nebraska. Although there was no work activity in the study area, the area was still considered to be a work zone because it was sandwiched between two work zones. The ADT was about 38,000 of which 22 percent was commuting traffic. The normal speed for the roadway was 75 mph, but it was reduced to 55 mph in the work zone. The best position for the SMDs was determined based on a preliminary speed profile of the road section in question. To reduce acceleration at the beginning of the section, the first SMD was positioned 1150 feet after the roadway opened up from one lane to two lanes. The second SMD was placed 1000 feet upstream of the location of the highest observed speeds. The third SMD was placed near the arrow board indicating the taper into the second construction area. Speed data were collected at four locations: upstream of the first SMD, about 1000 feet downstream of the first SMD, 1000 feet downstream of the second SMD, and where the vehicles passed the third SMD. Only the speeds of vehicles with at least 5-second headways were measured. Data were taken before the SMDs were positioned, each week during the 5-week period that the SMDs were active, and one week after the SMDs were removed. The researchers found that the SMDs reduced speeds and maintained the speed reductions throughout the 5-week period. For passenger cars, the mean speed were reduced by 3 mph and 85th percentile speed was reduced by 4 mph. For other vehicles, these reductions were both 2 mph. The percentage of vehicles complying with the speed limit was increased by 10 to 20 percentage points for all vehicles. After the SMDs were removed, speeds increased slightly, but they were still statistically significantly lower than before the use of the SMD.

Pesti and McCoy’s second study took place on on-ramps onto a section of I-80 that was under construction. SMDs were placed on two different on-ramps for two weeks each. Approximately 60 percent of the traffic on these ramps was local traffic. The researchers found that although speeds decreased by 4 mph during the first week, the effects did not continue into the second week. In fact, for some MOEs drivers were less compliant in the second week than they had been before the SMDs were used. The authors suggested two possible reasons for the failure of the SMD over the long term: the higher percentage of commuting traffic and the possible perception that police enforcement is more likely on the interstate itself than on an on-ramp. The authors suggest that more studies be undertaken to validate these findings.

Feedback signs (including CMSs with radar and SMDs) have shown promise in reducing the mean speed of vehicles on critical roadways, including in highway work zones. However, there are a number of questions regarding these types of signs that have not yet been addressed. Continued research is needed to determine the most effective position for the feedback sign, the best character size for the feedback message, how many feedback signs are needed in a given critical area, the comparative effectiveness of CMSs with radar and SMDs, what characteristics of the highway affect feedback signs, under what conditions the feedback signs remain effective in the long term (for instance, the level of commuting traffic, the type of roadway, the likelihood of police enforcement, etc.), and whether or not the SMD would remain effective if it were used more commonly.

4.5. Communication

Another method of improving safety in work zones is by publicizing the hazard using a driver's own communication devices. The SWS discussed in section 4.3 is an example of this concept. Other media through which traffic warnings can be issued include television and radio news or ads, Internet web sites, radio advisories, and CB radios.

It is difficult to find research on the effect of publicity alone on highway work zone safety. Most publicity is done in coordination with other measures. For instance, during the study performed by Hall and Wrage in New Mexico in 1997, an SMD was used in conjunction with a publicity campaign and intensive speed enforcement (*16*). The combination was very successful, but it was impossible to tell the contribution of each individual part of the treatment. In spite of the lack of research, however, it is generally believed that publicity in the form of television or radio ads or news can help keep drivers alert and cautious in work zones. In the survey of law enforcement that was performed by Schrock et al., 30 percent of the officers who were surveyed mentioned media campaigns when they were asked to name strategies to enhance enforcement of work zones (*7*).

One communication method that has been studied a little more extensively is the CB Wizard Alert System. This is a device that broadcasts a programmable message over CB radio channels. Researchers from the University of Missouri-Columbia published the results of their research on the CB Wizard Alert System in 2001 (*32*). The device was used at a work zone on I-70 (a four-lane freeway) where there was a lane closure. The message, "This is the Missouri Department of Transportation. The right lane of eastbound I-70 is closed ahead. Watch for slow or stopped traffic," was transmitted from a speed trailer set up several feet off the road. The data indicated that the CB message encouraged merging well in advance of the work zone for all classes of vehicles, even though it is assumed that the message was primarily received by truck drivers. Speeds upstream of the work zone increased when the CB message was being transmitted, but speed decreased closer to the work zone when the CB message was being transmitted. Greater speed decreases occurred when rumble strips were used in conjunction with the CB message than when the CB message was broadcast alone. There were no significant changes in speed variance. The device was easy to use and could be installed, operated, and removed without traffic disruption.

Kamyab et al. studied the CB Wizard Alert System in Iowa (*19*). The device was used in conjunction with a striping operation on I-35. The CB Wizard Alert was set up in the last truck involved with the moving operation and the message was broadcast at 30-second intervals to ensure that truckers would receive advance notice of the work ahead. The effectiveness of the device was measured subjectively by monitoring CB radio conversations and through driver interviews at rest areas. The message that was judged to be the most concise and clear was, "This is an Iowa DOT road work alert. Northbound drivers on I-35: you are approaching a slow-moving paint crew in the right lane. Please use caution." Of the 94 surveys that were completed, 59 were filled out by truckers who had their CB radios tuned to channel 19 as they passed the paint crew on the interstate (24 drivers were not tuned to channel 19 and 11 drivers did not pass the paint crew). The driver surveys were overwhelmingly positive. Seventy-five percent of the drivers who passed the paint crew and had their CB on channel 19 heard the warning. For 40 percent of these drivers, the warning was their first indication of the paint crew ahead. Eighty-nine percent felt the warning was effective and 99 percent felt that the message was not annoying or obtrusive. One hundred percent of the driers who heard the warning felt the system should be used in the future.

Eric Meyer reported on the results of several treatments that were examined in Kansas as part of the Midwest Smart Work Zone Deployment Initiative, including the CB Wizard Alert (*20*). The device was positioned at the lane drop at a typical interstate work zone. No change in lane distribution (the number of vehicles traveling in each lane) was detected, however the traffic volume was low and visibility was excellent at this site, so the full possibilities of this device were probably not tested. The Kansas Department of Transportation was still interested in using the device in the future.

Little information can be found on the effect of publicity on speeds and/or lane distributions in work zones. This refers to both local publicity like the SWS or the CB Wizard Alert and broader publicity like radio and television ads. Publicity is an area that deserves more attention in the future.

4.6. Roadway Changes

The final method of improving safety in highway work zones to be discussed in this paper involves making some type of change to the roadway to encourage alertness within the work zone, to change lane distributions approaching a lane closure, and/or to reduce vehicle speeds within the work zone.

4.6.1. Portable rumble strips

Portable rumble strips consist of orange plastic strips that are about 0.125 inch thick and have an adhesive backing. They are placed on the road surface under applied pressure. If a thicker strip is desired, they can be laid one on top of the other. Drivers in vehicles that travel over the rumble strips experience an auditory and vibratory warning. The rumble strips reduce speeds by about 2 mph, but there are some problems with them that may outweigh any benefit from this speed reduction. They can take a relatively long time to install, they must be installed on dry pavement, and they are probably not reusable. An additional problem is that some drivers will drive in oncoming traffic lanes to avoid them.

Difficulties with installing rumble strips were experienced by at least two sets of researchers. In the study by Richards et al. (*9*) previously mentioned in this paper, rumble strips only adhered to the pavement at one of the two sites where they were to be tested. At the site where the rumble strips did adhere to the pavement, they resulted in a 2 mph decrease in speed. Eight strips were laid down with decreasing logarithmic spacing. No information is given on why the strips would not adhere.

Researchers also had difficulty installing rumble strips in a study in Missouri (*32*). The first attempt to install them was after a short rain, when the pavement appeared to be dry. After a heavy rain, the strips had lost adhesion and traffic had removed them from the pavement. A second attempt to install the devices on thoroughly dry pavement was more successful, and the strips stayed on the pavement for 8 days. They required 3.5 hours to install and 2 hours to remove. The rumble strips did not have any effect on lane distribution, but did encourage greater speed limit compliance.

Epps and Ardila-Coulson (*33*), reporting on the economic ramifications of the Strategic Highway Research Program, mention that rumble strips work best when used in conjunction with flagger-controlled work zones under low speed conditions because high-speed traffic has a tendency to remove the strips from their place.

Fontaine and Carlson also examined rumble strips for use with rural short-term maintenance work zones (*23*, *24*). Passenger cars did not decrease their speeds as much as trucks, but the percentage of cars exceeding the speed limit decreased more consistently with passenger cars than with trucks. Although the researchers did not mention any difficulties with installing the strips, they did not feel that the effort to install the strips was worth the 1 to 2 mph speed decrease for a one-day maintenance work zone. There was also a tendency for cars to travel in oncoming traffic lanes in order to avoid the rumble strips, which might be dangerous on higher volume roads.

4.6.2. Lane width reductions

Reducing lane width does encourage vehicles to slow down, but it may also negatively impact safety. Richards and Dudek published two articles in the Transportation Research Record on the subject. In the first study (*9*), the researchers used cones to effectively reduce the lane width. Mean speed was reduced 2 to 8 mph, but larger vehicles hit the cones on numerous occasions. On the freeway, the reduced width had no speed reduction effect, perhaps because the cones were placed only on the outside of the lanes and not down the center lane. The cones still had a negative impact on safety and capacity, however, because large trucks tended to straddle the centerline when driving next to the cones.

The second article (*3*) discussed general costs and benefits associated with the treatments that had been studied for the first article. The cost to implement lane width reductions may not be very high, depending on the type of barriers used and the duration of the work zone. Problems with lane width reductions include the fact that they are associated with increases in speed variance and the observation that it may be difficult to decrease the lane width for multiple lanes of traffic unless there is restriping.

4.6.3. Optical bars

A small amount of research has been conducted on paint patterns that provide the optical illusion that a vehicle is traveling faster, encouraging the driver to slow down. Meyer reported on two studies using this technique. In the first (*34*), he ran computer simulations using several different designs and spacings to determine the best pattern to test on an actual roadway. The pattern that was chosen consisted of a leading pattern where the bars were evenly spaced, a primary pattern where the spacing between the bars gets smaller, and a work zone pattern where sets of bars are intermittently placed within the work zone. The second article (*35*) reported on the results of a field test of this pattern. The patterns were painted on the road and remained there for three months. There were statistically significant reductions in mean speed, in 85th percentile speeds, and in speed variation at a 95 percent confidence level. Meyer suggests that future research should examine how well the technique works under different conditions (variable levels of commuter traffic, rural and urban roads, etc.). This research validates the pattern that was chosen, but more research should be carried out to determine if greater speed reductions are possible under different conditions.

4.7. Summary

A number of devices that have the potential to reduce speed in highway work zones have been examined. The most promising methods include feedback devices (such as SMDs and CMSs with radar) and communication methods (such as CB radio alerts and publicity). Some devices are not recommended because, although they reduce speed, there are other safety hazards associated with them (lane narrowing and rumble strips, for example). Future research is necessary to establish the optimal conditions for each device and to find synergistic relationships among the devices.

CHAPTER 5. FIELD EVALUATION OF SPEED MONITORING DISPLAYS

Of the devices described in Chapter 4, UDOT was most interested in learning more about the SMD and performing a field evaluation of this device. To compare the results with current practice, three treatment conditions were tested: no additional treatment (the standard MUTCD-type signing was employed alone), SMD treatment, and police treatment (police officers took up various positions within the work zone). The remainder of this chapter describes the equipment that was used and the sites where the various treatments were tested and gives analyses of the data that were collected.

5.1. Description of Equipment

UDOT purchased two Speed-Rite™ Radar Trailers from National Signal, Inc. for use during this study. The SMD is orange in color, matching other work zone equipment. The character board display is 22.75 inches wide and 16.5 inches high. A picture of the SMD that was used is shown in Figure 2 (section 4.4).

Data were collected using speed tubes that were laid across the road and connected to TimeMark data collectors. Figure 3 shows a picture of the data collector and Figure 4 illustrates the tubes being nailed to the road. The data were downloaded from the data collectors using TimeMark analysis software. The software was then used to compile information on a per-vehicle basis, giving date, time, axles, speed, and gap spacing for each vehicle during the entire data collection period. Table 1 shows the beginning of a typical output file.

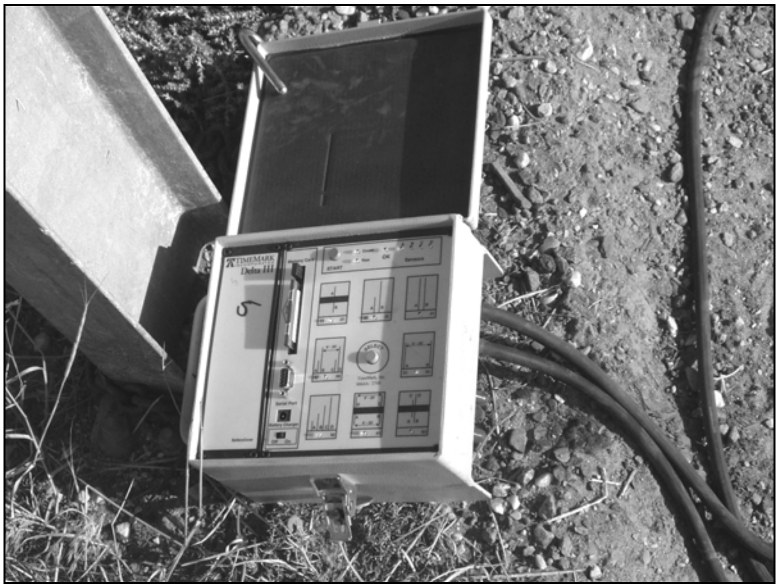


Figure 3. Timemark Data Collector

Figure 4. Placing the Speed Tubes

Table 1. Per-Vehicle Data Output for Timemark Software

Data File:	I-15SB-WK1-TM1.JDF
Site Code:	I15SBWK1TM1
Start Date:	10/8/2002
Start Time:	10:13
Sensor Layout:	52
Sensor Spacing:	200
Title1:	I-15SB-WK1-TM1
Title2:	
Title3:	

Veh#	Direction	Date	Time	Axles	Axle Spacing	Rule#	Class#	Speed	Gap	Spacings(Inches)>			
1		8/10/2002	10:13:54	2	10	2	2	660	0	115			
2		8/10/2002	10:14:02	2	11	3	3	700	6.99	132			
3		8/10/2002	10:14:18	2	9	2	2	573	16.79	103			
4		8/10/2002	10:14:25	2	9	2	2	580	6.9	108			
5		8/10/2002	10:14:59	2	8	2	2	549	33.61	91			
6		8/10/2002	10:15:07	2	4	1	1	554	0	48			
7		8/10/2002	10:15:15	2	8	2	2	580	8.1	101			
8		8/10/2002	10:15:16	2	8	2	2	608	1.44	102			
9		8/10/2002	10:16:13	2	9	2	2	582	56.71	106			
10		8/10/2002	10:16:47	2	9	2	2	495	33.72	104			
11		8/10/2002	10:16:55	5	15,4,29,4	25	9	535	7.61	186	52	353	46
12		8/10/2002	10:16:58	2	9	2	2	488	1.99	105			
13		8/10/2002	10:17:12	5	19,4,29,11	25	9	486	13	233	49	346	130
14		8/10/2002	10:17:30	5	17,4,31,4	25	9	542	16.59	199	51	377	44
15		8/10/2002	10:17:33	2	13	4	5	541	2.42	151			

5.2. Description of Study Sites

The following sections show schematic diagrams for each of the seven study sites and give a brief description of each site, the treatments that were applied at the sites, and the data that were collected at the sites. As described in more detail in the following section on analytical methods, the statistical analysis was performed using the data from only three data collectors at each site: the initial data collector (where the treatment had not yet been applied), the data collector directly following any treatment that was applied, and one of the final data collectors. For each site, the data collectors to be used were chosen based on location and on how well the data collector had operated during the data collection period. A table in each section shows which data collectors were chosen for the analysis at each site.

5.2.1. I-215 East (southbound)

Figure 5 shows a schematic diagram of the work zone for southbound I-215 East. At this study site, traffic control devices guided traffic from three lanes to two lanes (the shoulder and the left-most lane) starting just upstream of the 3300 South interchange. The work zone extended through 5600 South.

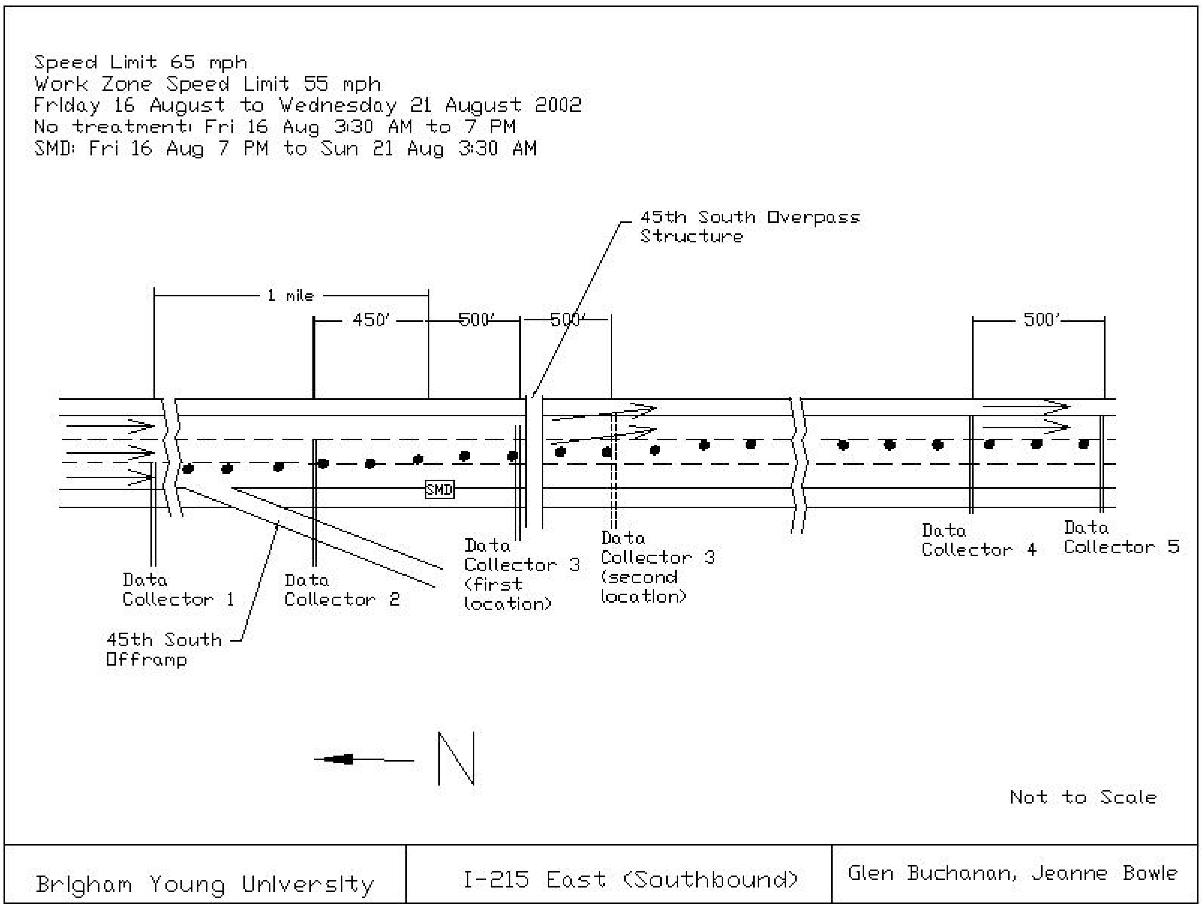


Figure 5. Schematic of Study Site for I-215 East (Southbound)

This was the first data collection site and served as an experiment. A total of five TimeMark data collectors were used, as shown in the figure. The tubes for the data collectors were installed around 3 AM, Friday, 16 August 2002. Initially, the tubes covered two lanes of traffic. Friday afternoon around 7 PM, the SMD was placed about 500 feet north of the 4500 South bridge and about 12 feet (one lane) from traffic. According to the UDOT field supervisor, no police were present during this data collection. Because the data collectors did not distinguish which lane vehicles were in, the tubes were moved so that they covered only the lane closest to the work zone starting the morning of Saturday, 17 August 2002 around 3 AM. At the same time, the third data collector was moved from 500 feet downstream of the SMD to 1000 feet downstream of the SMD (just upstream of the merge point of the 4500 South on-ramp). The figure indicates the final position of the five data collectors. The data collection continued until early morning Wednesday, 21 August 2002 the following week.

Speeds displayed by the SMD were checked with a hand-held radar gun for several vehicles. The speeds shown on the SMD display panel corresponded to the speeds indicated by the hand-held radar gun. The displayed speeds were also checked by driving through the test section. The speed displayed by the SMD was very close to the speed shown on the speedometer of the test vehicle. It should be noted that the speed display seemed small and inconspicuous when traveling at 55 to 65 mph with two open lanes of traffic. The work zone speed limit was 55 mph, but traffic speed seemed to be in the 55 to 65 mph range. Because of the changes that were made during the data collection at this site, the data from this site were excluded from the final analysis of the data.

5.2.2. I-215 East (northbound)

Figure 6 shows a schematic diagram of the work zone for northbound I-215 East. At this study site, traffic control devices guided traffic from four lanes to two lanes. The study site extended from 2200 East to 4500 South.

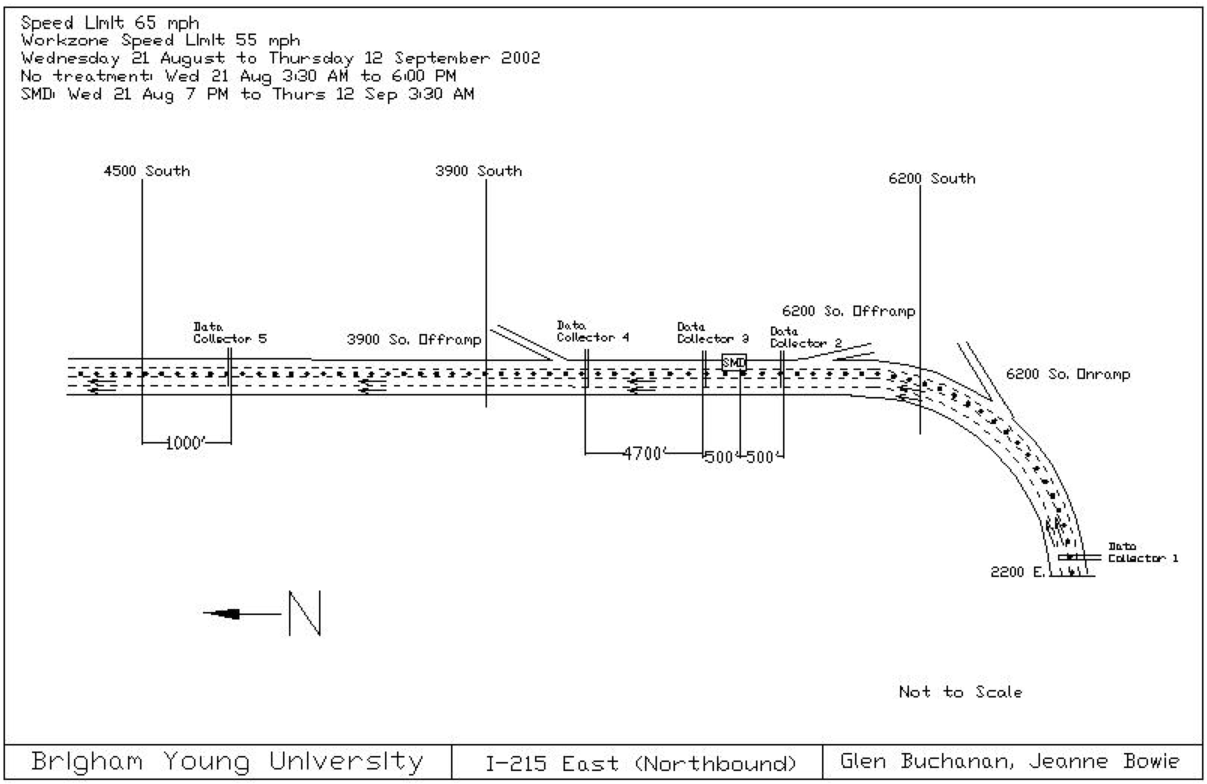


Figure 6. Schematic of Study Site for I-215 East (Northbound)

The first data collection began on Wednesday, 21 August 2002. Five data collectors were used. The tubes were laid down around 3 AM. They covered only the lane closest to the work zone. Data for the condition with no treatment were collected until about 6:25 PM on Wednesday, 21 August 2002. At this time, the SMD was set up in the work zone just north of the bridge structure for the 6200 South interchange near the beginning of the work zone. Data for the condition “with SMD” were collected until 3 AM on Friday, 23 August 2002. The SMD remained at the site until the second data collection, which started at 3 AM on Thursday, 12 September 2002 and ended at 3 AM on Friday, 13 September 2002. The SMD malfunctioned a few times during the period that it was employed, but it did not malfunction during the data collection. (The main problem was a loose connection between the display panel and the CPU of the SMD at the 32-pin connector.)

During the first week of data collection, no data were collected from data collector 4. Also, data collector 2 started malfunctioning around 1 PM on Thursday, 22 August 2002 and stopped working altogether around 10 PM. During the second week, data collector 2 didn’t collect as much data as expected, data collector 4 stopped working around 9 PM on Thursday, 12 September 2002, and data collector 5 malfunctioned during the entire period. (See Figures A-3 through A-6 in Appendix A. These figures are explained in more detail in section 5.3.1.) Data collectors 1, 3, and 5 were used in the statistical analysis for the initial, after-treatment, and final data collectors, respectively.

To eliminate possible effects due to the researcher’s presence, data taken before 3:30 AM on the first day or after 3:30 AM on the last day were excluded from the analysis. In addition, the peak periods (between 8 AM and 9 AM and between 5 PM and 7 PM) were excluded from the analysis.

On Monday, 26 August 2002, Fox TV broadcast from the work zone with the SMD in the background three times during the morning (at 7 AM, 8 AM, and 9 AM).

5.2.3. State Route 89 (SR 89)

Figure 7 shows a schematic diagram of the work zone for SR 89. This work zone was located on an 11-mile stretch of road along SR 89 near Brigham City. This was a chip seal project where the location of the workers changed rapidly. The work began near the I-15 Willard Bay exit and gradually moved north towards Brigham City (the work moved in the opposite direction from the traffic). As the work progressed, the left lane was gradually closed ahead of the workers.

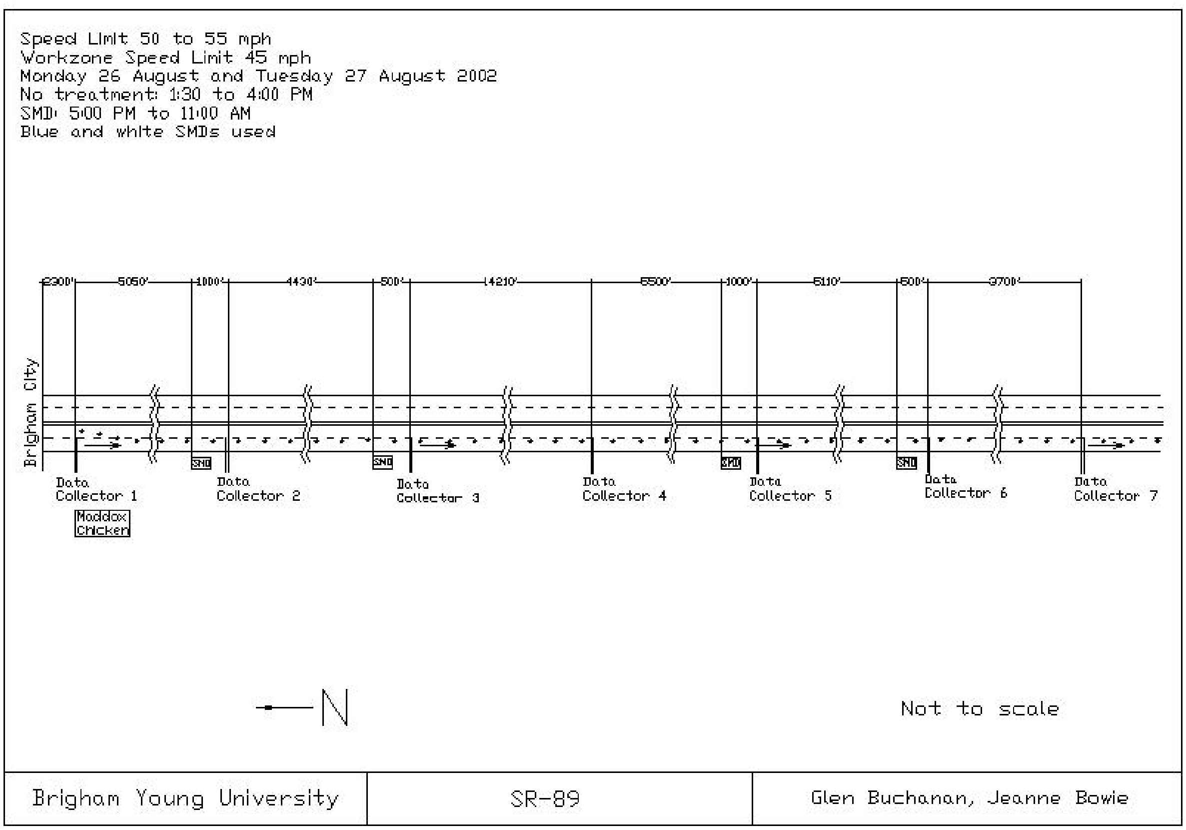


Figure 7. Schematic Diagram of Study Site for State Route 89

Seven data collectors were installed around 7 AM on Monday, 26 August 2002. Around 11 AM, the left lane was closed throughout the entire study site. At 1:30 PM the contractors put up a CMS indicating that the speed limit in the work zone was 45 mph. Four SMDs provided by the contractor were set up and turned on sometime around 4 PM on Monday, 26 August 2002. Data were collected until 11 AM on Tuesday, 27 August 2002.

The SMDs that were used at this site were white and blue, looking more like the ones used by police. They had a larger display than the SMDs used at the other study sites and were easier to set up.

There were a number of issues that made it difficult to analyze the data collected from this site. The main problem was that very little data were collected due to malfunctioning of the data collectors. At data collector 1, no data were collected between 7 PM on Monday, 26 August 2002 and 7 AM on Tuesday, 27 August 2002. Data collectors 2, 4, 5, 6, and 7 malfunctioned such that no data points could be used for the entire study period. Only data collector 3 produced good data for the entire period. (See Figures A-7 and A-8 in Appendix A.) Other problems with the site were that the workers never covered the existing speed limit signs (so that speed limit signs indicated both 50 mph and 55 mph throughout the study area) and that there were numerous access roads, which may have skewed the analysis. Finally, because of the way the chip sealing advanced, barrels were placed in the travel lane, effectively narrowing the lane to about 10 feet wide in most places. The shoulder width varied from 0.5 feet to 6 feet within the work zone. Because of these difficulties, this study site was not included in the statistical analysis.

5.2.4. I-80 East (first location)

There were two study sites located on I-80 East. The first site (shown in Figure 8) was a work zone between the off-ramp to State Street and the off-ramp to 700 East. The work zone began at the traffic merge between eastbound I-80 and the on-ramp to eastbound I-80 from I-15. Two lanes of traffic were coned off, leaving one lane available for traffic. The speed limit was not lowered from the existing 65 mph speed limit because the section had a wide shoulder throughout the work zone. Because the work was

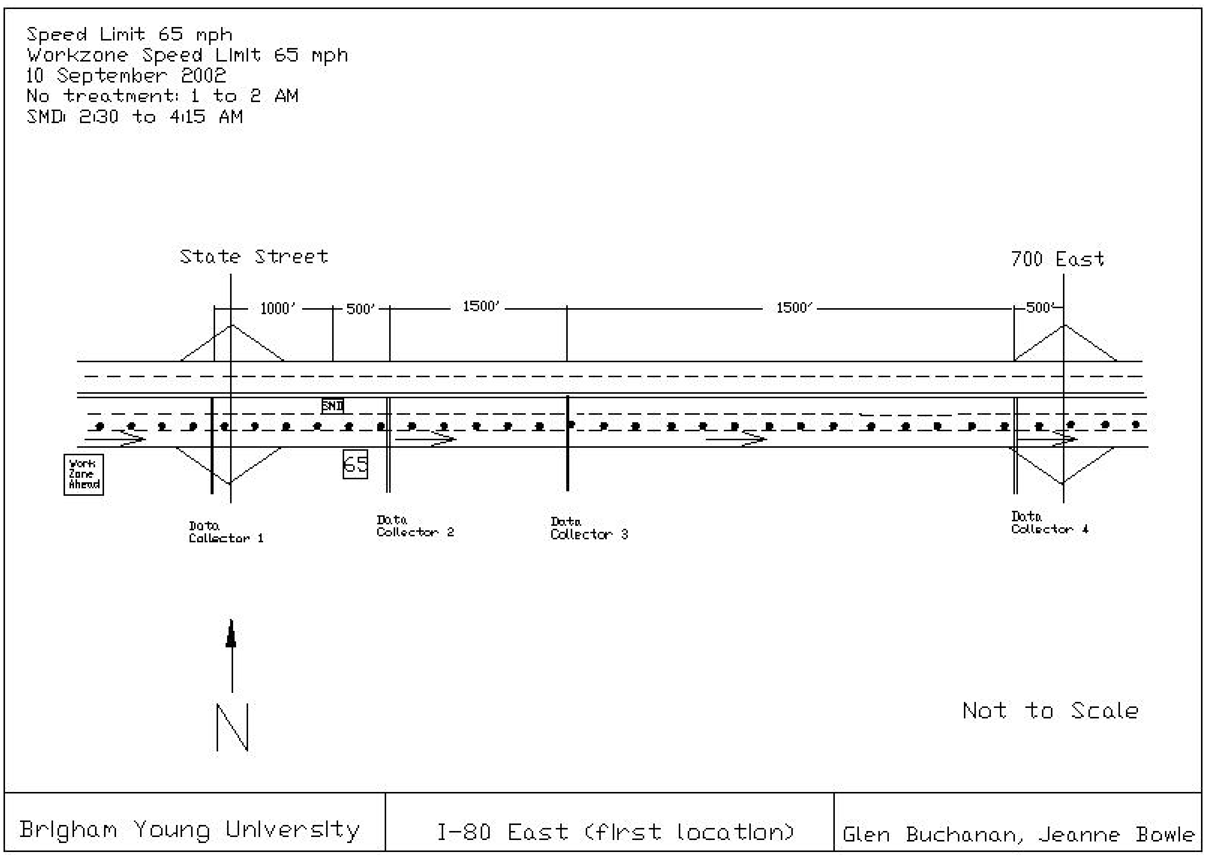


Figure 8. Schematic Diagram of Study Site for I-80 East (First Location)

performed at night, there were not a lot of vehicles observed and interactions among the drivers were minimal. The vertical profile was fairly flat with a mild upslope toward the 700 East off-ramp.

Four data collectors were set up in the work area between midnight and 1 AM on Tuesday, 10 September 2002. Data for the no-treatment condition were collected until 2:30 AM when the SMD was set up near the 65-mph speed limit sign just before the bridge over State Street. Data for the SMD condition were then collected until about 4:15 AM. Because of the nighttime condition, speed values on the SMD could be clearly seen from about 500 feet upstream.

Data collector 2 did not work for the entire study period. Data collectors 1 and 4 collected much less data than data collector 3. This was especially true of data collector 4, which registered only 5 vehicles over the 4.5-hour period of interest. (See Figures A-9 and A-10 in Appendix A.) Nevertheless, the information that was collected by data collector 4 appeared to be valid and was used in the analysis. Data collectors 1, 3, and 4 were used in the statistical analysis for the initial, after-treatment, and final data collectors, respectively. To eliminate possible effects due to the researcher’s presence, data taken before 1 AM or after 4:15 AM were excluded from the analysis.

5.2.5. I-80 East (second location)

Figure 9 shows the schematic diagram for the second data collection on I-80 East, between the off-ramp to 700 East and the off-ramp to 1300 East. At this site, only one lane was closed off, leaving two lanes open to traffic. Because the shoulder on the median side was wide with ample space to maneuver, the speed limit was not lowered in the work zone, remaining at 65 mph. The vertical profile was not ideal for data collection.

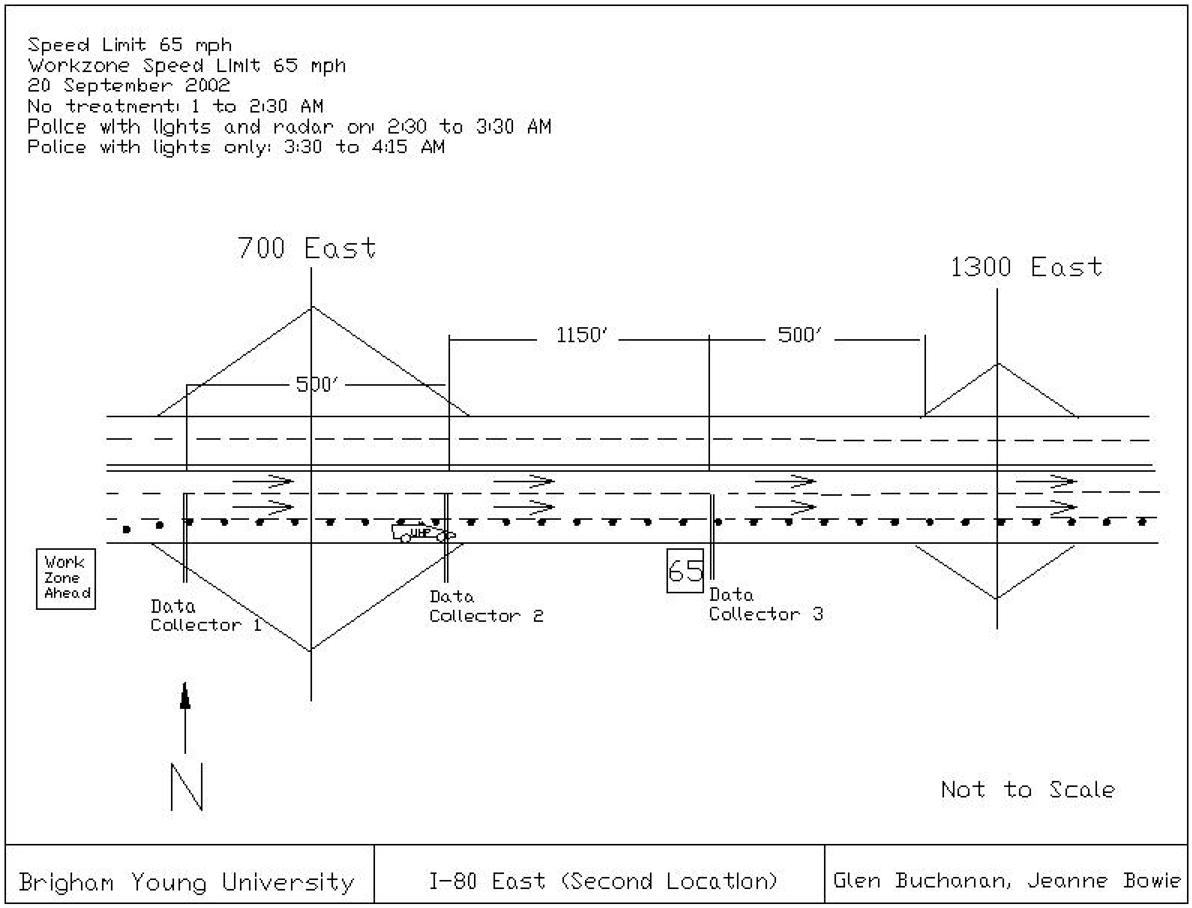


Figure 9. Schematic Diagram of Study Site for I-80 East (Second Location)

There was a crest vertical curve just upstream of the initial speed sensor. Only after passing this crest could drivers see the treatment (the police vehicle). Just downstream of the police vehicle, there was a sag vertical curve and then a mild upslope from the 700 East on-ramp toward 1300 East.

Due to the relatively short length of the work zone, only three data collectors were set up, starting at about midnight on Friday, 20 September 2002. The tubes covered only the lane nearest the work zone. Data for the no-treatment condition were collected from about 1 AM to 2:30 AM. At 2:30 AM, a state trooper stationed his vehicle near the merge from the 700 East on-ramp. Upon arrival, the trooper turned on the radar and the roof lamp. Starting at 3:30 AM the trooper turned off the radar, but kept the roof lamp on.

All three data collectors worked well at this location throughout the study period. (See Figures A-11 and A-12 in Appendix A.) Data collectors 1, 2, and 3 were used in the statistical analysis for the initial, after-treatment, and final data collectors, respectively. To eliminate possible effects due to the researcher's presence, data taken before 1 AM or after 4:15 AM were excluded from the analysis.

5.2.6. I-80 West

Figure 10 shows a schematic drawing of the data collection on I-80 West between the 1300 East off-ramp and the 700 East off-ramp. Only one lane was open to traffic at this site. The vertical profile of the section was undulating. The road sloped downward at the beginning of the study site to a sag vertical curve near the police and SMD. The road then sloped upward to reach a crest vertical curve around data collector 4. Data collector 5 was then located on a downward slope after the crest vertical curve. The activity area was near the crest vertical curve. Once again, because of the wide shoulder the speed limit was not lowered in the work zone from the normal 65 mph.

Five sensors were set up, as shown in Figure 10. The second data collector was located at the end of the taper, with the trooper positioned just downstream of the second sensor. Due to the design of the 1300 East ramps, the third data collector recorded the speeds of the vehicles entering I-80 East from the 1300 East on-ramp.

Data collection began around 1 AM on Tuesday September 24, 2002. At 2:30 AM, the state trooper arrived and turned on his radar and roof lamp. The SMD was turned on at the same time. Starting at 3:30 AM the trooper turned off the radar, but kept the roof

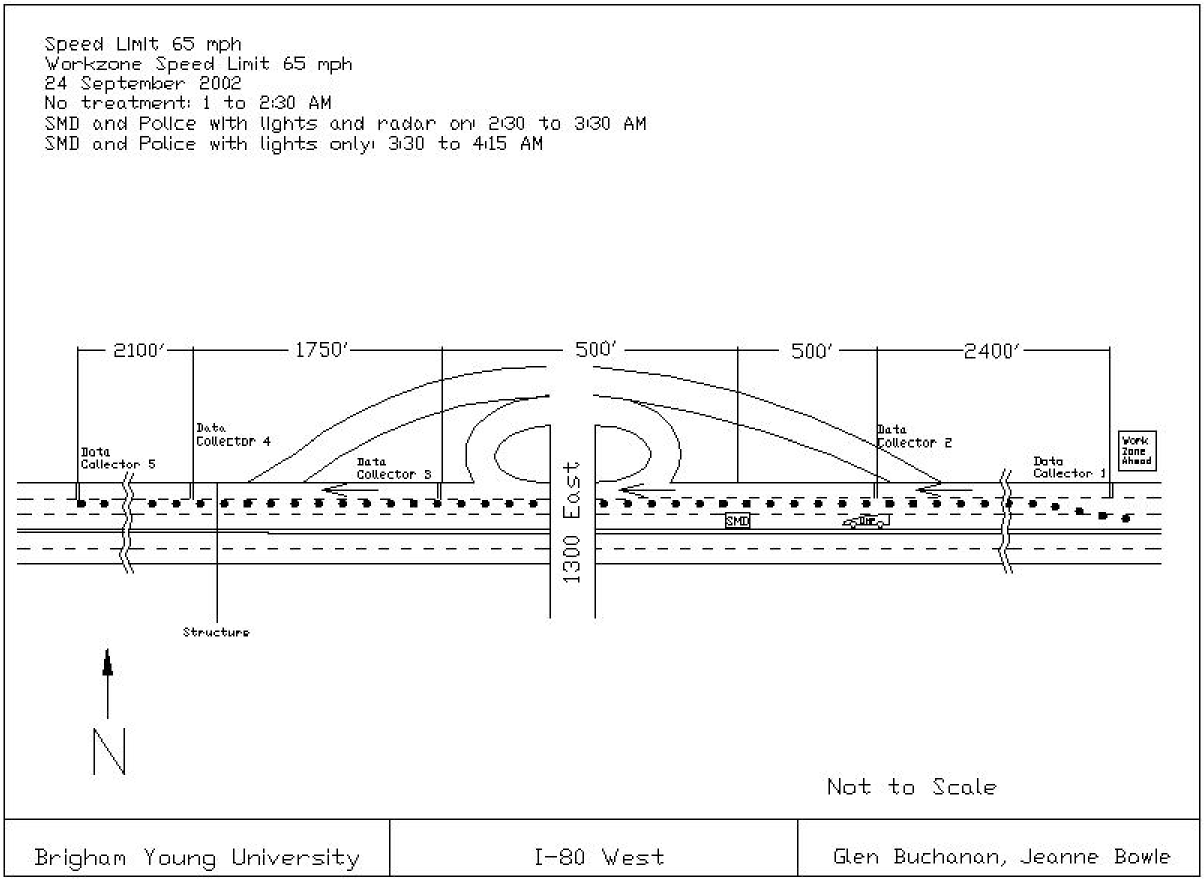


Figure 10. Schematic Drawing of Study Site for I-80 West

lamp on. The SMD remained on the entire time. Data collection ended at about 4:15 AM. It was noted that drivers voluntarily significantly slowed down near the workers because the workers were very close to the open lane.

Data collector 2 did not collect as much information as expected after 2 AM. All other data collectors worked well at this location throughout the study period. (See Figures A-13 and A-14 in Appendix A.) Data collectors 1 and 5 were used in the statistical analysis for the initial and final data collectors, respectively. Data collector 2 was used for the after-police-treatment data and data collector 3 was used for the after-

SMD-treatment data. To eliminate possible effects due to the researcher's presence, data taken before 1 AM or after 4:15 AM were excluded from the analysis.

5.2.7. I-15 South of Nephi

Figure 11 shows the schematic diagram for this site. This was an ideal work zone for the project for three reasons: vehicles were forced to travel in one lane for a long distance with no on- or off-ramps, data could be collected over several weeks and with several different conditions, and drivers were primarily non-commuters. Data were

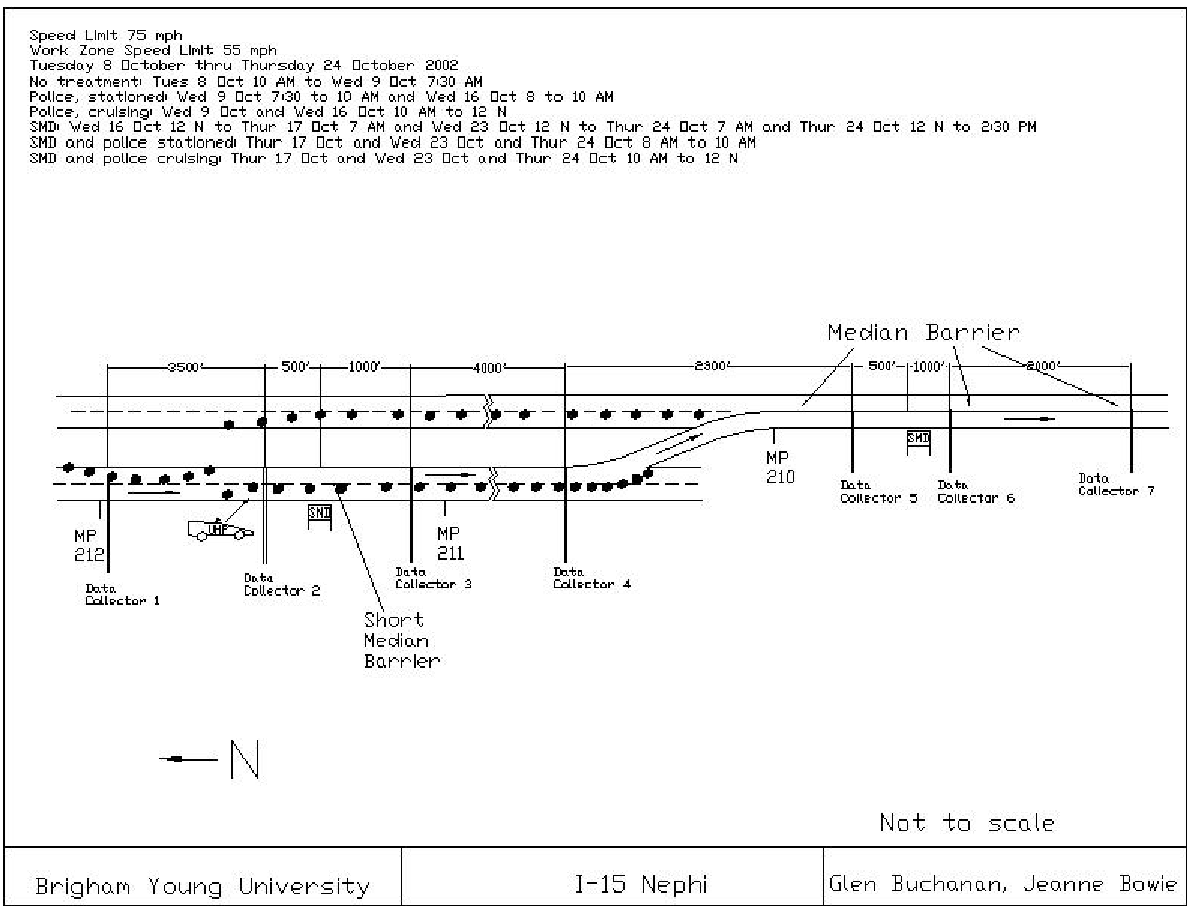


Figure 11. Schematic Drawing of Study Site for Southbound I-15 South of Nephi

collected in the southbound direction between milepost 212 and milepost 209 over a 3-week period. The normal speed limit in the study area is 75 mph, but it was decreased to 55 mph in the work zone. The change occurred entirely upstream of the study site in 10 mph steps (so that it was changed from 75 mph to 65 mph and then to 55 mph).

Seven data collectors were used at this site. The fourth data collector was placed only about 500 feet upstream of the crossover, so traffic was probably influenced by the crossover at this point. Additionally, there were two distinct sections of traffic conditions. At data collectors 1 through 4, barrels defined the traffic path. At data collectors 4 through 7, the traffic path was defined by median barriers and the traffic was head-to-head (the roadway operated as a two-lane, two-way road). Data collector 7 was located about 1400 feet upstream of the crossover that brought the southbound traffic back to its own lanes, so that the crossover did not influence traffic at this data collector.

The data collectors were initially set up at 10 AM on Tuesday, 8 October 2002. Data for the no-treatment condition were taken until 7:30 AM on Wednesday, 9 October 2002. A police vehicle was stationed near the second data collector with radar on starting at 7:30 AM on Wednesday, 9 October 2002. At 10 AM, the police vehicle began cruising the work site. The vehicle continued cruising until noon, at which point the officer left and data collection stopped. A police officer also came on Thursday, 10 October 2002 and repeated the same pattern of stationing and then cruising from 8 AM until noon, although no data were collected at this time. Thus, data were collected during that week for the no-treatment condition and for the condition with police stationed and police cruising.

Data collectors 3 and 7 did not operate very well during that week, although some data were collected for both of these. Data collectors 2, 3, 5, 6, and 7 had periods of missing data that started between 1 PM and 9 PM on Tuesday, 8 October 2002 and continued until around 7 AM on Wednesday, 9 October 2002. (See Figures A-15 and A-16 in Appendix A.)

The following week, the police officer came on Monday, 14 October 2002 through Friday, 18 October 2002 from 8 AM to noon each day, with the same pattern of stationing and cruising. Data collection this week began at 8 AM on Wednesday, 16 October 2002 and continued until noon on Thursday, 17 October 2002. Two SMDs were set up as shown in Figure 11 starting at noon on Wednesday, 16 October 2002. Thus, data were collected that week for the treatments with police stationed, police cruising, SMD alone, and SMD with police stationed and cruising.

The second week, data collectors 1 and 6 did not operate well throughout the entire period, but data collector 1 did collect some data for each hour of the study period. In addition, data collectors 2 and 6 had periods of missing data. For data collector 2, the period of missing data started at 4 PM on Wednesday October 16, 2002 and continued until 8 AM on Thursday October 17, 2002. For data collector 6, the missing periods occurred before 10 AM on Wednesday and between 8 PM on Wednesday and 8 AM on Thursday. (See Figures A-17 and A-18 in Appendix A.)

The third week, the police followed the same pattern, coming each day between 8 AM and noon from Monday, 21 October 2002 through Thursday, 24 October 2002. The SMDs remained on the entire time. Data were collected from 8 AM on Wednesday, 23 October 2002 through 2:30 PM on Thursday, 24 October 2002. Thus, data were collected this week for the treatments for the SMD alone and for the SMD with police stationed and cruising.

This final week, all of the data collectors worked well throughout the entire period except for data collector 4, which did not collect any data for the last four hours (starting at 11 AM on Thursday, 24 October 2002). (See Figures A-19 and A-20 in Appendix A.) Data collectors 1 and 4 were used in the statistical analysis for the initial and final data collectors, respectively. Data collector 2 was used for the after-police-treatment data and data collector 3 was used for the after-SMD-treatment data.

5.3. Analysis of Data

There were two basic stages of analysis for this project. Initially, there was a visual inspection of the data and a determination of missing data. The statistical analysis was then performed in conjunction with the Center for Collaborative Research and Statistical Consulting at Brigham Young University (BYU).

5.3.1. Visual inspection

The visual inspection of the data consisted of two parts: histograms showing the number of vehicles an hour collected by each data collector and graphs showing the average speed of vehicles for each hour of data collection. These graphs are shown in Appendix A. These graphs were used to determine the data collectors to use for the statistical analysis.

A typical histogram and average speed graph for a data collector that worked well throughout the entire data collection period are shown in Figure 12 and Figure 13, respectively. These graphs clearly show the peak periods of traffic flow, the volume of

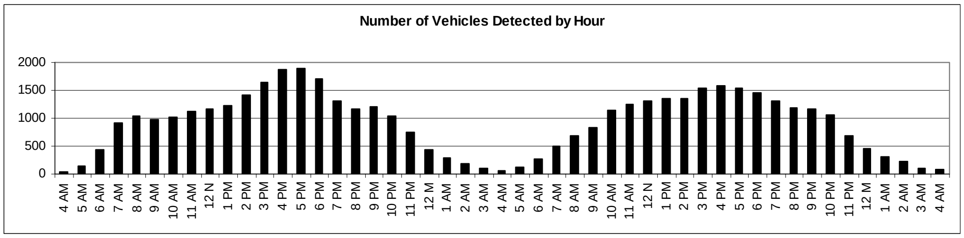


Figure 12. Example Histogram for Working Data Collector

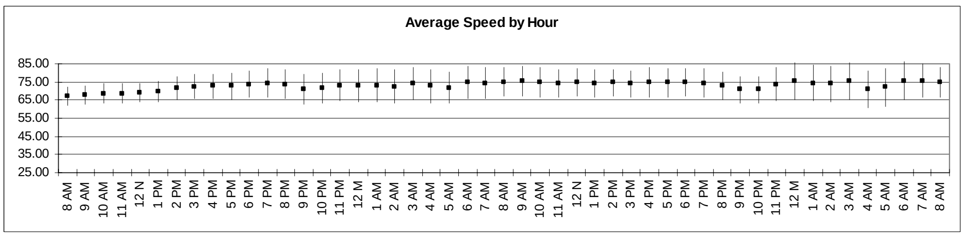


Figure 13. Example of Average Speed Graph for Working Data Collector

traffic for each hour, and any changes in speed from one hour to another over a two-day period. Additionally, the lines extending above and below each data point in the average speed graph give an indication of the standard deviation for that hour.

For comparison, Figure 14 and Figure 15 show a histogram and average speed graph, respectively, for a data collector at the same site that was not working well. Note the difference in scale between Figure 12 and Figure 14. One can clearly see the lack of good information from this data collector.

5.3.2. Statistical analysis methodology

The next step was to discuss the project with personnel at the Center for Collaborative Research and Statistical Consulting at BYU. An initial consultation determined the analysis to be performed (Analysis of Variance) and the response and

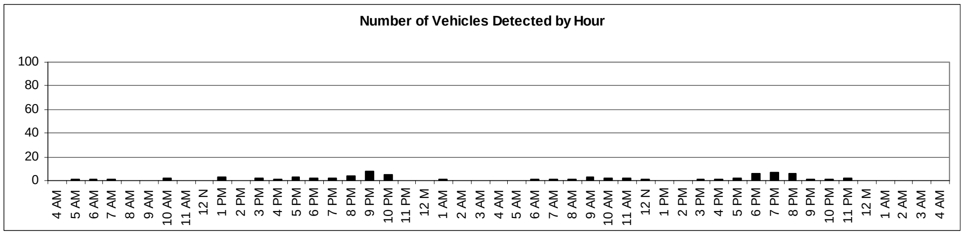


Figure 14. Example of Histogram for Non-Working Data Collector

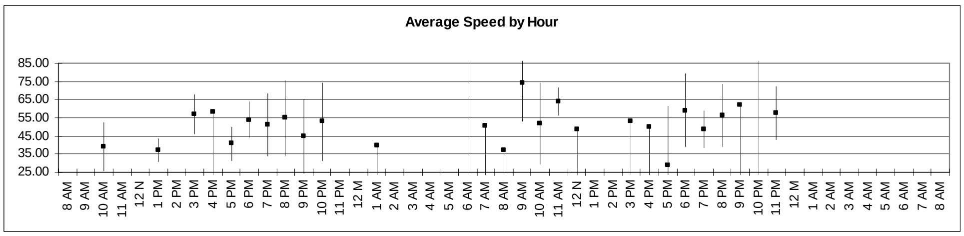


Figure 15. Example of Average Speed Graph for Non-Working Data Collector

explanatory variables to be included in the analysis. The data were then formatted as necessary for the analysis and a graduate student in the Department of Statistics at BYU performed the analysis using SAS statistical software. Several iterations of analyses were performed before the exact research questions could be answered. The final SAS code and output pages are found in Appendix C. Interpretation of the analysis was completed in collaboration with the consulting center staff.

The SAS command “proc glm” (general linear model) was used for the final analysis. This procedure tests the equivalence of the response under different conditions as defined by a particular set of explanatory variables. These explanatory variables include those that answer a research question as well as variables that are known to have an effect on the response, but are not of interest to the researcher (also known as covariates). In SAS, the “lsmean” option provides a printout of the mean response for each value of each of the explanatory variables so that hypotheses can be tested.

In order for this procedure to be valid, the explanatory variables must be independent. That is, the value of one explanatory variable must not depend upon the value of another explanatory variable. It is also assumed that the response is a normally distributed continuous variable. However, some deviations from normality can be tolerated, and the variable can be measured discretely as long as it approximates a continuous function. These conditions were met by the data used in this analysis.

Upon visual inspection of the standard deviations for each data point, the consulting center staff concluded that there were not significant differences between the standard deviations across sites or treatments, indicating that speed distributions were not affected by the treatments. Standard deviation was therefore not considered in the analyses.

The following null hypotheses were tested at a 95 percent confidence level (also known as alpha level 0.05):

1. Average vehicle speed at all measurement locations is unaffected by any treatment (SMD or police).
2. If there is a change in average vehicle speed at all measurement locations with treatment, the change is the same for the SMD treatment and the police treatment.
3. Average vehicle speed at each measurement location is unaffected by any treatment (SMD or police).

4. If there is a change in average vehicle speed with treatment at each measurement location, the change is the same for the SMD treatment and the police treatment.

P-values were used to determine statistical significance. A p-value below 0.05 indicated that the responses under different conditions were statistically different and p-values above 0.05 indicated that the responses under different conditions were statistically the same at a 95 percent confidence level. If the p-value was near 0.05, it was considered a borderline case where a subsequent study with a larger sample size might provide a better determination of significance or non-significance.

The “proc glm” procedure was used for three different analyses: all of the sites at one time, the I-80 West site alone, and the I-15 south of Nephi site alone. (Two sites were excluded from the analysis of all of the sites, I-215 East southbound and SR 89. See sections 5.2.1 and 5.2.3 for an explanation.) Analyzing all of the sites at one time allowed the analysis to be enhanced by looking at data over several sites at once, but limited the number of data collectors that could be used in the analysis. Analyzing the I-80 West and I-15 south of Nephi sites alone limited the analysis to only one site at a time, but allowed information from all of the data collectors to be used at that site. The formatted data that were provided to the consulting center are shown in Tables B-1 through B-3 in Appendix B.

5.3.2.1. Response variables

The average speed of vehicles for each condition, weighted by the number of samples, was used to calculate the values of the response variables for the analyses. Three different response variables were analyzed:

- the average speed at each data collector divided by the work zone speed limit,
- the average speed at each data collector minus the work zone speed limit, and
- the average speed at each data collector divided by the average speed at the initial data collector (where the treatment could not yet be seen in every case).

The first two response variables give a measure of adherence to the work zone speed limit. The results of the analysis did not differ between these two variables, so speed divided by the work zone speed limit was used in the final analysis. The work zone speed limit rather than the normal speed limit was used because all of the data collectors fell within the work zone speed limit area.

The third response variable adjusts for a condition that could not be controlled in this experiment (the speed of vehicles entering the study area). Variables that cannot be controlled by the experiment are called covariates. Adjusting the response variable (average speed at each data collector) with the covariate (average speed at the initial data collector) is called covariate analysis. Covariate analysis can improve precision because it removes systematic variation associated with the covariate from the analysis. See Table 2 for a description of the response variables.

Table 2. Response Variables

Variable	Values	Explanation
Response	spdsl	Average speed divided by the work zone speed limit
	cov	Covariate analysis – Average speed at each data collector divided by the average speed at the initial data collector

5.3.2.2. Explanatory variables

Four categorical explanatory variables were chosen based on the available data and the parameters of interest: site, type of vehicle, treatment, and measurement position. In addition, a continuous variable, “initial” was used in the covariate analysis. These explanatory variables are explained below.

5.3.2.2.1. Site

The “site” variable had six values, one for each site that was analyzed, as shown in Table 3. A description of each study site can be found in section 5.2. I-215 East southbound was not included in this analysis because it was the first study site and as a result the data tubes had been set up differently at this site compared to all of the other sites. State Route 89 was not included in the analysis because of a lack of data.

Table 3. Values for "Site" Variable

Variable	Values	Explanation
Site	I-215 East NB	None necessary
	I-80 EB1	(first location)
	I-80 EB2	(second location)
	I-80 WB	None necessary
	Nephi	I-15 south of Nephi

5.3.2.2.2. Type of vehicle

The "car" variable was used to distinguish between cars and trucks (see Table 4).

Table 4. Values for "Car" Variable

Variable	Values	Explanation
Car	1	Vehicles with 2 axles
	0	Vehicles with more than 2 axles

5.3.2.2.3. Treatment

The "treatment" variable was used to show the effect of the different treatments. No distinction was made between whether or not police were using radar because preliminary analysis showed the radar did not have any effect on speed. There was also no distinction made between whether or not the police flashing lights were turned on because there was not enough data to make a good analysis if that distinction was made. For the analysis of all of the sites at once and for the I-80 West site, this variable simply distinguished between the absence of any treatment, police presence, and SMD presence (see Table 5). For the analysis of the I-15 south of Nephi site, this variable distinguished between the absence of treatment, stationary police, cruising police, and the SMD (see Table 6).

Table 5. Values for "Treatment" Variable (All Sites, I-80 WB)

Variable	Values	Explanation
Treatment	Nothing	Neither SMD nor Police
	Police	Police present
	SMD	SMD present

Table 6. Values for "Treatment" Variable (I-15 South of Nephi)

Variable	Values	Explanation
Treatment	Nothing	Neither SMD nor Police
	P_crusi	Police cruising the work zone
	P_stati	Police stationed in the work zone
	SMD	SMD present

5.3.2.2.4. Measurement position

The “measurement” variable was used to show the position of the data collector in the work zone (see Table 7). For the analysis of all of the sites at one time, three positions from each study site were chosen. For the individual analysis of I-15 south of Nephi and of I-80 West, all of the data collectors that were available were used.

The three data collectors from each site used in the analysis of all of the sites were labeled n1, n2, and n3. The initial position was in all cases the initial data collector where the work zone speed limit was in effect, but no treatment was yet visible. The second position was initially chosen as the data collector downstream of both the police and the SMD. Because of the manner in which the treatments were placed, however, this meant that the chosen data collector was further downstream of the police than it was of the SMD. Running the statistical analysis in this way, it appeared that the police had no significant effect on speed. Because many studies have shown that police do have an effect on traffic speeds, the analysis was redone. This time, speed measurements for the “with police” case were taken from the data collector near the stationary police officer and included measurements for all of the periods when police were present at the work zone, regardless of whether or not the SMD was active. Measurements for the “with SMD” case were taken from the data collector just downstream of the SMD and included measurements for all of the periods that the SMD was active, regardless of whether or not police were present. Measurements for the case with no SMD and no police were taken from the location closest to the police. The third position was generally the last data collector. For the exact locations of the data collectors that were chosen for the analysis at each site, see section 5.2.

Table 7. Values for "Measurement" Variable

Variable	Values	Explanation
Measurement	n1	Initial data collector, no treatment visible
	n2	Data collector at or directly downstream of treatment
	n3	Final data collector

5.3.2.2.5. Initial speed

The "initial" variable was used in the covariate analysis to adjust for differences in the initial speed at different times (see Table 8).

Table 8. Values for "Initial" Variable

Variable	Values	Explanation
Initial	continuous	Average speed at the initial data collector

5.3.3. SAS analysis

The SAS code used for the analysis and the SAS output file can be found in Appendix C. Six separate analyses were performed: all of the sites at once for the response spdsl (speed divided by the speed limit), all of the sites at once for the response cov (covariate analysis), I-15 south of Nephi for both of these responses, and I-80 West for both of these responses. These two particular sites were chosen for individual analyses to make sure the effect of police on speed would be apparent. Also, the data collectors worked more consistently at these sites than at other sites, and analyzing these sites individually would allow information to be used from all of the data collectors. It should be noted that the SMD and the police were at the I-80 West site simultaneously, so this site does not compare the two treatments, it compares using both of the treatments at once to a situation with no treatment.

For each analysis, the full general linear model included all of the variables described above as well as interaction terms. Interaction terms are used when the effect of one explanatory variable on the response depends upon the value of another explanatory variable. An interaction term is signified by placing a "*" between the names of the two variables. Thus, the full model included the terms: site, car, site*car, treatment, site*treatment, car*treatment, measurement, site*measurement, car*measurement, and treatment*measurement. The SAS code was run on the full model, and the output was checked to determine if any of the explanatory variables included in the analysis were not significant at a 95 percent confidence level. If there were insignificant variables, the least significant variable was removed from the model and the SAS code was run again. These steps were repeated until all of the explanatory variables remaining in the model were significant. Significance was determined from the p-value shown in the output for each variable. If the p-value was less than 0.05, the alpha level associated with the chosen confidence level of 95 percent, the variable was important to the model. If the p-value was greater than 0.05, the variable did not significantly affect the response and was therefore not important to the model. The statistical program also provides an R-squared value, which measures how well the model fits the supplied data. The values for R-squared can range from zero, which would indicate that the data did not fit the model, to one, which would indicate an exact fit. The reduced models, the p-values associated with the chosen variables, and the R-squared values for each reduced model are shown in Table 9. (See also Tables C.1, C.4, C.7, C.10, C.13, and C.16 in Appendix C.) The SAS code in Appendix C shows the p-values for each explanatory variable that was initially considered for the model, but did not appear in the final model.

5.3.4. Results

The BYU Center for Collaborative Research and Statistical Consulting suggested that only one set of results should be reported, either the results from the covariate analysis or the results of the speed divided by the speed limit analysis, but not both. Because the analyses for both responses gave approximately the same results and the desired outcome is more a reduction in speed rather than adherence to the speed limit, the covariate analysis was chosen for this report. Nevertheless, the results for both responses are provided in Appendix C.

The explanatory variable of interest is “Treatment.” Fortunately, this variable remained in the final model in each case. This term compares the values of the response variables in the no-treatment case to the values of the response variables in the case

Table 9. Models Used for Analysis

Sites	Response	Explanatory Variables	p-value	R-square
All sites	Speed divided by speed limit	Site	< 0.0001	0.92
		Car	0.0062	
		Treatment	< 0.0001	
		Measurement	< 0.0001	
		Site*Measurement	< 0.0001	
		Treatment*Measurement	0.0090	
	Covariate	Initial	0.0130	0.78
		Site	0.0016	
		Treatment	0.0020	
		Measurement	0.0398	
		Site*Measurement	< 0.0001	
		Treatment*Measurement	0.0070	
I-15 Nephi	Speed divided by speed limit	Car	< 0.0001	0.998
		Treatment	< 0.0001	
		Car*Treatment	0.0223	
		Measurement	< 0.0001	
		Car*Measurement	0.0048	
		Treatment*Measurement	< 0.0001	
	Covariate	Initial	< 0.0001	0.997
		Car	0.0226	
		Treatment	< 0.0001	
		Measurement	< 0.0001	
		Car*Measurement	0.0167	
		Treatment*Measurement	< 0.0001	
I-80 West	Speed divided by speed limit	Car	< 0.0001	0.99
		Treatment	< 0.0001	
		Measurement	< 0.0001	
		Treatment*Measurement	< 0.0001	
	Covariate	Initial	0.0008	0.99
		Car	< 0.0001	
		Treatment	0.0026	
		Measurement	< 0.0001	
		Treatment*Measurement	0.0007	

where the treatments were applied, thus testing hypotheses 1 and 2 (section 5.3.2). The interaction term "Treatment*Measurement" was also in the final model for each case. This term shows how the effect of the treatments varied with the measurement position, thus testing hypotheses 3 and 4 (section 5.3.2). For each of the analyses described in the next three sections, the results for the "Treatment" term are presented first, followed by the results for the interaction term "Treatment*Measurement."

5.3.4.1. All sites

5.3.4.1.1. Effect of treatment without regard to measurement position

The average speed within the work zone with no treatment applied was 4 percent less than the average speed at the initial data collector near the beginning of the work zone (statistically significant, p-value < 0.0001). This is to be expected as previous research has shown that vehicles do slow down somewhat in work zones with the regular MUTCD sign and barrier treatments, especially in the activity area (*5*, *36*). When the SMD was present, the speed decreased an additional 6 percent for a total reduction of 10 percent (statistically significant, p-value 0.0003). With police present, the speed decreased an additional 10 percent over the no-treatment condition for a total reduction of 14 percent (statistically significant, p-value < 0.0001). Because the p-value is very close to the chosen alpha level of 0.05, it is unclear from this analysis whether or not the effects of the police and SMD were statistically different (p-value 0.0400). Repeating the analysis with more data would clarify this issue. See Table C-5 in Appendix C for the SAS results.

5.3.4.1.2. Effect of treatment depending on measurement position

It is also interesting to see how the speed varied according to position within the work zone (see Figure 16). The speed decreased at the treatment location for both treatment cases (statistically significant, SMD p-value 0.0014, police p-value < 0.0001). The SMD did not have as large an effect as police presence at the treatment location (statistically significant, p-value 0.0007); however, the effect of the SMD did continue throughout the work zone (p-value for hypothesis that SMD value at the treatment and final locations was the same is 0.8620). Because of a large variance, it cannot be determined from this analysis whether or not the police effect continued at the final data collector. See Table C-6 for the SAS results. Note that the average speed at the initial data collector for all of the sites together was a little lower than the speed limit.

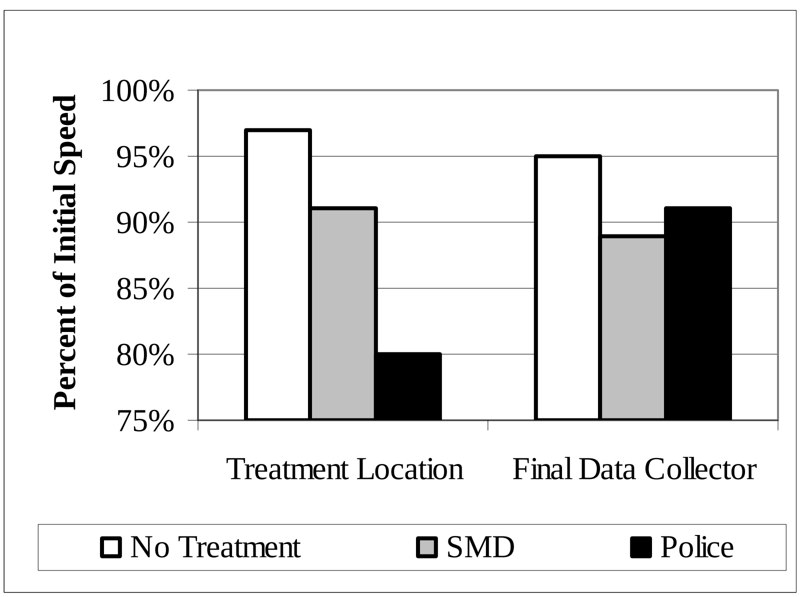


Figure 16. Speed Change with Location in Work Zone

5.3.4.2. I-15 South of Nephi

5.3.4.2.1. Effect of treatment without regard to measurement position

The highest quality data were collected at the site on I-15 south of Nephi, both because the data collectors worked very well overall and because there were no entrance or exit ramps on the freeway in the work zone. Thus, there was a uniform traffic flow at each data collection point and throughout the study area. The average speed within the work zone with no treatment was 6 percent less than the average speed before the work zone (statistically significant, p-value < 0.0001). The SMD resulted in an additional speed decrease of 4 percent for a total reduction of 10 percent (statistically significant, p-value < 0.0001). The police treatment resulted in a 5 percent additional speed decrease regardless of whether the police were cruising or stationary for a total reduction of 11 percent (statistically significant, p-value < 0.0001). The effects of the SMD and the police were statistically different (statistically significant, p-value for cruising police compared to SMD is 0.0033 and for stationary police compared to SMD is 0.0009), indicating that the SMD did not reduce the speed as much as police did. (Note that the observed average speed at the initial data collector was 63 mph and the work zone speed limit at this location was 55 mph.) See Table C-17 in Appendix C for the SAS results.

5.3.4.2.2. Effect of treatment depending on measurement position

Because there were seven data collection locations for this site, the analysis of speed variation with position and treatment is easier to describe in conjunction with a picture (see Figure 17). The reasons for specific changes can’t be determined, but there are some particular attributes of this speed profile that should be noted. At data

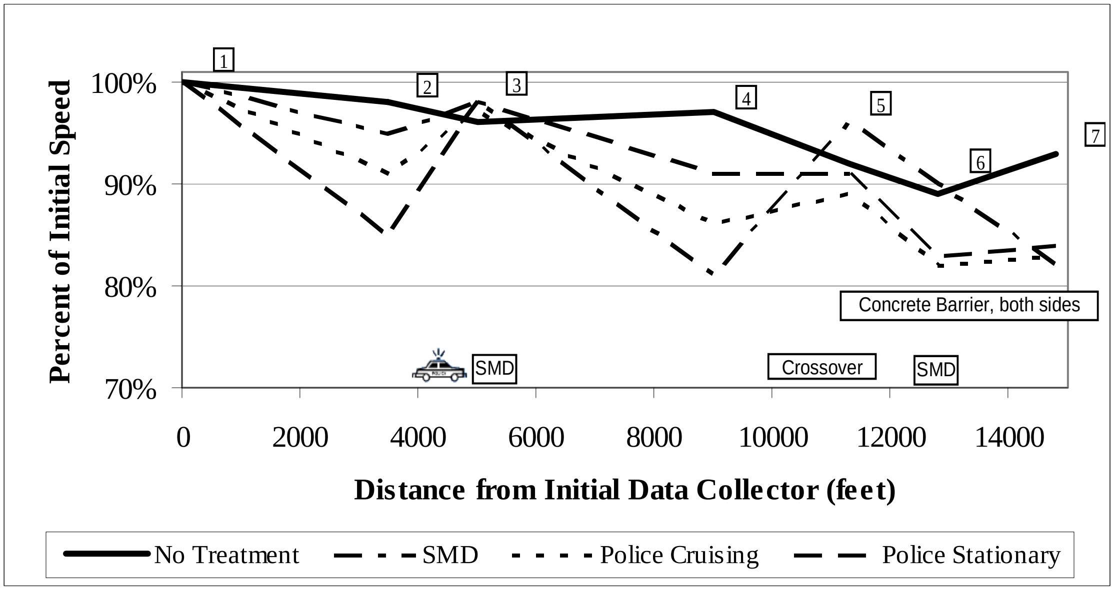


Figure 17. Speed Profile at I-15 South of Nephi Work Zone

collector 2, where the police officer was stationed, all of the treatments are statistically different (p-values less than 0.0010). The speed reduction at this location due to the stationary police officer is substantial (13 percent). At data collector 3, just downstream of the SMD, the speed reductions for each treatment are equivalent to the no-treatment case (p-values greater than 0.42). At data collector 4, just before the crossover, the SMD treatment is responsible for the largest speed reduction seen at this site.

At data collector 5, however, the situation is reversed, with the SMD treatment showing an increase in speed over the base case. After the vehicles pass the second SMD, the speed reduces for the SMD case until it meets the speed reduction for the police treatments at data collector 7. In the meantime, the police cruising treatment has been more efficacious at reducing speed than the stationary police treatment at data collectors 4 and 5 (p-values 0.0009 and 0.0339, respectively) and the two are statistically the same for data collectors 6 and 7 (p-values greater than 0.42). See Table C-18 in Appendix C for the SAS results.

At this site, the SMD definitely reduced speeds, especially at key points such as near the crossover. However, the speed reduction was not very predictable throughout the study area. Interestingly, in opposition to the research cited in the literature review that stationary police are more effective at reducing average speed, this study found that the two techniques were comparable overall and that the cruising police vehicle resulted in more consistent reductions throughout the work zone. Perhaps the geometry of this site (one lane of traffic with no place to enter or exit) contributed to this result.

5.3.4.3. I-80 West

5.3.4.3.1. Effect of treatment without regard to measurement position

It turns out that not much can be inferred from the information taken at the I-80 West site alone because the police and SMD were used simultaneously. The average speed within the work zone with no treatment was 7 percent less than the average speed before the work zone (statistically significant, p-value < 0.0001). The police and SMD combination resulted in a statistically significant additional speed decrease of 15 percent (p-value 0.0003).

1.1.1.1.1. Effect of treatment depending on measurement position

Of more interest is how speed varied through the work zone for this case. The speed profile for this site is shown in Figure 18. The greatest speed decrease occurred at the location where the police officer was stationed at data collector 2. The profile looks very similar to the profile for the stationary police officer at the I-15 site where the speed

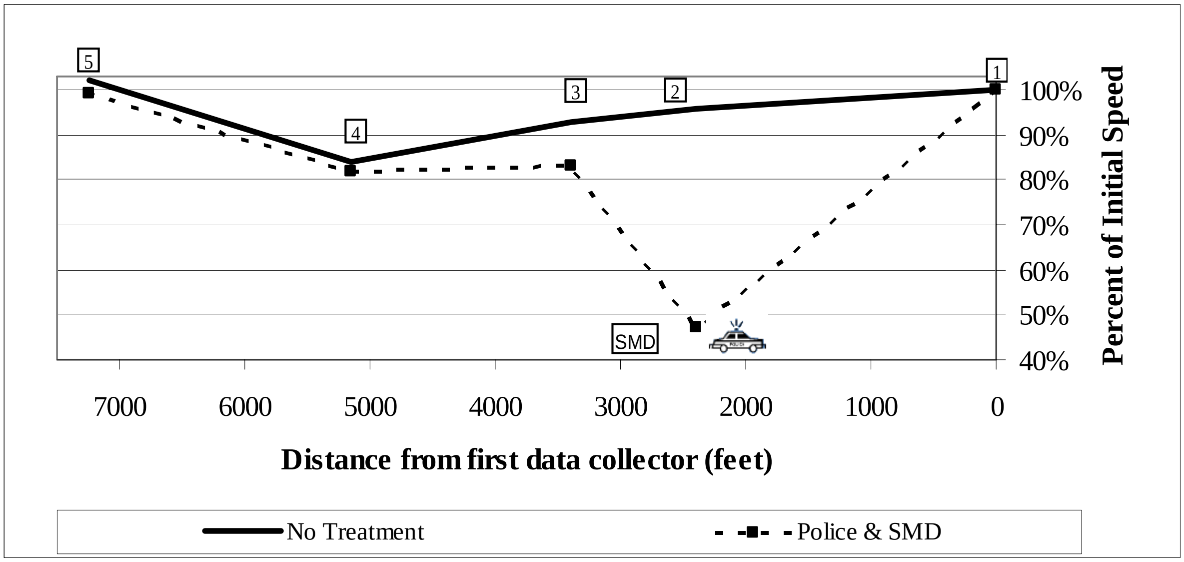


Figure 18. Speed Profile Through I-80 West Work Zone

drops dramatically in the vicinity of the officer and then increases rapidly immediately afterward. The SMD was located between data collectors 2 and 3. Without anything to compare it to, it is impossible to tell whether or not the SMD encouraged drivers to drive more slowly for a greater distance in the work zone than is normally seen with police alone. At data collectors 4 and 5, the speeds were statistically the same for the no-treatment case and the case with police and SMD (p-values greater than 0.09). (Note that the observed average speed at the initial data collector was 65 mph and the work zone speed limit at this location was 65 mph.) See Tables C-11 and C-12 in Appendix C for the SAS results.

5.3.4.4. Caveat

It is important to note that as with most traffic studies these sites were not chosen randomly nor were the treatments applied randomly. Thus, inferences about other work zone sites cannot be made. Additionally, it cannot be definitively stated that the treatments applied were the cause of changes in vehicle speeds that were observed.

5.3.4.5. Effect of SMD over time

The question of whether or not the SMD remains effective over time was not one of the main questions addressed by this research, but it is of interest to those who want to use SMDs at highway work zones that will last several weeks. Since the SMD was used longer than one week at the sites on I-215 East northbound and I-15 South, general trends over time at these sites are presented here.

For the site on I-215 East northbound, data collector 3 was the data collection site located near (500 feet downstream from) the SMD. Figure 19 shows the percentage of baseline speed at data collector 3 for several hours during the first and third weeks of the study. (Baseline speed is the average speed at the initial data collector.) The figure shows

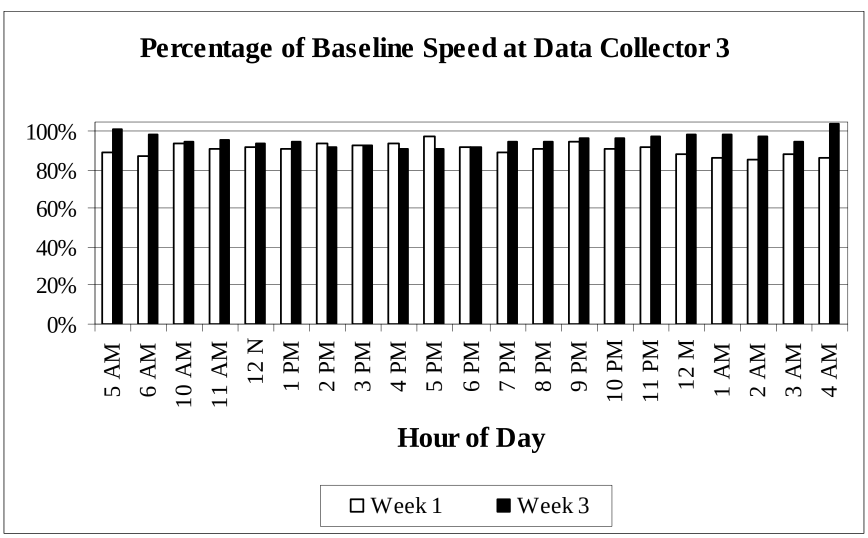
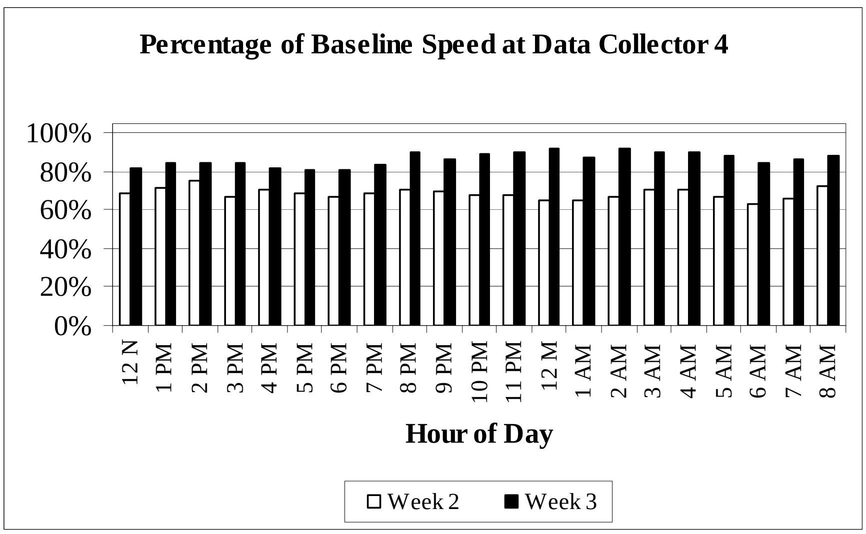


Figure 19. Comparison of Week 1 and Week 3 at I-215 East Northbound (SMD)

that from approximately 10 AM to 10 PM the SMD's effect was about the same between weeks one and three. In the early morning or late at night, however, the SMD was less effective in week three than it had been in week one.

For I-15 south of Nephi, Figure 20 presents the same information for data collectors 4 and 7. These data collectors were chosen for this analysis because they are at



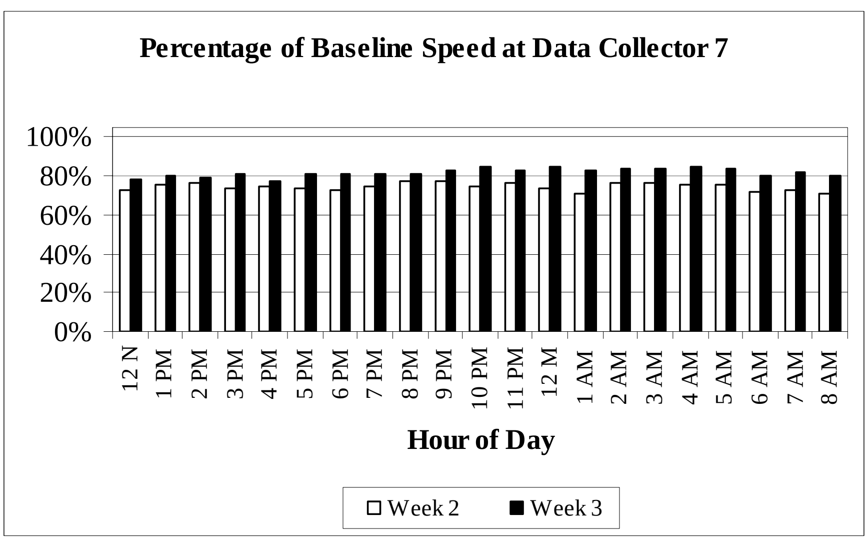


Figure 20. Comparison of Week 2 and Week 3 at I-15 South of Nephi (SMD)

the locations where the SMD had the largest effect. Note that the SMD was not placed at this site until the second week of data collection so that the comparison is between the second and third weeks. As the figures show, the SMDs at these sites were not quite as effective in the third week as they had been in the second week. However, speeds were still reduced in comparison to baseline speed.

To compare these results with those that might be obtained when the treatment is police presence, Figure 21 shows the same information for data collector 2 (where the police officer was stationed) at the I-15 south of Nephi location. Here the comparison is between the first and second weeks because this is data collected without the SMD. Police presence appears to be at least as effective the second week as it was the first week.

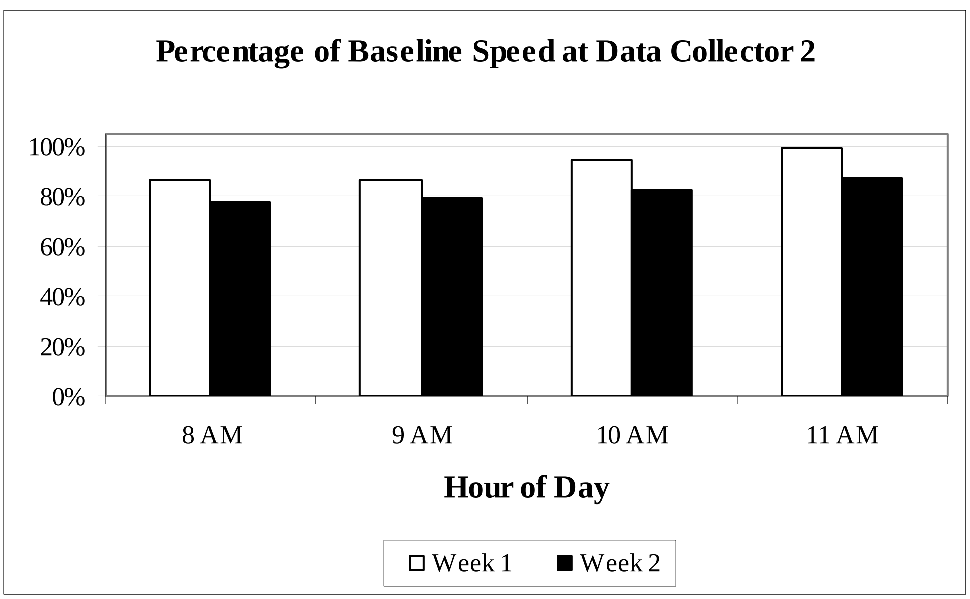


Figure 21. Comparison of Week 1 and Week 2 at I-15 South of Nephi (Police)

5.4. Summary

The SMD was effective at reducing average vehicle speed in highway construction zones. The effect was statistically significant at a 95 percent confidence level, but not necessarily as great as the effect due to police presence. With MUTCD signing alone, the average vehicle speed decreased 4 percent from the initial data collector to downstream data collectors within the work zone. For the range of speeds in this study, this is equivalent to about 3 mph. With an SMD, however, the average vehicle speed downstream decreased an additional 6 percent (for a total speed decrease of about 10 percent). For the range of speeds in this study, this is equivalent to a marginal speed reduction of about 4 mph (the total speed reduction is about 7 mph). (These results are all statistically significant.) The effect continued throughout the study area. It appears that the SMD is less effective as it is used over several weeks.

When police are present, the average vehicle speed is 10 percent less than when only MUTCD signing is present (for a total speed decrease of about 14 percent), indicating marginal speed reductions of about 6 mph (a total speed reduction of about 9 mph). (Again, these results are all statistically significant.) The greatest speed reductions occurred in the vicinity of the police vehicle, and speeds increased downstream of the police vehicle. Police presence appears to remain effective over several weeks.

CHAPTER 6. DRIVER QUESTIONNAIRE

In addition to the field evaluation of the SMD, UDOT was also interested in knowing drivers' perceptions of the SMD. As a result, a questionnaire was administered to 622 drivers, the majority of whom were Utahans. This chapter describes the questionnaire and summarizes the results.

6.1. Description of Questionnaire

The questionnaire was one page long (see Figure 22). The questions can be divided into three general areas: demographic information, drivers' tendencies, and drivers' opinions of the SMD. The demographic information collected was sex, age, home state, and type of vehicle driven (car or truck). The questions about "drivers' tendencies" were designed to determine a driver's normal reaction (in terms of changes in speed) to speed signs, to work zones, and to SMDs. The remaining questions were designed to determine how drivers interpret the SMD and asked questions about the design of the SMD (such as accuracy and legibility).

6.2. Survey Sites

The survey was administered at three locations over five different days. The initial plan was to administer the surveys at a few of the busier Driver License Offices in Utah and Salt Lake Counties. These would be supplemented by some surveys administered at the Utah Welcome Center located on I-80 near the border with Wyoming

This is an anonymous survey conducted by BYU students to determine driver's opinions of highway safety measures. There are 10 questions that take 2 to 3 minutes to answer. Completing this survey is voluntary. Please answer each question honestly.

1. Sex: Male ☐ Female   Age: ________________

2. What state of the US or province of Canada do you live in? _______________________

3. What kind of vehicle do you most often drive?
   - ☐ a. Personal vehicle (motorcycle, car, van, SUV, light truck, etc.)
   - ☐ b. Truck (commercial license)

4. How would you characterize your driving?
   - ☐ a. I usually drive at or below the speed limit
   - ☐ b. I usually drive at or a little faster than the speed limit (0 to 5 mph above the speed limit)
   - ☐ c. I usually drive quite a bit faster than the speed limit (more than 5 mph above the speed limit)
   - ☐ d. I usually match my speed to the other cars on the road

5. When you enter a highway construction area with a lower speed limit, do you usually…
   - ☐ a. Ignore the new speed limit
   - ☐ b. Slow down to a speed at or below the speed limit
   - ☐ c. Slow down, but not as low as the speed limit
   - ☐ d. Adjust my speed to match what other cars are doing
   - ☐ e. Look for workers and slow down if I see them
   - ☐ f. It depends on whether I see a police car or not

6. If you saw a Speed Display on the road, what message would you get from it?
   - ☐ a. "Check your speed and slow down"
   - ☐ b. "Danger ahead, drive carefully"
   - ☐ c. "Police are enforcing the speed limit"

7. How would you react to a Speed Display that showed you were driving faster than the speed limit?
   - ☐ a. Ignore the Speed Display
   - ☐ b. Slow down so that my speed matched or was lower than the speed limit
   - ☐ c. Slow down so that my speed matched or was just higher than the speed limit
   - ☐ d. Speed up to see how high the Speed Display will go

8. Would you speed up if the Speed Display showed you were driving slower than the speed limit?
   ☐ Yes ☐ No ☐ I'm not sure

9. If you saw a Speed Display in a highway construction area, would you be more likely to slow down to the construction area speed limit?
   ☐ Yes ☐ No ☐ I'm not sure

10. Have you ever seen a Speed Display before?
    ☐ Yes ☐ No ☐ I'm not sure
    If you answered yes, please circle your answer to each of the following.

a. Speed Displays encourage vehicles to go the speed limit	Agree	Disagree	I'm unsure
b. Speed Displays aren't accurate	Agree	Disagree	I'm unsure
c. I never know when the Speed Display is showing my speed	Agree	Disagree	I'm unsure
d. Speed Displays are distracting to the driver	Agree	Disagree	I'm unsure
e. Speed Displays are difficult to see and/or read	Agree	Disagree	I'm unsure

If you have any questions about this survey, you may contact Dr. M. Saito at (801) 422-6326. If you have questions regarding your rights as a participant in research projects, you may contact Dr. Shane S. Schulthies, Chair of the Institutional Review Board for Human Subjects, 120B RB, Brigham Young University, Provo, UT 84602; phone, (801) 422-5490.

Figure 22. Questionnaire

to get the opinions of some out-of-state drivers as well. Because UDOT is responsible for the Welcome Center, permission to administer the surveys at the Welcome Center was easily obtained. However, the Driver License Division of the Utah Department of Public Safety refused to allow surveys to be administered at their offices. Consequently, other locations were chosen.

The first surveys were administered at the Welcome Center. The majority of respondents were either truck drivers or older couples traveling to warmer climates as the weather grew cooler. Sixty-three surveys were collected. Surveys were next administered outside of the LaVell Edwards Stadium prior to BYU football games on two different occasions. Respondents were men and women attending the football game. About 400 surveys were collected. The final surveys were administered outside of the Provo City Library at Academy Square one evening and one morning. About 200 surveys were collected.

At each location, potential participants were approached by the researchers and asked if they would take a survey on road safety. They were offered a free candy bar in exchange for filling out the form. The participants were shown a picture of an SMD and were given a paper copy of the questionnaire on a clipboard.

6.3. Analysis

As mentioned above, there were three basic sets of information that were to be determined from the analysis. First, demographic information was taken to make sure the surveys were a fairly reasonable representation of the population. Second, questions about drivers' tendencies were compared with each other to determine if the SMD would change the drivers' reported behavior. Finally, drivers were asked how they feel about the SMD.

6.3.1. Demographic information

The average age of the participants was 37 years old with a minimum age of 16 years and a maximum age of 79 years. The distribution of ages is shown in Figure 23. As should perhaps be expected of surveys that were mostly collected at football games, there were more surveys filled out by men than by women (59 percent of respondents were men). The percent distribution of sex by age is shown in Figure 24. In addition, 83 percent of the respondents were from Utah and 94 percent of the respondents drove personal vehicles as opposed to commercial vehicles.

6.3.2. Drivers' tendencies

Questions 4, 5, 7, 8, and 9 were used to determine how different types of drivers react to work zones and to SMDs. Based on their answers to Question 4, each driver was placed in one of three categories: drivers who pay attention to the speed limit and like to drive a little slower (15 percent of respondents), drivers who pay attention to the speed limit but like to drive a little faster (67 percent of respondents), and drivers who don't pay attention to the speed limit either because they drive quite a bit faster than the speed limit or because they prefer to just go the same speed as everyone else (18 percent of respondents). Respondents were categorized into three similar groups for Question 5 (which refers to driving in work zones) and Question 7 (which refers to driving past a SMD). For Questions 8 and 9, drivers were categorized into two groups: those who

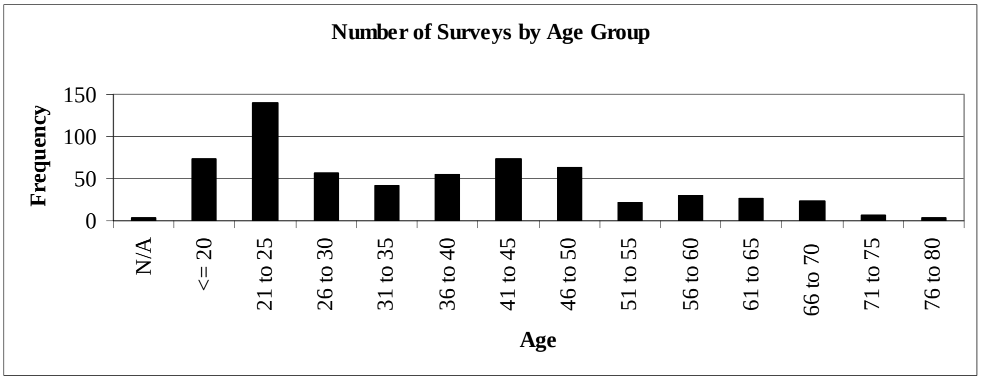


Figure 23. Age Group Distribution of Questionnaire Participants

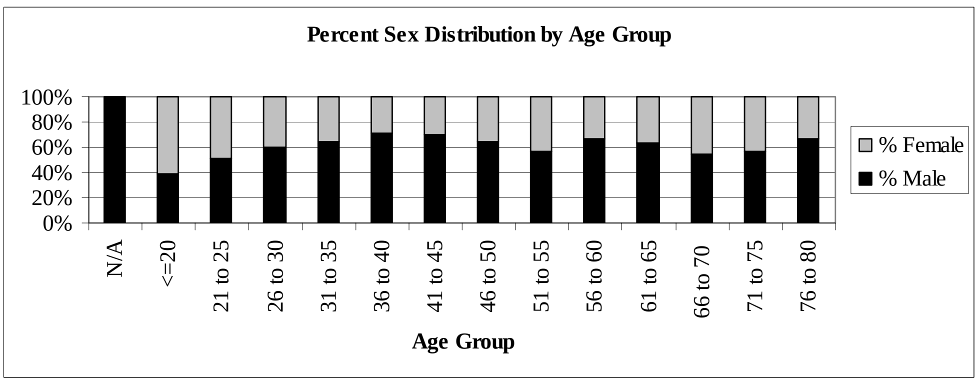


Figure 24. Percent Male and Female by Age Group

would respond to an SMD and those who would ignore an SMD or are not sure what their response to an SMD would be.

For the next step, the information was summarized into four tables where a respondent's answers to Question 4 were compared to the answers to Questions 5, 7, 8, and 9. The summaries are shown in Table 10, Table 11, Table 12, and Table 13, respectively. (Note that the first number in each cell of the tables indicates the number of respondents that fall into each category. The second number in each cell indicates the number that would be expected in the cell if the answers to both questions were independent.) The tables were analyzed in SAS using the chi-square test to determine if the respondents' answers to question 4 were independent from their answers to the other questions. In cases where values in at least one cell of the table were less than 5, the exact chi-square test was used. For all four tables, the null hypothesis that the answers to each question were independent was rejected at a 95 percent confidence level. This means that there is some kind of pattern to how a person answered question 4 and how they answered each of the other questions. The SAS code and output are shown in Appendix D.

The chi-square and exact chi-square tests measure whether or not the actual values in the table deviate significantly from the values that would be expected if the respondents' answers to each question were independent. Once it is established that the actual values in the table differ from the expected values (at a 95 percent confidence level), the researcher can examine the tables more closely to find the cells where the deviations are the largest. A discussion of this analysis for each of these tables follows.

Table 10 shows that drivers who tend to drive slower than the speed limit under normal conditions are also likely to respond to a highway work zone by slowing down below the work zone speed limit. Drivers who tend to drive a little faster than the speed limit also slow down in response to a highway work zone, but usually drive a little faster than the work zone speed limit. Drivers who ignore the speed limit under normal circumstances are likely to use criteria other than the speed limit to determine what speed to travel in the work zone.

Table 11 shows a similar pattern. Drivers who tend to drive slower than the speed limit under normal conditions are also likely to respond to a SMD by slowing down

Table 10. Comparison of Questions 4 (Normal Condition) and 5 (Work Zones)

	In highway work zone:		
Under normal driving conditions:	Slow down to slower than speed limit	Slow down to faster than speed limit	Change speed based on other criteria
Pay attention to speed limit, drive slower	68 42	11 25	11 23
Pay attention to speed limit, drive a little faster	196 195	126 115	91 104
Ignore speed limit	28 55	35 32	54 29

Table 11. Comparison of Questions 4 (Normal Conditions) and 7 (SMD)

	If an SMD showed you were speeding:		
Under normal driving conditions:	Slow down to slower than speed limit	Slow down to faster than speed limit	Ignore the SMD
Pay attention to speed limit, drive slower	82 54	5 31	3 5
Pay attention to speed limit, drive a little faster	243 248	159 143	11 22
Ignore speed limit	47 70	51 41	19 6

below the speed limit. Drivers who tend to drive a little faster than the speed limit also slow down in response to an SMD, but would not slow down all the way to the speed limit. Drivers who ignore the speed limit, however, show a slightly different pattern. They are unlikely to slow down so that they are traveling slower than the speed limit, but both the "slow down to faster than the speed limit" and the "ignore the speed limit" options were chosen more often than expected.

Question 8 was asked to assess the likelihood that the SMD would reduce speed variance by encouraging slower cars to drive faster. The results in Table 12 show that drivers who normally drive below the speed limit are unlikely to speed up in response to an SMD which shows they are driving below the speed limit. The other types of drivers, however, are likely to speed up in a similar situation.

Table 13 simply shows that drivers who pay attention to the speed limit under normal circumstances would slow down in response to an SMD whereas drivers who ignore the speed limit are likely to also ignore an SMD.

Table 12. Comparison of Questions 4 (Normal Conditions) and 8 (SMD)

	If an SMD showed you were slower than the speed limit:	
Under normal driving conditions:	Speed up	Ignore the SMD
Pay attention to speed limit, drive slower	33 47	57 43
Pay attention to speed limit, drive a little faster	222 215	191 199
Ignore speed limit	67 61	50 56

Table 13. Comparison of Questions 4 (Normal Conditions) and 9 (SMD, Work Zone)

	If an SMD were in a highway construction zone:	
Under normal driving conditions:	Slow down	Ignore the SMD
Pay attention to speed limit, drive slower	87 80	3 10
Pay attention to speed limit, drive a little faster	378 368	35 45
Ignore speed limit	87 104	30 13

6.3.3. Opinions about SMDs

Ninety-six percent of drivers surveyed had seen an SMD before. Seventy-nine percent of drivers felt that the SMD conveys the message, “Check your speed and slow down.” Twelve percent of drivers felt that the SMD conveys the message, “Police are enforcing the speed limit.” The remaining nine percent felt that the SMD conveys the message, “Danger ahead drive carefully.” The majority of drivers felt positively towards SMDs and did not report significant difficulties with them. Figure 25 contains a series of pie charts that show how drivers responded to the opinion questions.

6.4. Comments

There was no place for free response comments on the questionnaire, however many participants gave verbal comments either when they were shown the picture of the SMD or as they handed in the questionnaire. These verbal comments were overwhelmingly positive. Truck drivers reported using SMDs to calibrate the speedometer in their vehicles.

6.5. Summary

Drivers generally have positive reactions to SMDs. Ninety-five percent of the respondents reported that they would slow down if the SMD showed they were traveling faster than the speed limit. Drivers who are most likely to react to SMDs are those who are normally aware of the speed limit and who adjust their speed in response to speed limit changes.

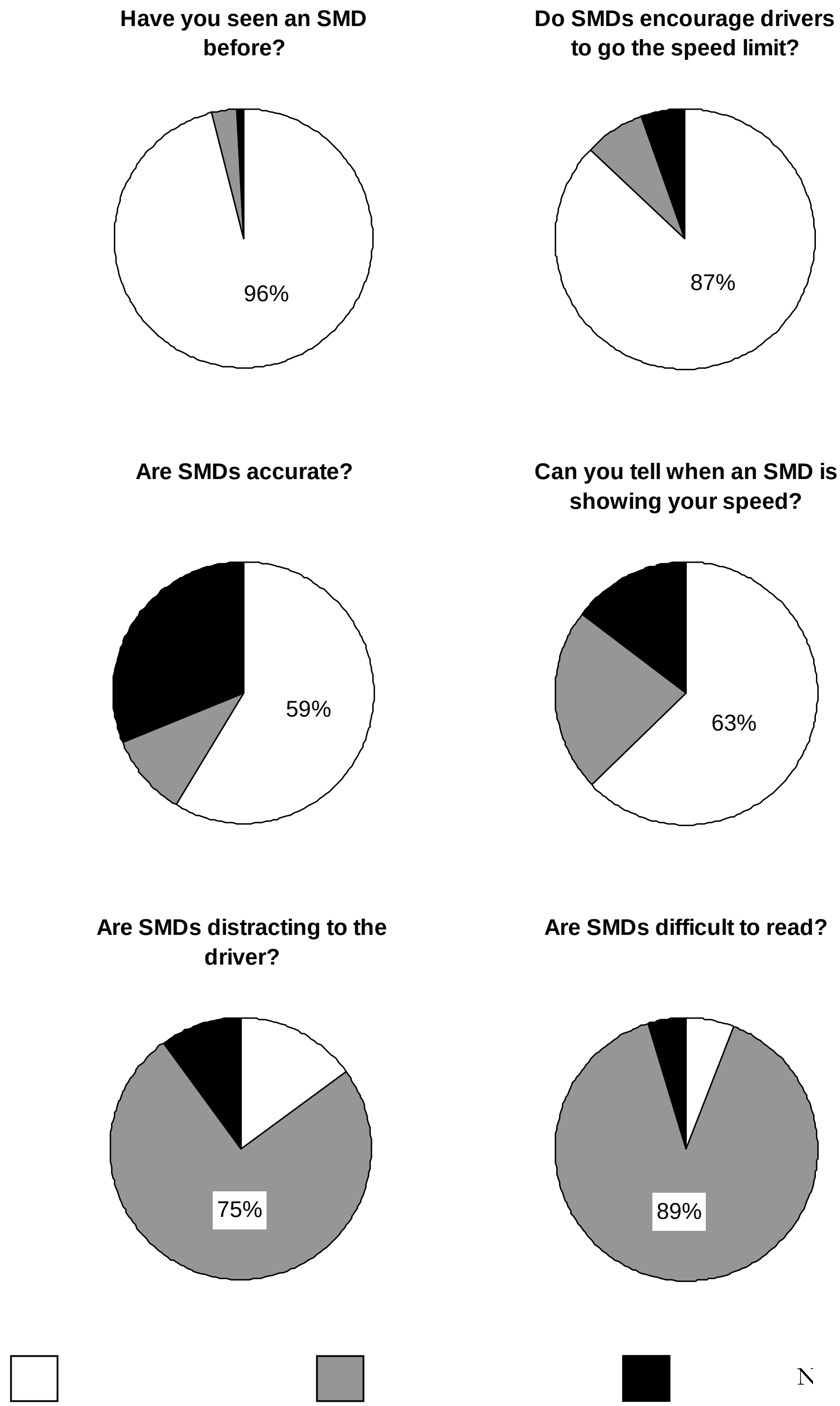


Figure 25. SMD Opinion Responses to the Driver Survey

CHAPTER 7. CONCLUSIONS AND RECOMMENDATIONS

As the roads in the United States have become more congested and as the highway infrastructure continues to deteriorate and need repair, highway work zone safety is an increasingly urgent issue. There are a number of methods of increasing work zone safety, including providing better visibility of the work zone hazards, reducing speed and speed variance in the work zone, and increasing driver alertness in the work zone.

This study focused mainly on reducing the average speed of vehicles traveling through the work zone. A number of treatments that have been studied were described. One of these treatments in particular, the SMD, was chosen for a more thorough study that included a field evaluation and a drivers' opinion survey. The SMD was compared to police presence, the most effective treatment currently known.

With the MUTCD signing alone, the average speed of vehicles traveling through freeway work zones decreased 4 percent (about 3 mph). The SMD was shown to decrease the average speed of vehicles traveling through freeway work zones by an additional 6 percent (about 4 mph). In contrast, police presence decreased the average speed by an additional 10 percent (about 6 mph). The SMD appeared to be most effective in the first week that it was used and to lose some efficacy in the weeks thereafter, whereas police presence was equally effective over several weeks. On the other hand, the effects of police presence are localized (especially for stationary police vehicles), whereas the effects of the SMD continue further downstream. The high cost of police presence and the comparatively small difference in the effects of these two treatments makes the SMD an attractive method of encouraging safer driving in highway work zones.

Drivers who completed opinion surveys regarding the SMD generally reported positive attitudes about the SMD. Drivers who are aware of the speed limit when they are driving reported that they would slow down in response to an SMD. Those who choose their speed based on other factors are less likely to change their speed in response to an SMD. For the majority of the drivers surveyed, the SMD conveys the message, “Check your speed and slow down.”

Future studies should focus on increasing the efficacy of the SMD. For instance, larger CMS-size speed displays may be easier to read and attract more attention, especially on high-speed roadways. Also, occasionally using police to reinforce the message of the SMD may increase the efficacy. Finally, it could be helpful to analyze the best place to position the SMD within the work zone. That is, it should be determined how far upstream of a hazard the SMD should be placed so that drivers are alert and are traveling at a safe speed as they pass the hazard.

Other speed control treatments that are recommended for more study include radio and TV publicity, CB radio alerts, and optical speed bars. It is also recommended that the new MUTCD guidelines for determining work zone speed limits be used. These guidelines are designed to increase driver confidence in the necessity of work zone speed limits and thereby increase compliance.

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APPENDIX

APPENDIX A

Hourly Volume and Speed Graphs

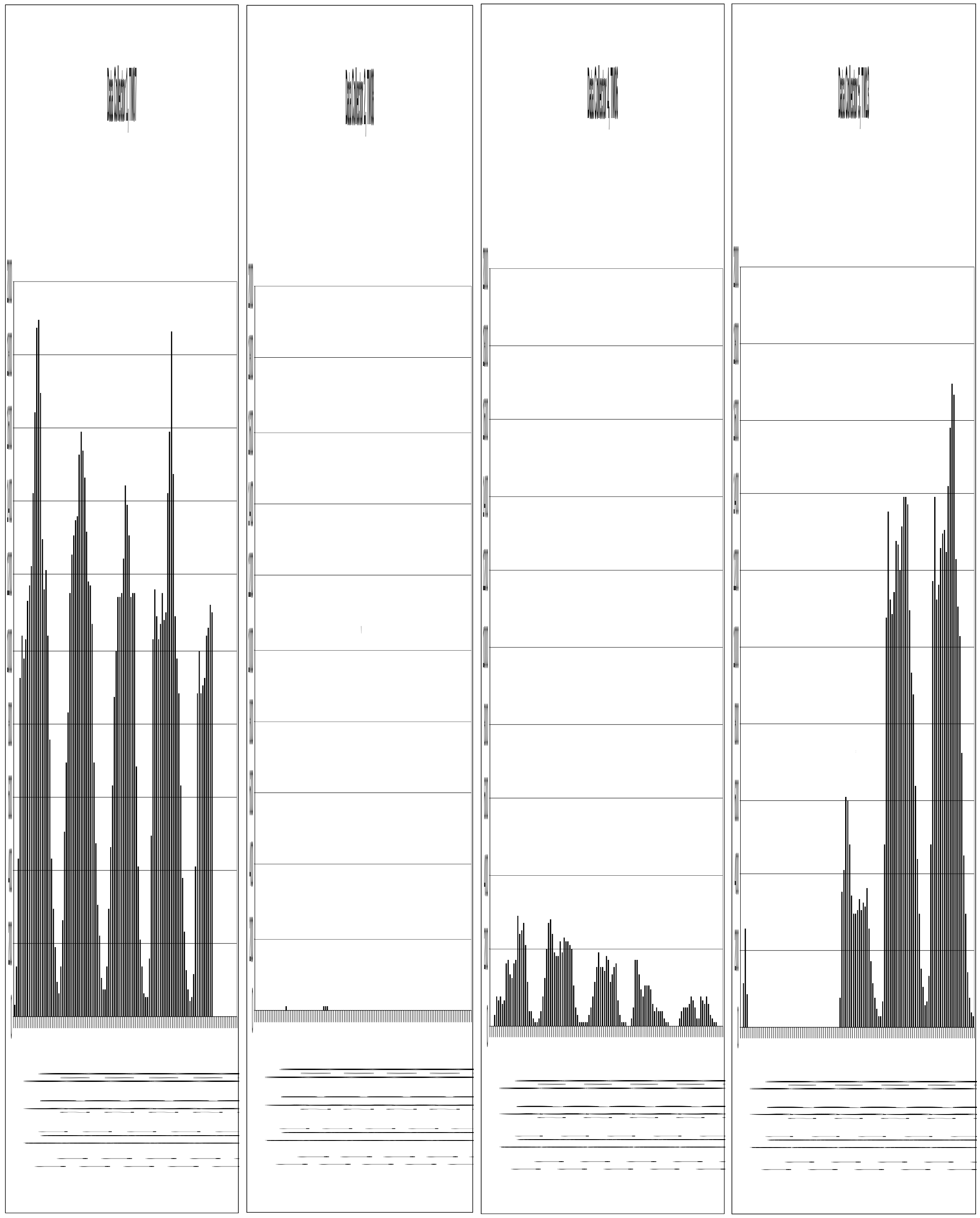

Figure A-1. Histogram of Hourly Volume
I-215 East (southbound)
Friday, 16 August 2002 through Wednesday, 21 August 2002

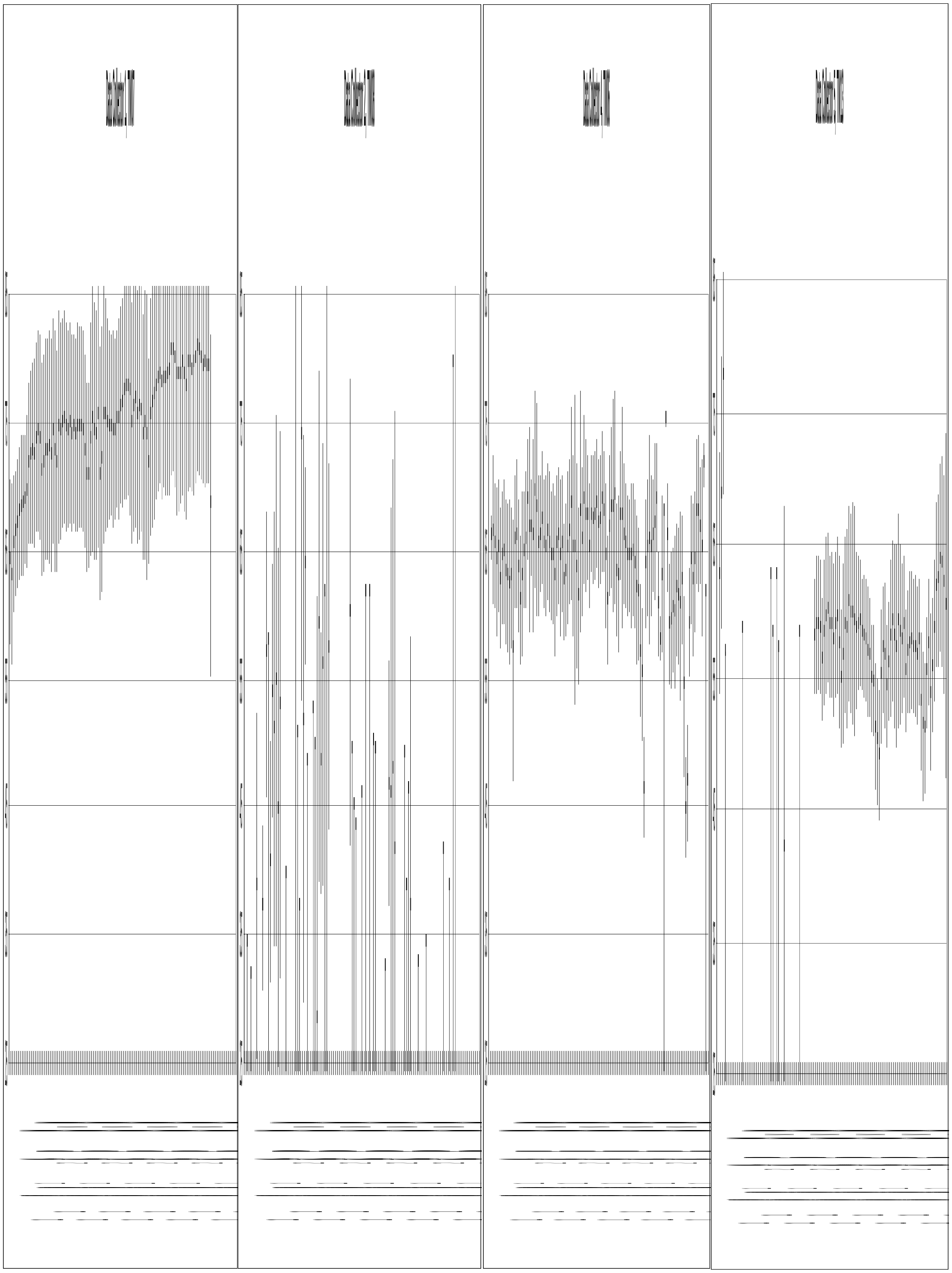

Figure A-2. Average Speed by Hour
I-215 East (southbound)
Friday, 16 August 2002 through Wednesday, 21 August 2002

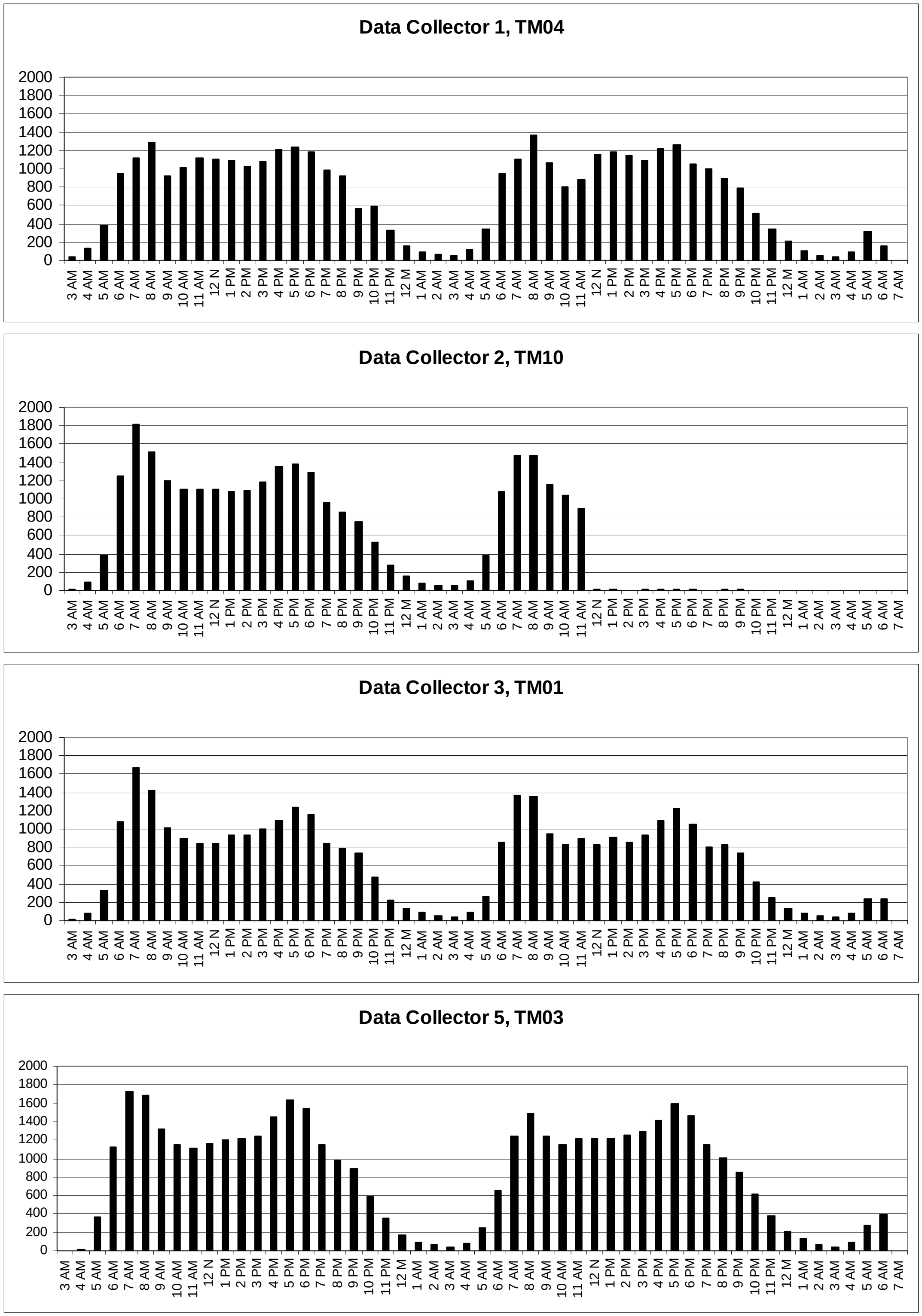

Figure A-3. Histogram of Hourly Volume
I-215 East (northbound)
Wednesday, 21 August 2002 through Friday, 23 August 2002

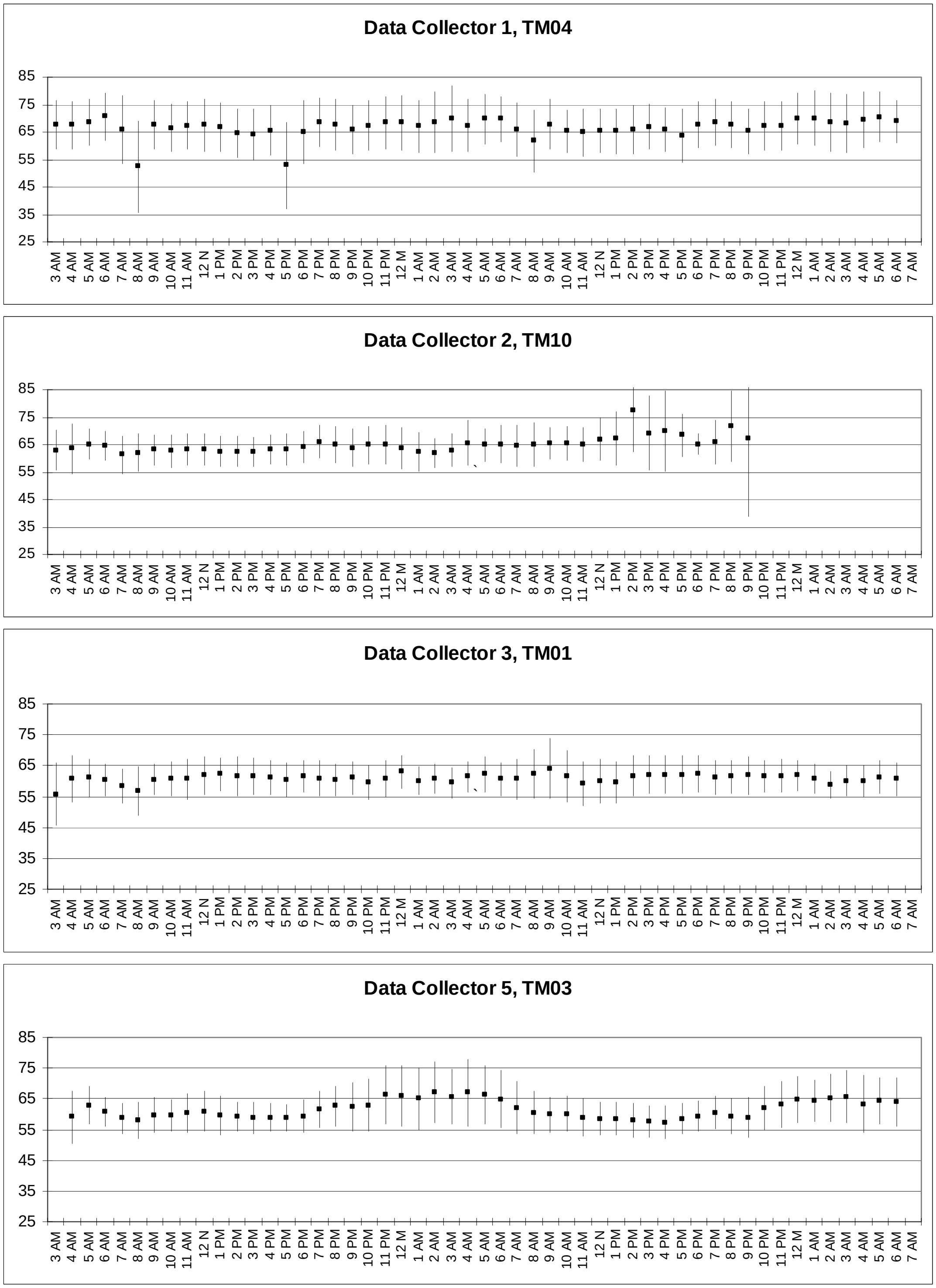

Figure A-4. Average Speed by Hour
I-215 East (northbound)
Wednesday, 21 August 2002 through Friday, 23 August 2002

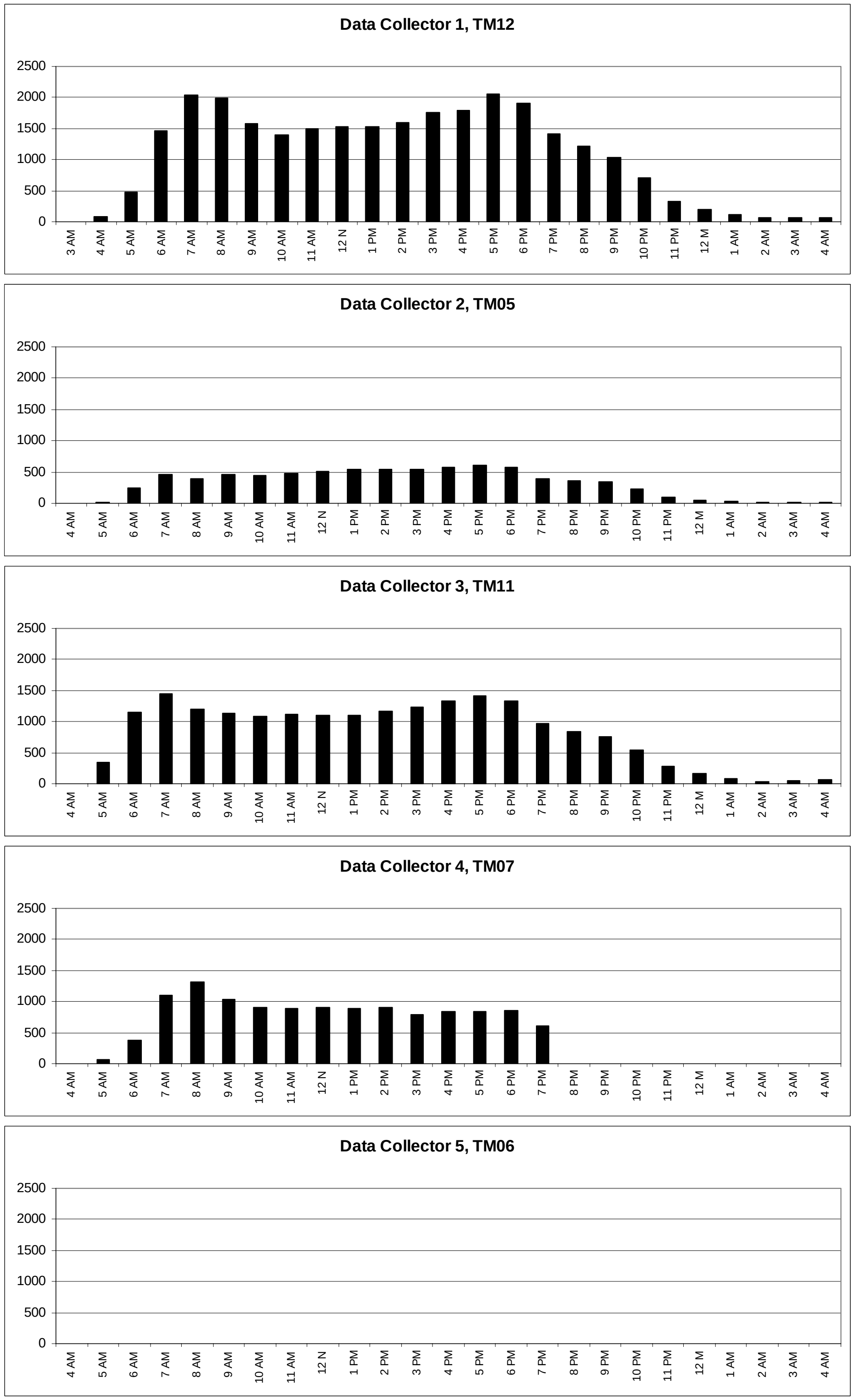

Figure A-5. Histogram of Hourly Volume
I-215 East (northbound)
Thursday, 12 September 2002 through Friday, 13 September 2002

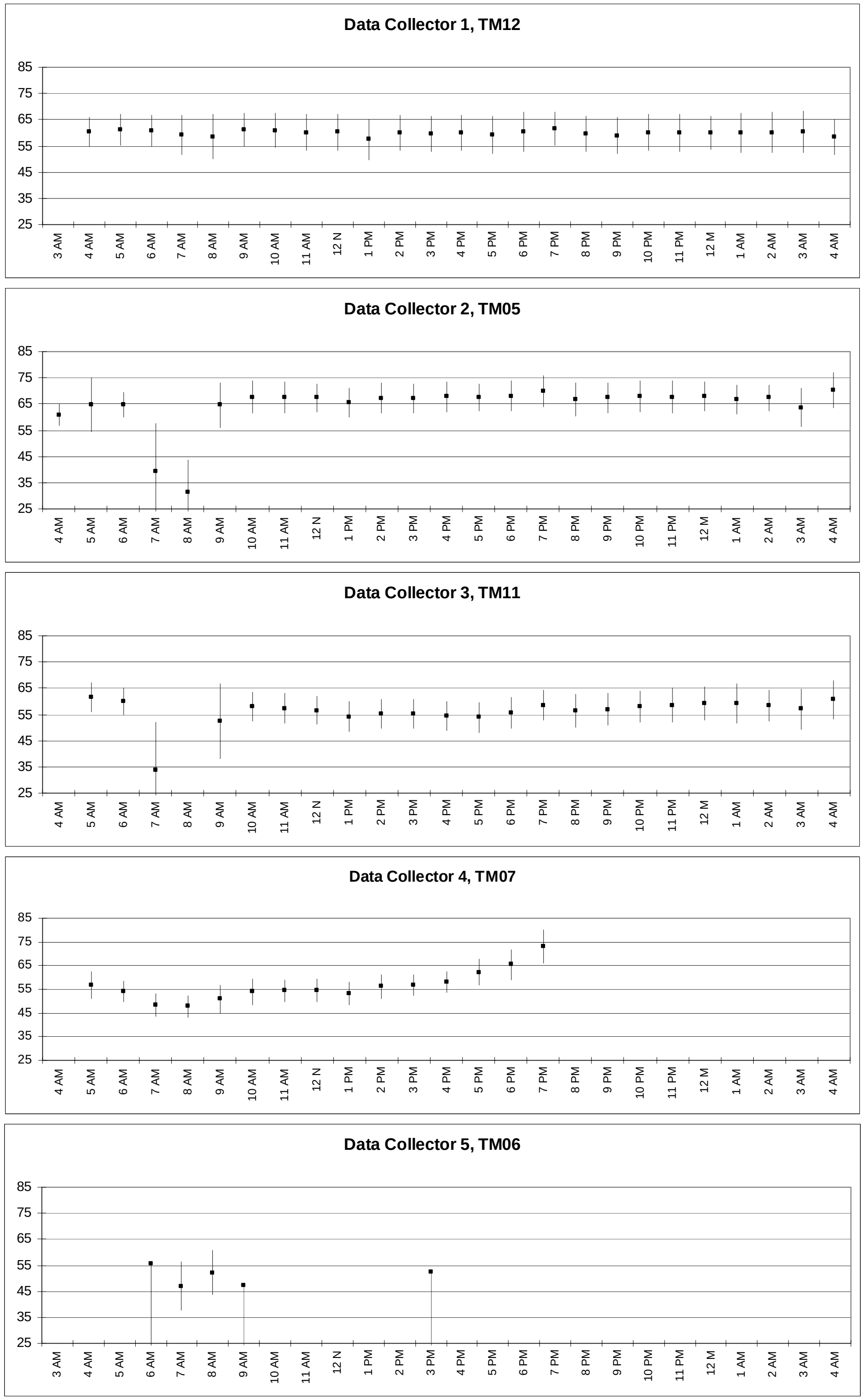

Figure A-6. Average Speed by Hour

I-215 East (northbound)

Thursday, 12 September 2002 through Friday, 13 September 2002

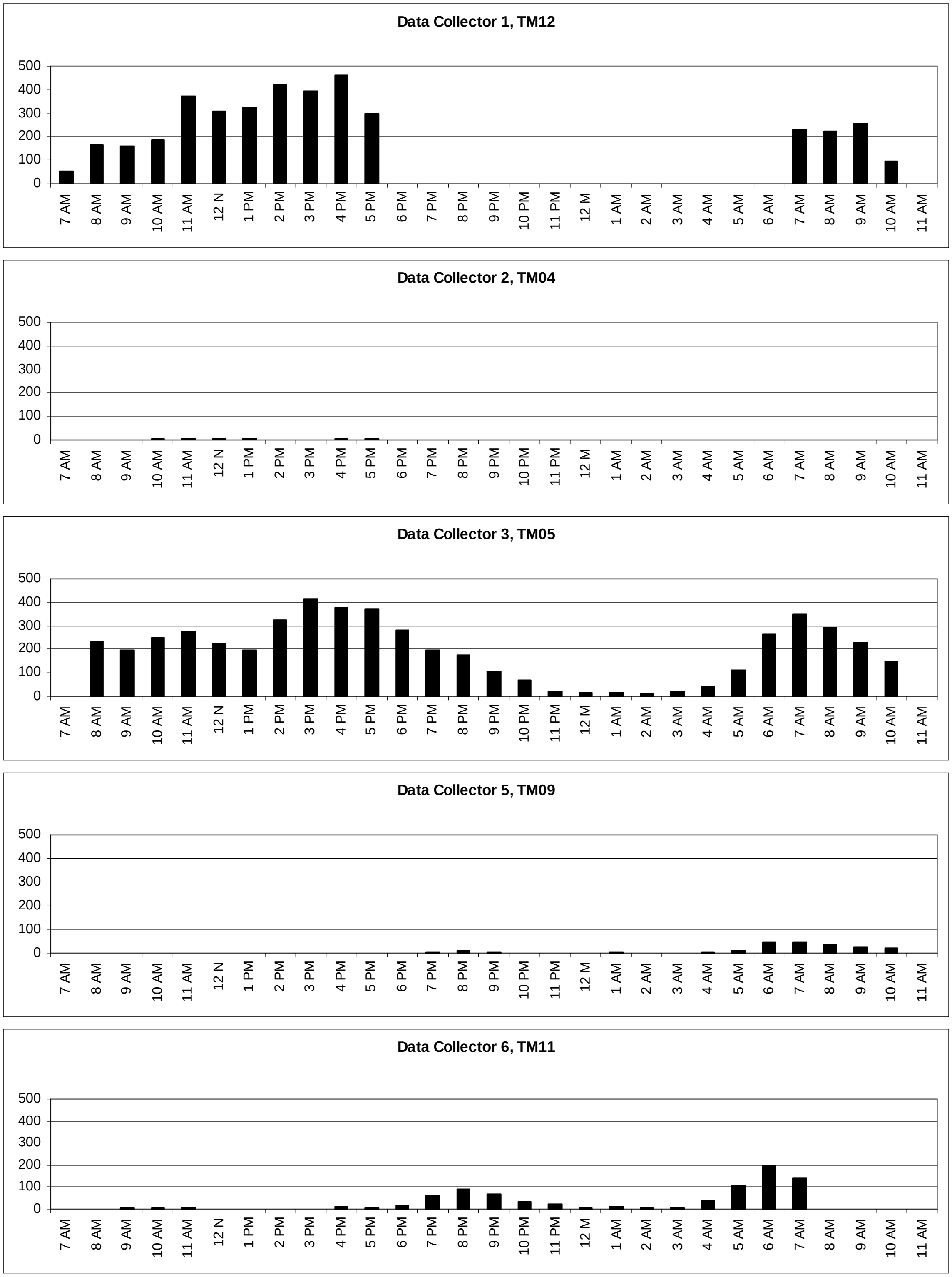

Figure A-7. Histogram of Hourly Volume
State Route 89
Monday 26 August 2002 through Tuesday, 27 August 2002

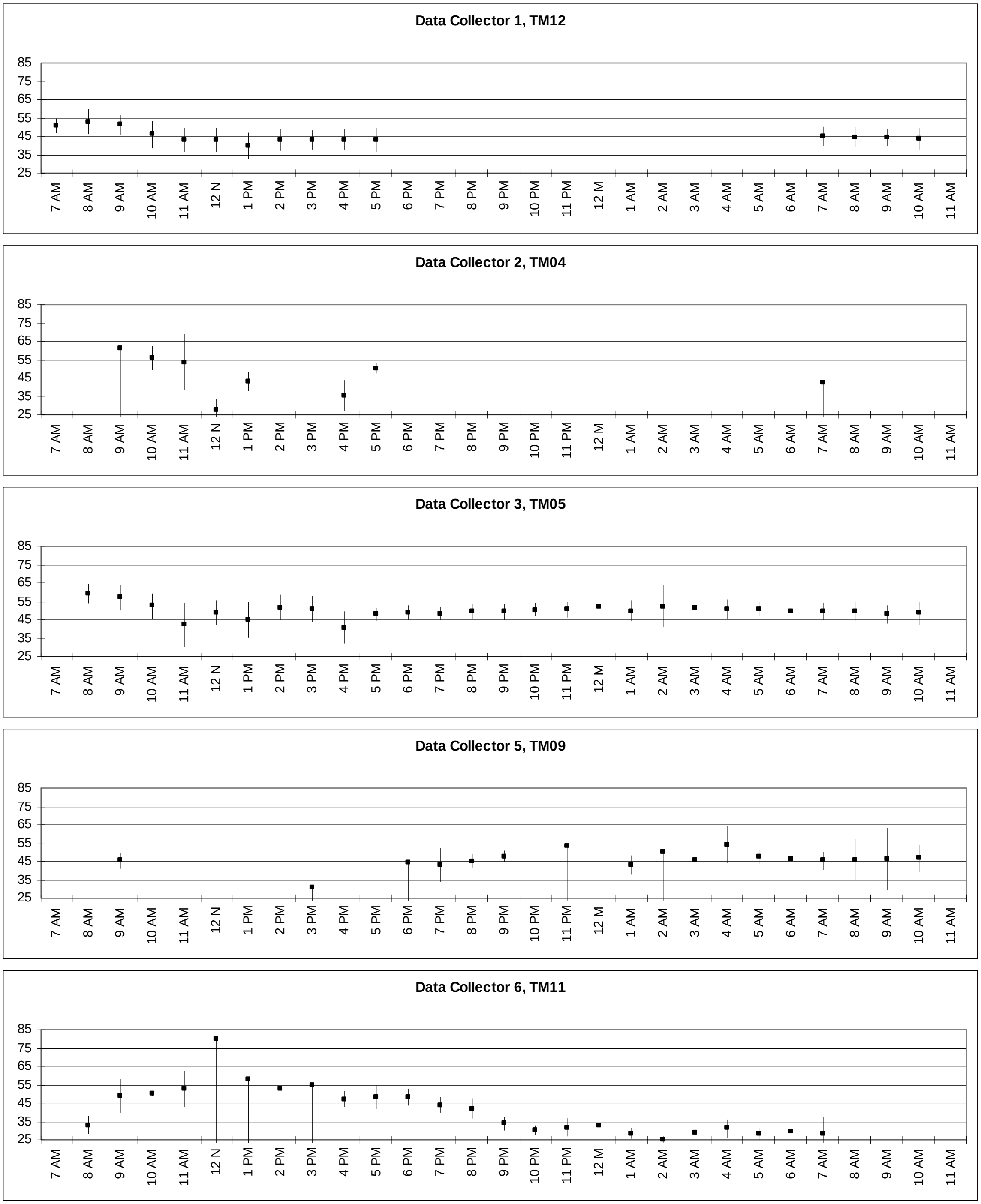

Figure A-8. Average Speed by Hour
State Route 89
Monday 26 August 2002 through Tuesday, 27 August 2002

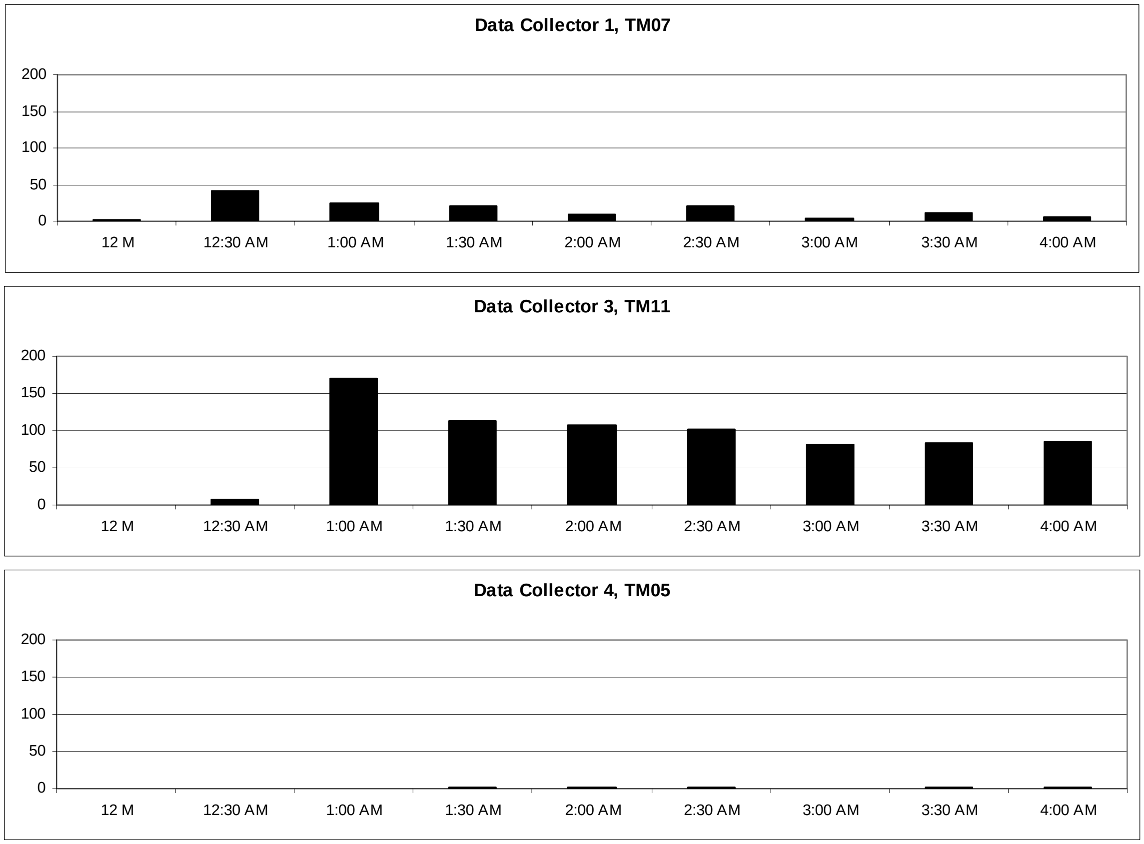

Figure A-9. Histogram of Hourly Volume
I-80 East (first location)
Tuesday 10 September 2002

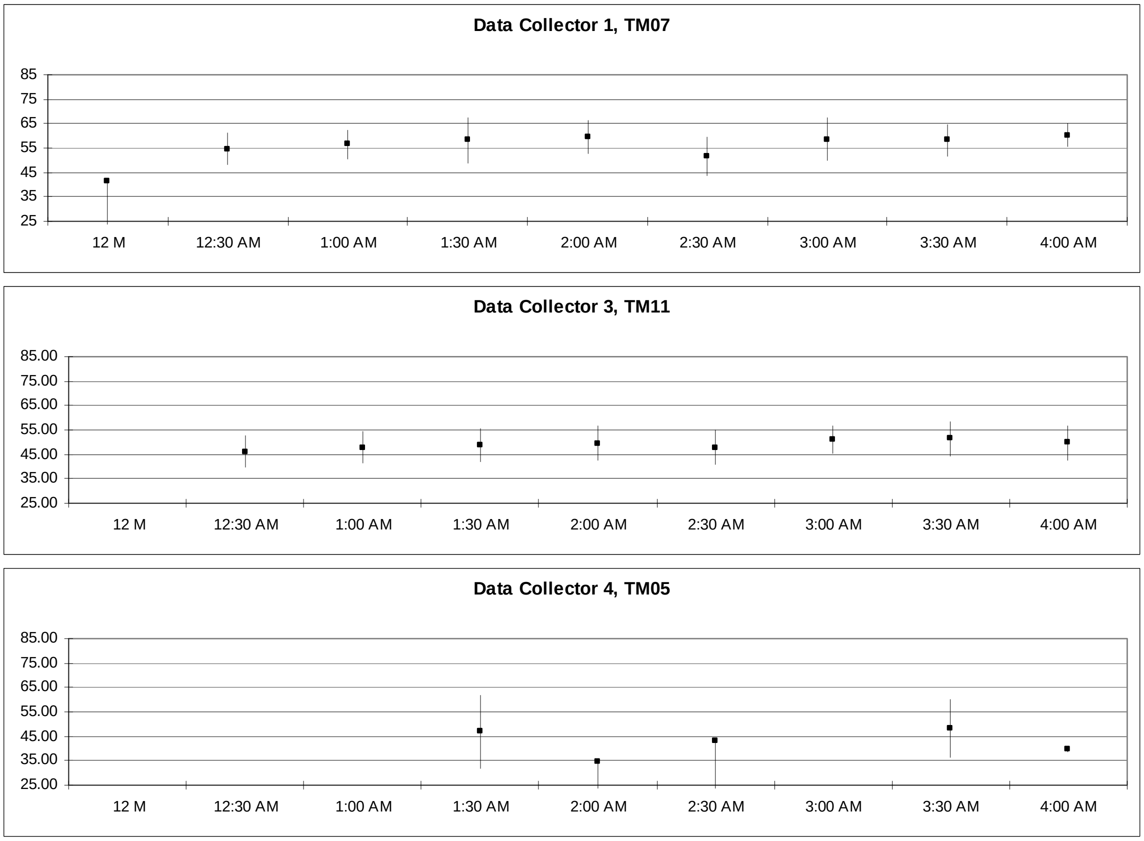

Figure A-10. Average Speed by Hour
I-80 East (first location)
Tuesday 10 September 2002

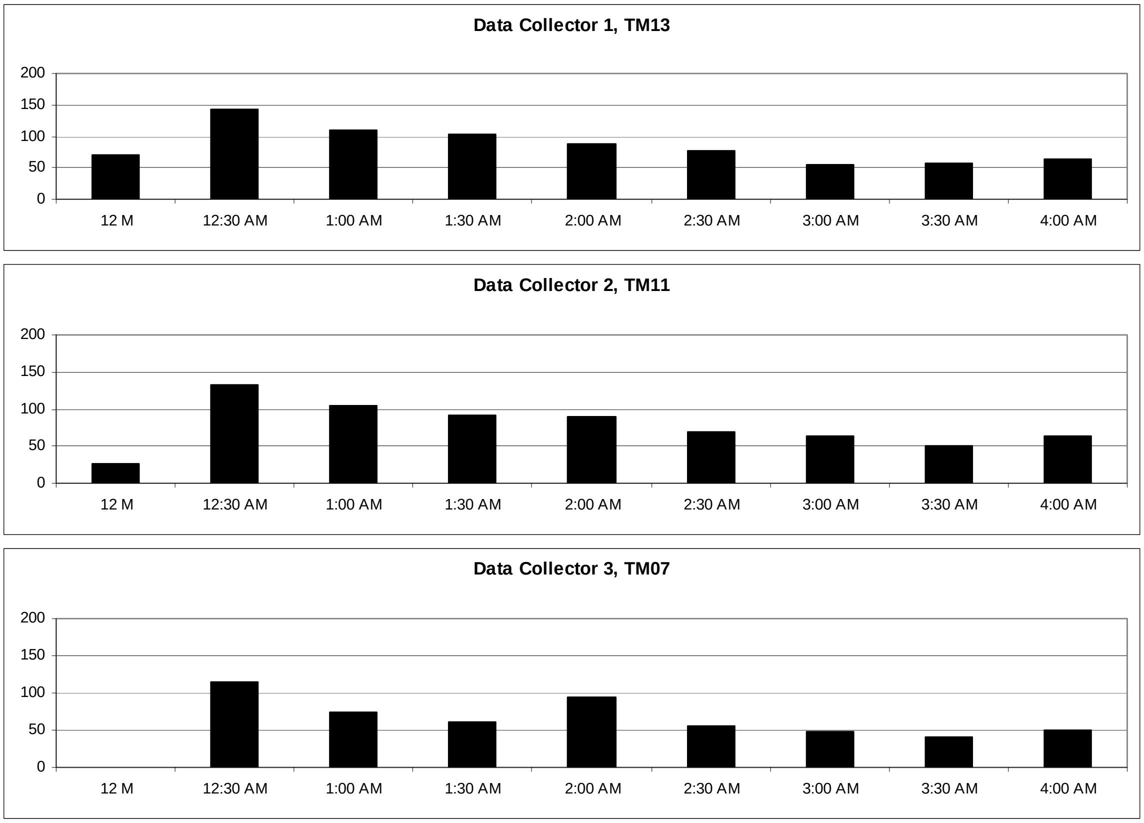

Figure A-11. Histogram of Hourly Volume
I-80 East (second location)
Friday, 20 September 2002

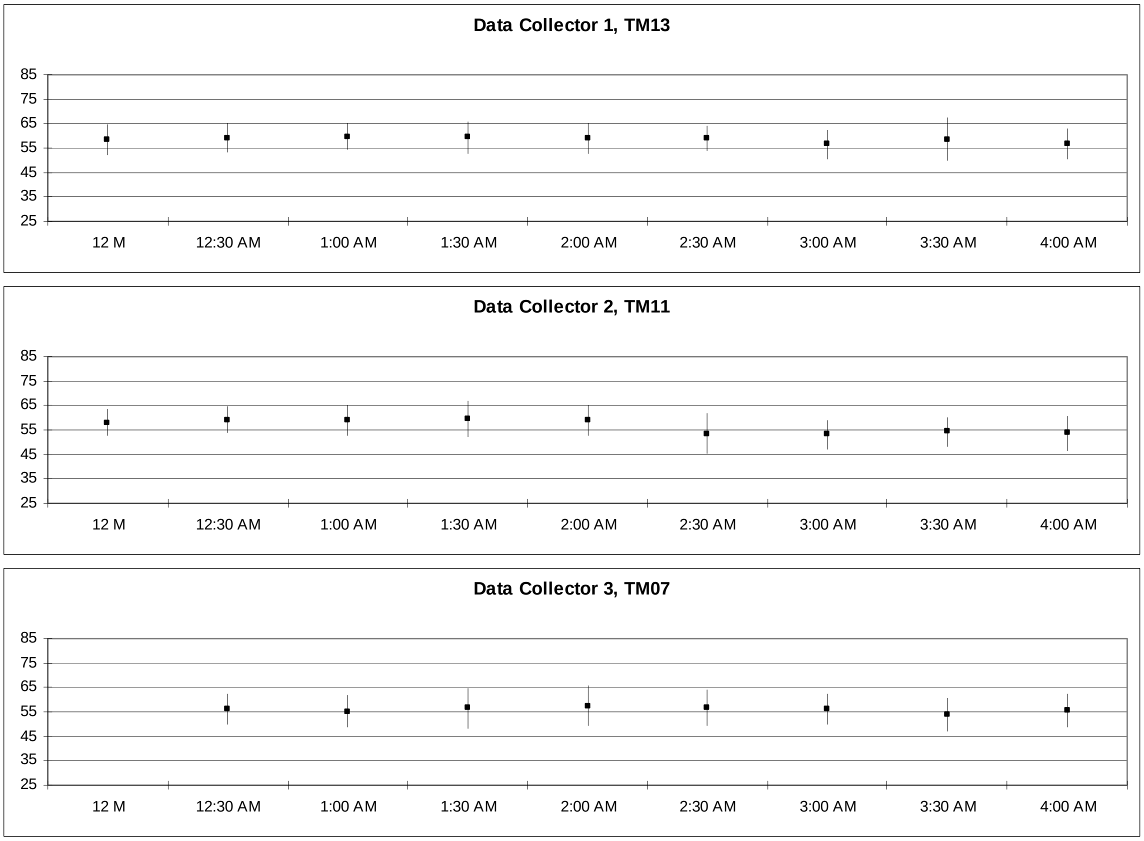

Figure A-12. Average Speed by Hour
I-80 East (second location)
Friday, 20 September 2002

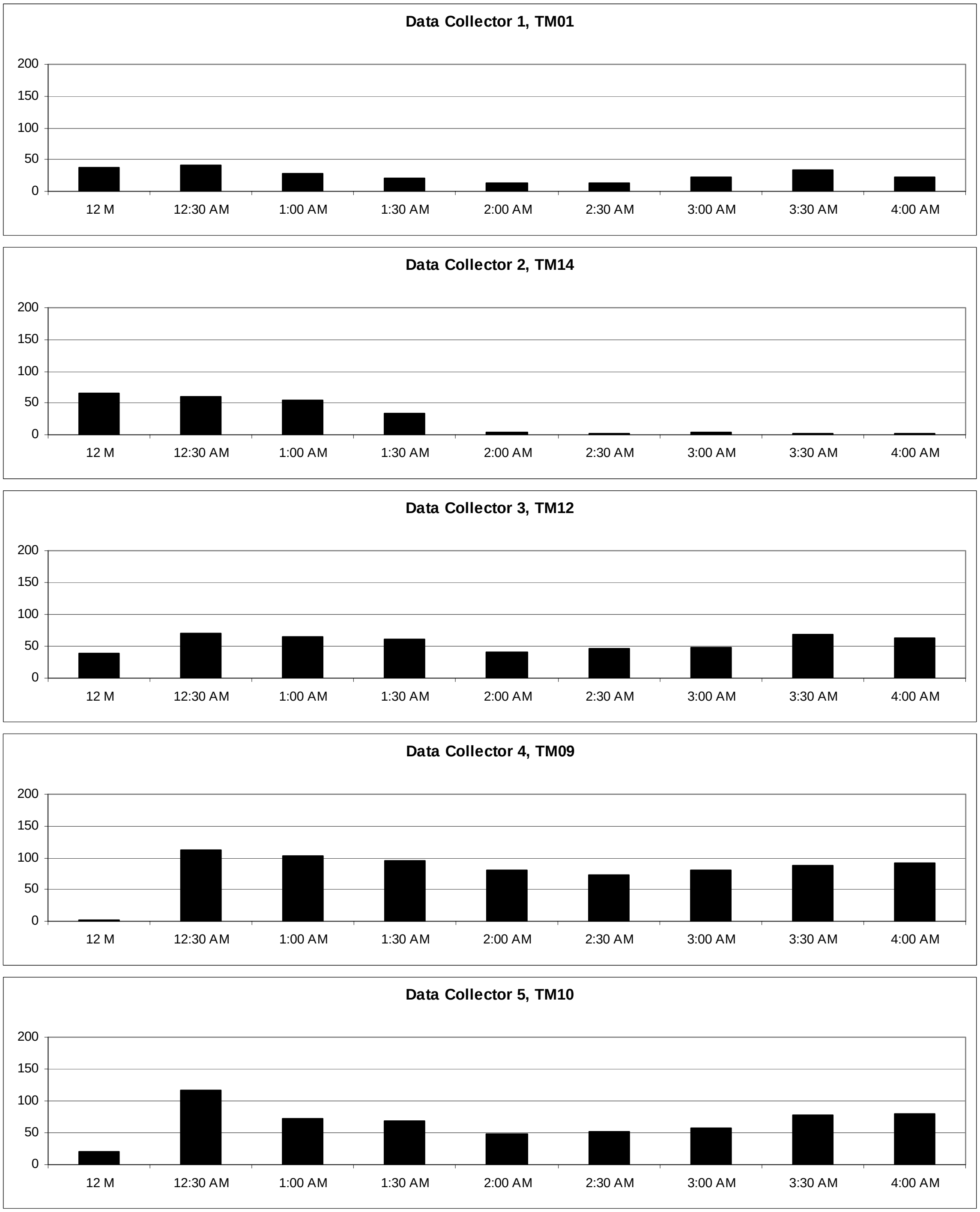

Figure A-13. Histogram of Hourly Volume
I-80 West
Tuesday, 24 September 2002

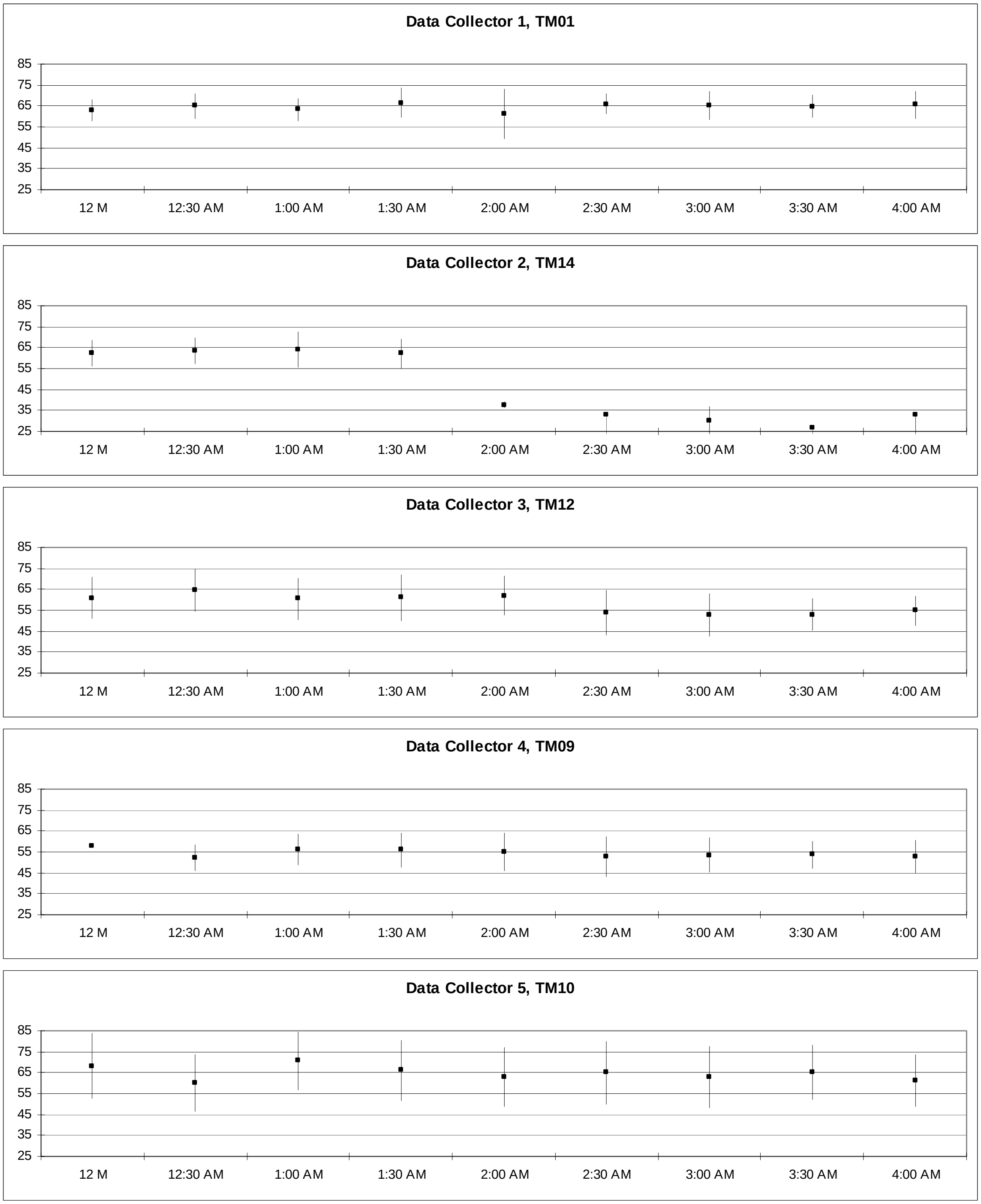

Figure A-14. Average Speed by Hour
I-80 West
Tuesday, 24 September 2002

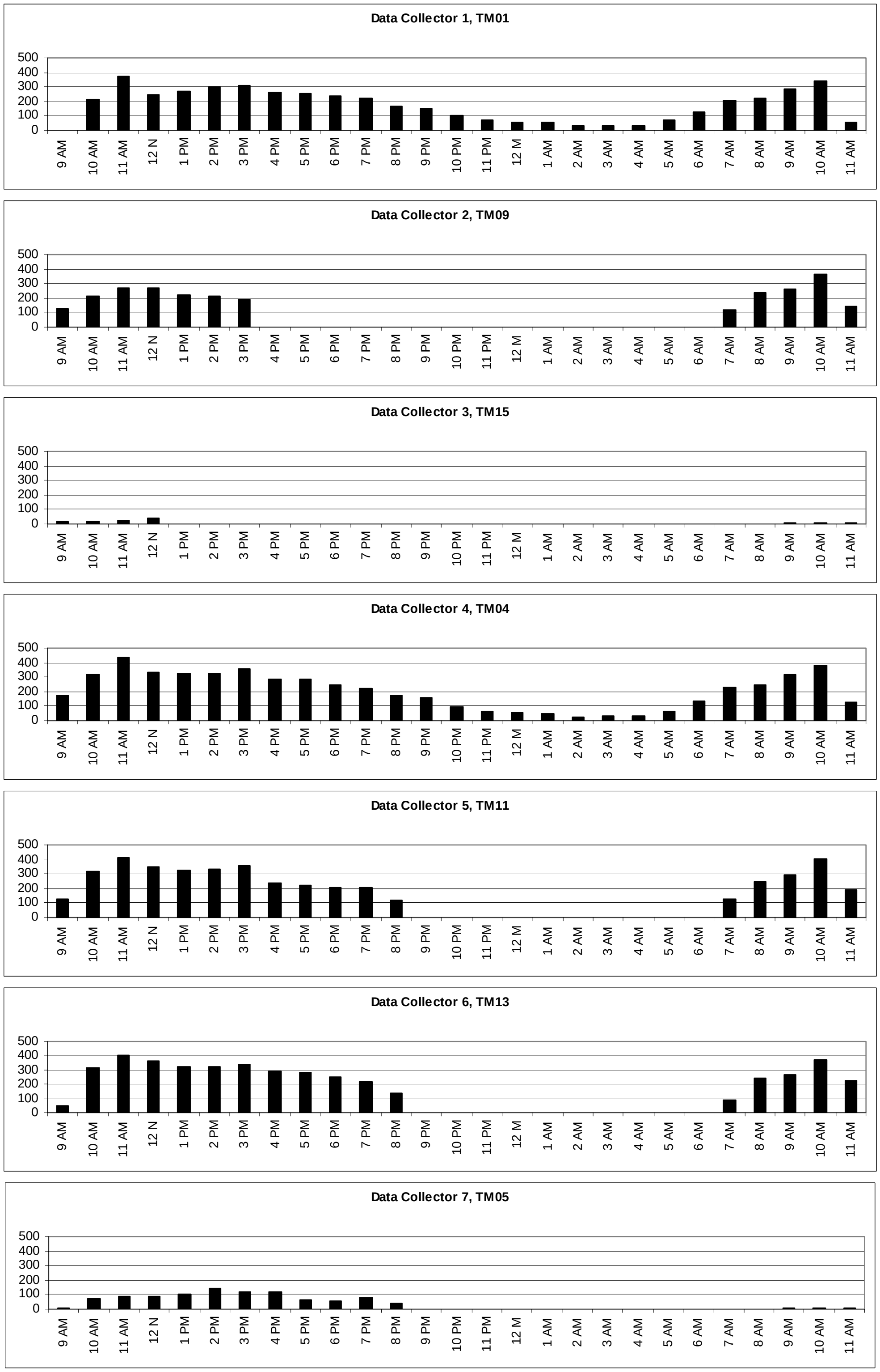

Figure A-15. Histogram of Hourly Volume
I-15 south of Nephi
Tuesday, 8 October 2002 through Wednesday, 9 October 2002

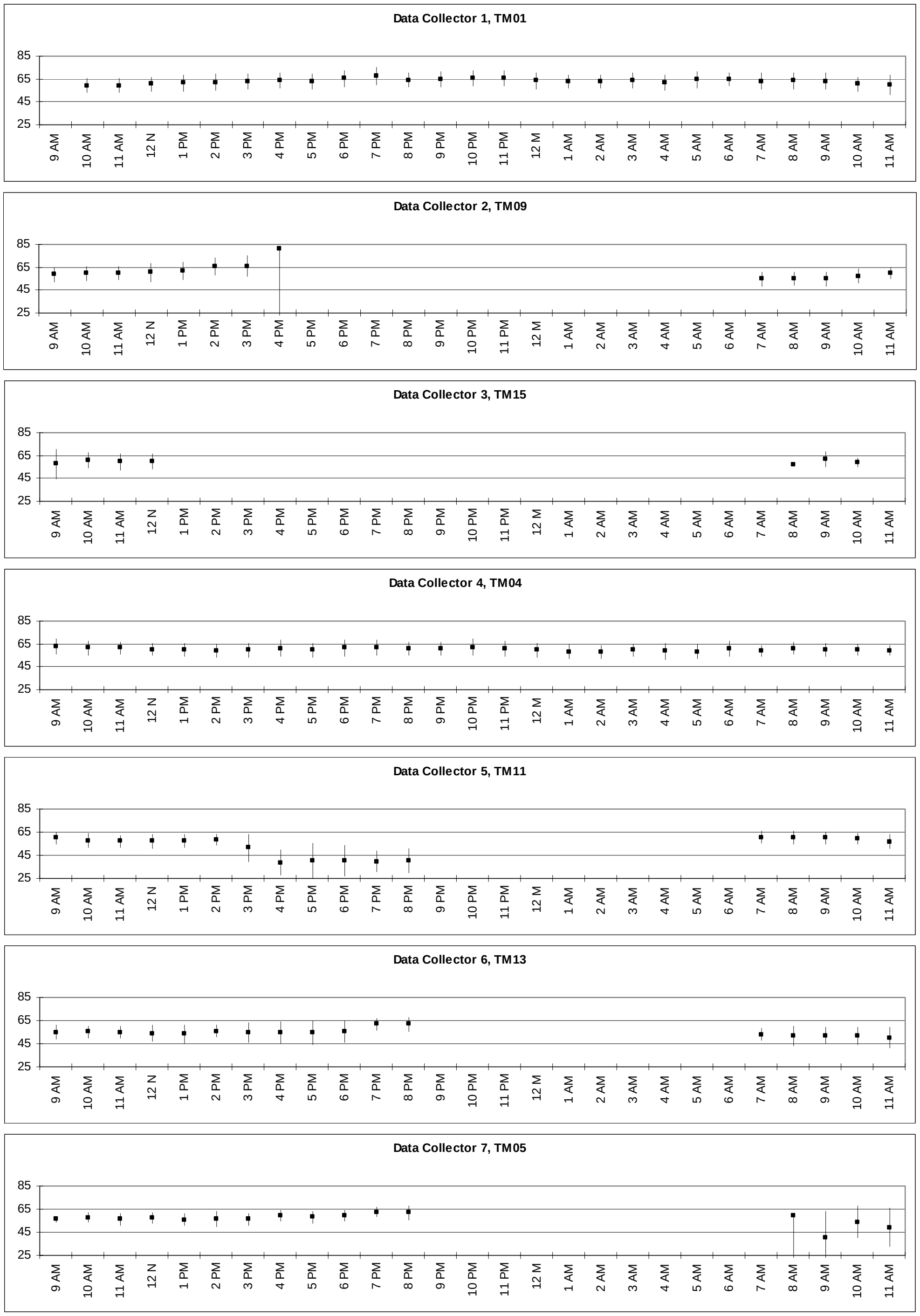

Figure A-16. Average Speed by Hour

I-15 south of Nephi

Tuesday, 8 October 2002 through Wednesday, 9 October 2002

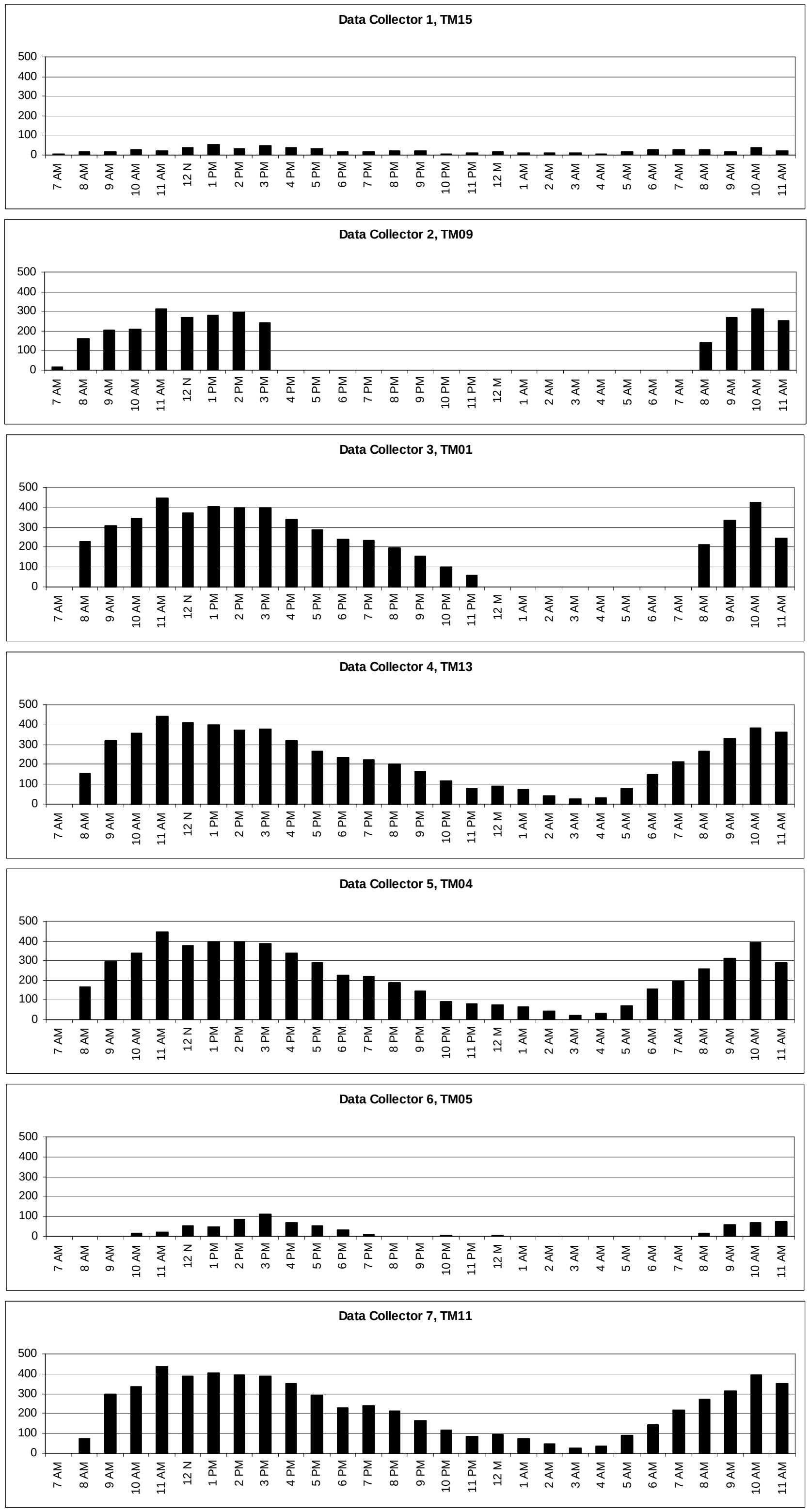

Figure A-17. Histogram of Hourly Volume
I-15 south of Nephi
Wednesday, 16 October 2002 through Thursday, 17 October 2002

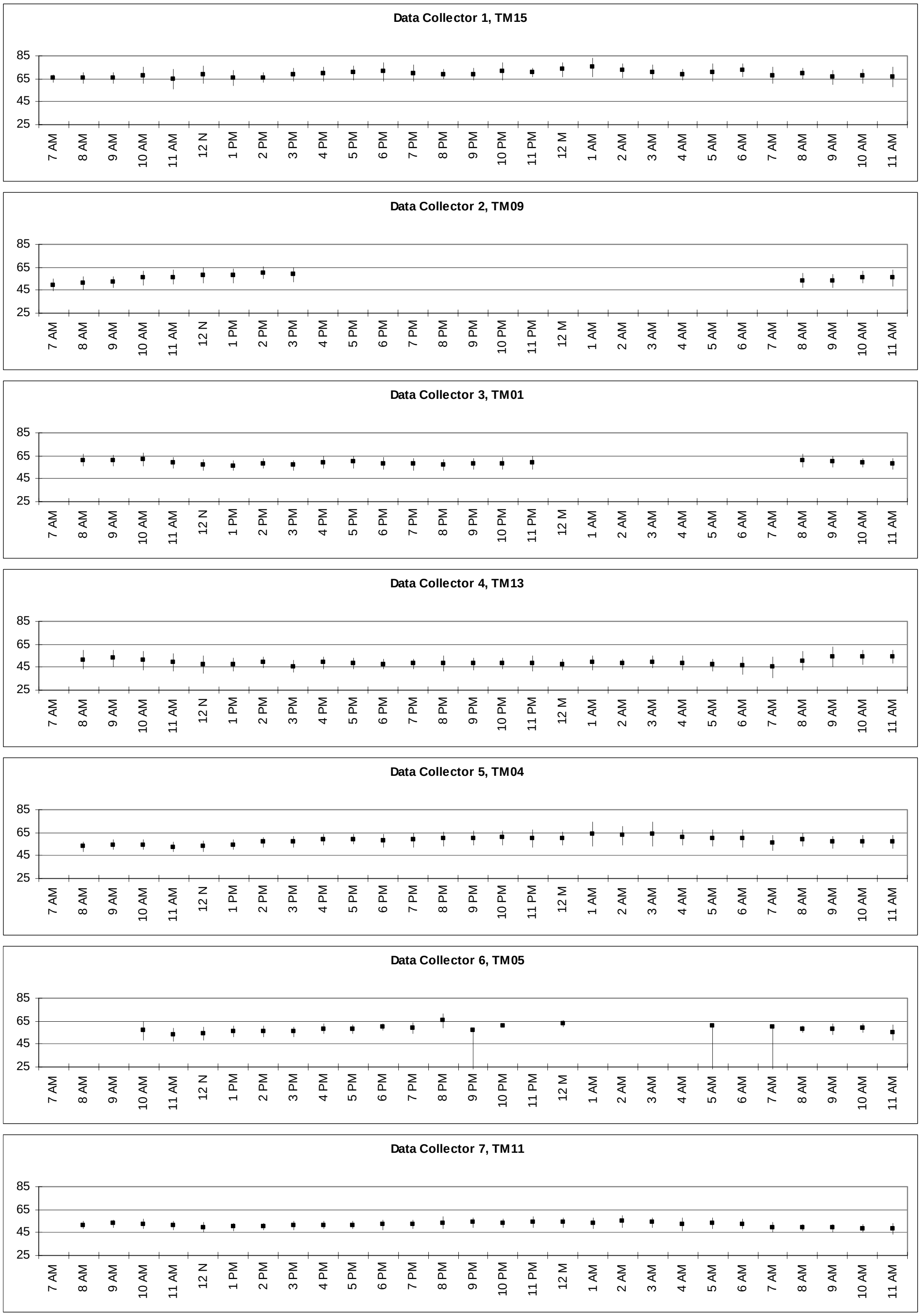

Figure A-18. Average Speed by Hour

I-15 south of Nephi

Wednesday, 16 October 2002 through Thursday, 17 October 2002

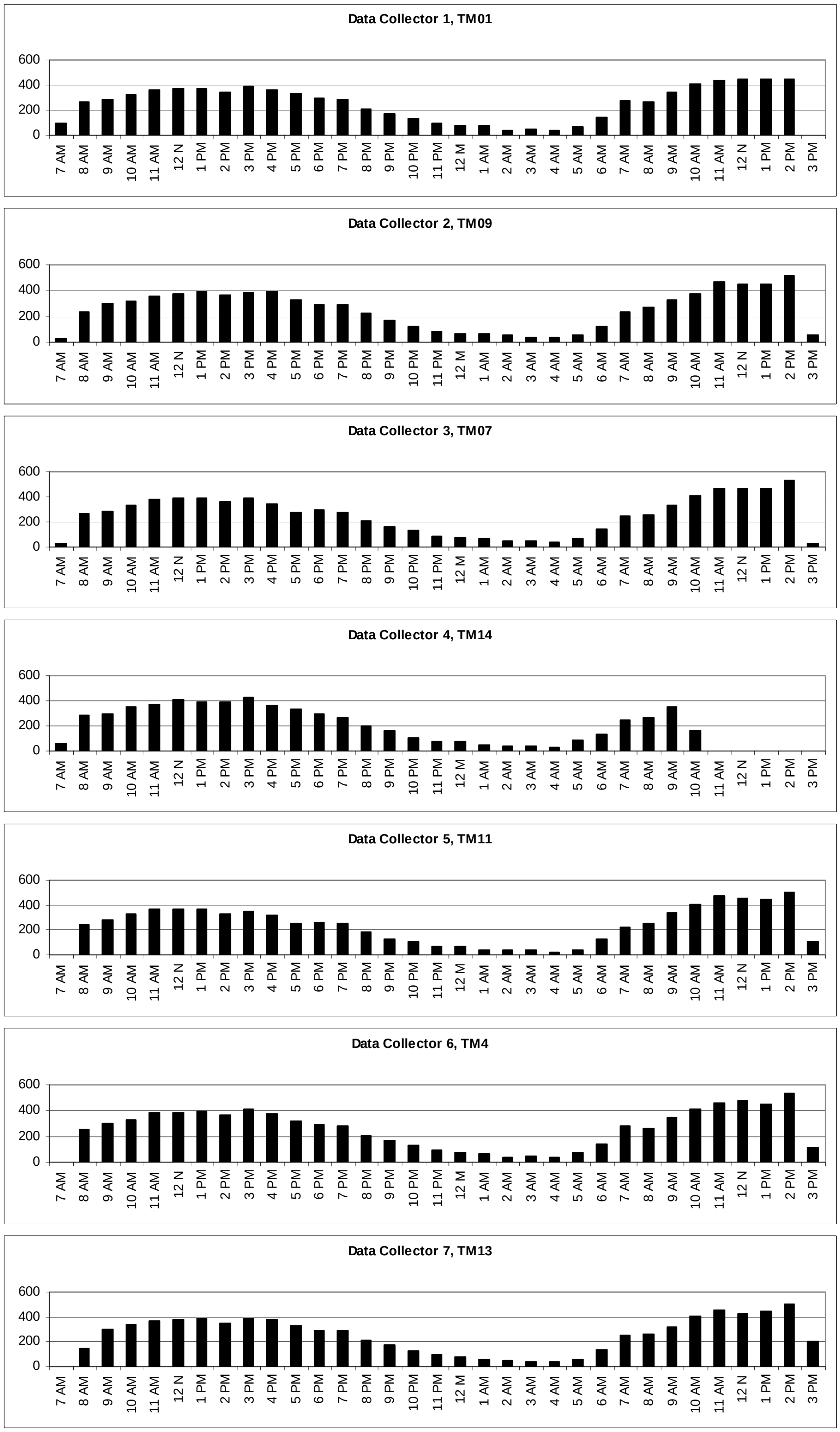

Figure A-19. Histogram of Hourly Volume
I-15 south of Nephi
Wednesday, 23 October 2002 through Thursday, 24 October 2002

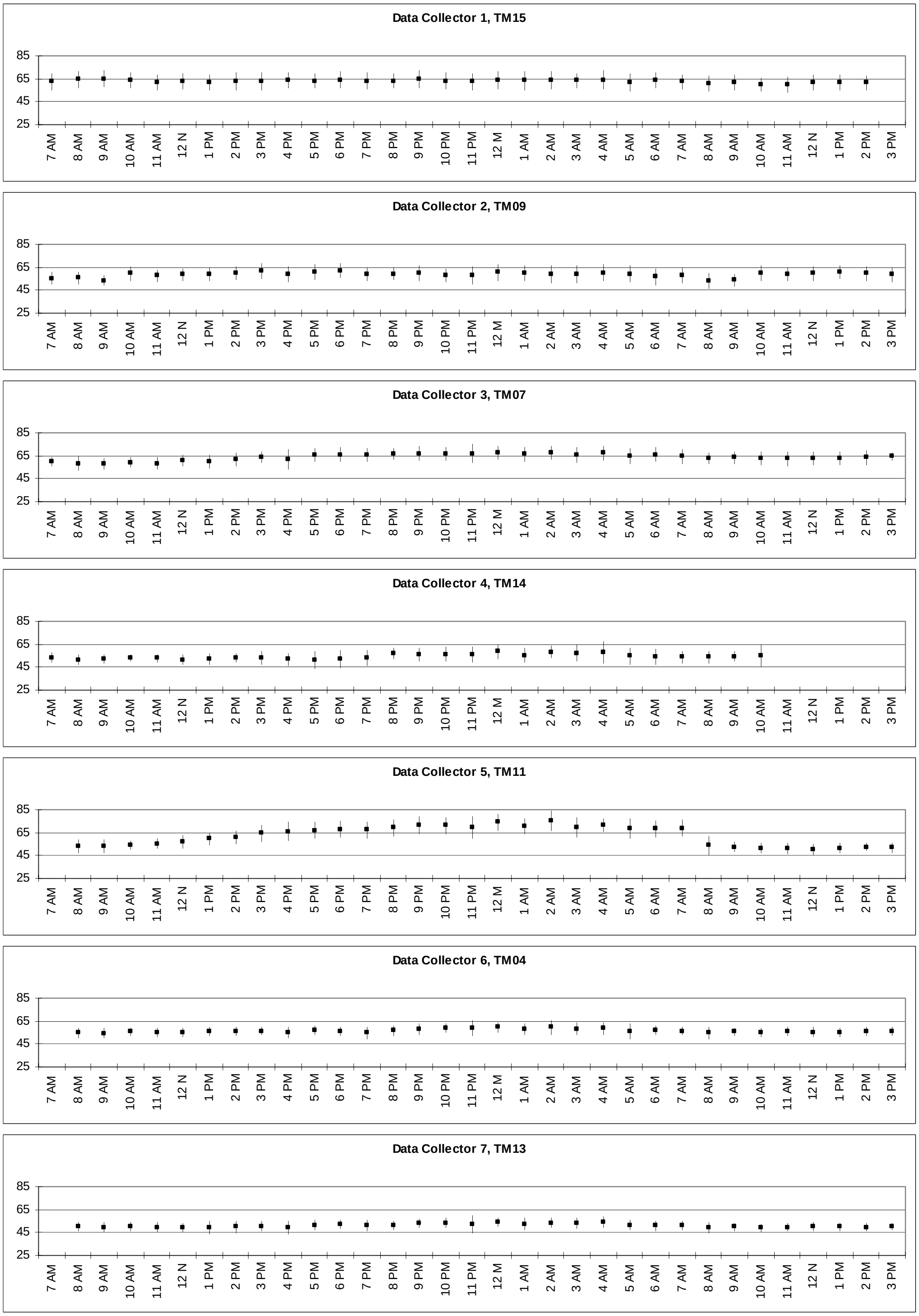

Figure A-20. Average Speed by Hour

I-15 south of Nephi

Wednesday, 23 October 2002 through Thursday, 24 October 2002

APPENDIX B

Compiled Average Speed Data

Table B-1. Speed Data for All Sites

Site	Normal Speed Limit	Workzone Speed Limit	Car	SMD	Police Stationed	Police Radar	Police Cruising	Initial Speed	Initial StdDev	Initial N	After Treatment Speed	After Treatment StdDev	After Treatment N	Final Speed	Final StdDev	Final N
Nephi	75	55	1	0	0	0	0	63.69	7.29	2478	62.23	7.21	1176	61.12	6.34	2929
Nephi			0	0	0	0	0	60.98	6.29	1114	59.38	3.92	328	59.20	6.03	1258
Nephi			1	1	0	0	0	63.37	5.83	5929	61.31	5.85	8494	51.63	5.96	7937
Nephi			0	1	0	0	0	61.68	5.29	2297	60.22	5.29	3626	50.78	5.56	3023
Nephi			1	0	1	1	0	63.82	7.10	1331	53.73	4.99	1767	54.39	6.45	2111
Nephi			0	0	1	1	0	61.01	5.92	407	53.10	5.10	638	53.51	5.72	713
Nephi			1	0	0	0	1	61.99	6.75	1509	58.28	5.42	2285	53.92	6.42	2111
Nephi			0	0	0	0	1	60.01	6.07	531	56.61	5.24	832	53.12	5.27	826
I-215 NB	65	55	1	0	0	0	0	66.59	9.42	8548	60.56	6.91	13950	59.77	5.31	12536
I-215 NB			0	0	0	0	0	67.10	13.35	2643	58.72	6.62	583	56.99	5.65	557
I-215 NB			1	1	0	0	0	62.94	7.41	34468	58.51	8.30	35640	60.49	6.67	20090
I-215 NB			0	1	0	0	0	64.34	9.76	6098	55.38	10.61	1227	59.48	7.84	889
I-215 SB	65	55	1	0	0	0	0	69.68	6.25	11991	62.92	6.85	1312	68.99	10.76	444
I-215 SB			0	0	0	0	0	68.85	7.37	1003	64.60	3.83	7	68.80	14.47	19
I-215 SB			1	1	0	0	0	75.84	8.93	62422	64.77	5.76	8309	56.50	5.59	40437
I-215 SB			0	1	0	0	0	77.36	8.91	3581	59.40	5.16	45	55.76	5.27	1218
I-80 EB 1	65	65	1	0	0	0	0	57.76	5.14	42	48.93	6.61	354	42.73	12.73	3
I-80 EB 1			0	0	0	0	0	57.51	12.47	14	45.44	5.70	36	0.00	0.00	0
I-80 EB 1			1	1	0	0	0	58.21	6.43	26	50.53	6.89	251	50.00	9.48	2
I-80 EB 1			0	1	0	0	0	48.81	6.94	13	48.37	7.28	55	39.90	0.00	1
I-80 EB 2	65	65	1	0	0	0	0	60.12	5.86	266	59.84	7.89	249	56.78	7.89	208
I-80 EB 2			0	0	0	0	0	53.24	4.72	36	54.75	7.14	38	53.64	7.14	20
I-80 EB 2			1	0	1	1	0	58.75	5.80	104	53.75	6.89	102	57.01	6.89	90
I-80 EB 2			0	0	1	1	0	55.19	4.38	29	52.12	4.59	30	52.80	4.59	17
I-80 EB 2			1	0	1	0	0	59.25	8.44	63	55.05	6.83	53	54.79	6.83	47
I-80 EB 2			0	0	1	0	0	55.49	7.28	20	51.27	6.62	21	51.57	6.62	13
I-80 WB	65	65	1	0	0	0	0	64.01	8.11	59	61.55	10.81	132	68.14	15.01	158
I-80 WB			0	0	0	0	0	61.55	2.39	4	58.80	7.22	34	61.48	8.76	31
I-80 WB			1	1	0	0	0	65.60	5.28	72	53.94	9.54	145	64.54	14.50	184
I-80 WB			0	1	0	0	0	61.75	6.55	10	51.71	7.86	51	61.92	10.74	34
I-80 WB			1	0	1	0	0	65.60	5.28	72	30.51	10.74	7	64.54	14.50	184
I-80 WB			0	0	1	0	0	61.75	6.55	10			0	61.92	10.74	34

Table B-2. Speed Data for I-15 South of Nephi

Site	Normal Speed Limit	Workzone Speed Limit	Car	SMD	Police Stationed	Police Radar	Police Cruising	DC1 Speed	DC1 StDev	DC1 N	DC2 Speed	DC2 StDev	DC2 N	DC3 Speed	DC3 StDev	DC3 N	DC4 Speed	DC4 StDev	DC4 N	DC5 Speed	DC5 StDev	DC5 N	DC6 Speed	DC6 StDev	DC6 N	DC7 Speed	DC7 StDev	DC7 N
Nephi	75	55	1	0	0	0	0	63.69	7.29	2478	62.23	7.73	1176	60.38	7.21	77	61.12	6.34	2929	57.83	5.63	1415	55.87	7.62	2312	57.94	5.75	823
Nephi			0	0	0	0	0	60.98	6.29	1114	59.38	7.62	328	59.19	3.92	19	59.20	6.03	1258	56.80	5.18	693	54.69	8.29	984	56.67	5.21	176
Nephi			1	1	0	0	0	63.79	7.05	3803	60.31	6.51	4226	61.60	6.11	5588	50.82	6.11	5392	60.30	7.01	6091	56.21	4.45	3839	51.17	4.55	6195
Nephi			0	1	0	0	0	62.07	6.66	1628	57.73	5.71	1863	60.48	5.29	2585	50.00	5.68	2143	58.29	6.93	2019	56.10	4.42	1730	50.72	4.37	2572
Nephi			1	0	1	1	0	64.53	7.03	403	53.65	6.02	629	61.43	5.04	395	57.13	6.79	736	57.51	4.99	736	52.67	7.33	367	52.65	4.68	279
Nephi			0	0	1	1	0	60.09	5.60	131	52.66	5.60	239	60.39	4.41	151	55.20	5.94	295	56.15	4.56	270	49.51	9.26	139	51.87	4.57	102
Nephi			1	0	0	0	1	62.09	7.07	311	57.27	5.91	741	60.58	5.94	586	54.02	7.20	941	55.72	5.13	959	51.54	8.05	445	51.84	4.98	571
Nephi			0	0	0	0	1	59.36	5.90	138	56.56	6.08	288	59.81	4.95	216	53.32	5.75	364	54.75	4.30	421	50.73	8.63	187	51.29	3.62	213
Nephi			1	1	1	1	0	63.51	7.13	928	53.78	5.63	1138	61.03	4.97	1252	52.93	6.26	1375	54.87	5.90	1311	55.22	4.21	918	49.42	3.54	1206
Nephi			0	1	1	1	0	61.44	6.06	276	53.37	5.39	399	59.38	5.47	433	52.32	5.56	418	54.23	6.25	377	54.76	4.85	327	49.41	4.26	409
Nephi			1	1	0	0	1	61.97	6.66	1198	58.77	6.07	1544	60.57	5.15	1654	53.84	5.71	1170	54.25	4.81	1708	55.43	3.93	1287	49.17	3.99	1721
Nephi			0	1	0	0	1	60.24	6.13	393	56.64	5.75	544	59.70	5.39	608	52.96	4.85	462	53.58	4.81	549	55.10	4.13	449	48.83	3.74	600

Table B-3. Speed Data for I-80 West

Site	Normal Speed Limit	Workzone Speed Limit	Car	SMD	Police Stationed	Police Radar	Police Cruising	DC1 Speed	DC1 StDev	DC1 N	DC2 Speed	DC2 StDev	DC2 N	DC3 Speed	DC3 StDev	DC3 N	DC4 Speed	DC4 StDev	DC4 N	DC5 Speed	DC5 StDev	DC5 N
I-80 WB	65	65	1	0	0	0	0	64.01	8.11	59	63.82	9.24	70	61.55	10.81	132	56.00	8.12	252	68.14	15.01	158
I-80 WB			0	0	0	0	0	61.55	2.39	4	57.36	6.97	21	58.80	7.22	34	51.90	7.04	26	61.48	8.76	31
I-80 WB			1	1	1	1	0	66.40	5.33	28	30.78	6.01	5	54.36	11.81	62	54.25	9.12	121	64.43	15.34	95
I-80 WB			0	1	1	1	0	62.29	7.25	8			0	51.09	6.88	32	48.97	7.08	33	59.69	11.39	14
I-80 WB			1	1	1	0	0	65.09	5.25	44	29.85	4.31	2	53.63	7.41	83	54.40	6.90	120	64.66	13.55	89
I-80 WB			0	1	1	0	0	59.60	1.98	2			0	52.76	9.27	19	48.48	8.09	14	63.49	10.27	20

APPENDIX C

Field Data SAS Code and Output

SAS Code for Field Study Data:

```
*********************************************************************;
/*Traffic Data Revisited*/
options page no=1 ls=72 ps=2000;
DATA traffic all;
  INFILE 'd:\consulting\jbowie\smdallsites.csv' dlm = "," firstobs=2 missover;
  INPUT site $ nsl wsl car smd police prad pcru spd1 stdev1 n1 spd2 stdev2 n2 spd3 stdev3
n3;
  sp1dsl = spd1/nsl;
  sp2dsl = spd2/wsl;
  sp3dsl = spd3/wsl;
  sp1 cov = spd1/spd1;
  sp2_cov = spd2/spd1;
  sp3 cov = spd3/spd1;
  if (site = 'I-215 SB') then delete;
  if (smd = 0) then if (police = 0) then treatment = "nothing";
              else treatment = "police";
       else treatment = "smd";
  drop prad pcru smd police;
run;
PROC SORT data=traffic all;
  by site car treatment nsl wsl;
run;
PROC TRANSPOSE data=traffic_all out=a1;
  var sp1dsl sp2dsl sp3dsl;
  by site car treatment;
run;
data a11;
  set a1;
  rename col1 = spdsl;
  drop col2 /* = spdsl2*/;
run;
PROC TRANSPOSE data=traffic all out=a2;
  var sp1 cov sp2 cov sp3_cov;
  by site car treatment;
run;
data a22;
  set a2;
  rename col1 = cov;
  drop col2 /* = cov2*/;
run;
PROC TRANSPOSE data=traffic_all out=a4;
  var n1 n2 n3;
  by site car treatment;
run;
data a44;
  set a4;
  rename col1 = n;
  drop col2;
run;
PROC TRANSPOSE data=traffic_all out=a3;
  var spd1 spd2 spd3;
  by site car treatment;
run;
data a33;
  set a3;
  rename col1 = speed;
  drop col2;
run;
data combined;
  merge a11 a22 a33 a44;
  by site car treatment;
  initial = speed/cov;
  rename _name_=measurement;
run;
options ls=80 pageno=1;
/*full model: site car site*car treatment site*treatment car*treatment measurement
site*measurement car*measurement treatment*measurement*/
```

```
PROC GLM data = combined;
  class site car treatment measurement;
  model spdsl = site car treatment measurement site*measurement treatment*measurement;
  weight n;
  lsmeans site car treatment measurement site*measurement treatment*measurement /pdiff
stderr;
run;
/*Remove
       site*car                      (p=.9529)
       site*treatment         (p=.8751)
       car*treatment          (p=.6036)
       car*measurement               (p=.2765)*/
data combined cov;
  set combined;
  if (measurement = "n1") then delete;
run;
PROC GLM data = combined_cov;
  class site car treatment measurement;
  model cov = initial site treatment measurement site*measurement treatment*measurement /
solution;
  weight n;
  lsmeans site treatment measurement site*measurement treatment*measurement /pdiff
stderr;
run;
/*Removed Parameters
       car*measurement                                     (p=.9682)
       car*treatment                                (p=.9139)
       site*car                                            (p=.7941)
       site*treatment                               (p=.4463)
       car                                                        (p=.1356)*/
/*Analysis for the I-80WB Site*/
DATA traffic i80wb;
  INFILE 'd:\consulting\jbowie\smdi-80wb.csv' dlm = "," firstobs=3 missover;
  INPUT site $ nsl wsl car smd police prad pcru spd1 stdev1 n1 spd2 stdev2 n2 spd3 stdev3
n3 spd4 stdev4 n4 spd5 stdev5 n5;
  sp1dsl = spd1/nsl;
  sp2dsl = spd2/wsl;
  sp3dsl = spd3/wsl;
  sp4dsl = spd4/wsl;
  sp5dsl = spd5/wsl;
  sp1 cov = spd1/spd1;
  sp2 cov = spd2/spd1;
  sp3 cov = spd3/spd1;
  sp4 cov = spd4/spd1;
  sp5 cov = spd5/spd1;
  if (smd = 0) then if (police = 0) then treatment = "nothing";
               else treatment = "police";
       else treatment = "smd";
  drop prad pcru site smd police;
run;
PROC SORT data=traffic_i80wb;
  by car treatment nsl wsl;
run;
PROC TRANSPOSE data=traffic i80wb out=a1;
  var sp1dsl sp2dsl sp3dsl sp4dsl sp5dsl;
  by car treatment;
run;
data a11;
  set a1;
  rename col1 = spdsl;
run;
PROC TRANSPOSE data=traffic i80wb out=a2;
  var sp1 cov sp2 cov sp3_cov sp4_cov sp5_cov;
  by car treatment;
run;
data a22;
  set a2;
  rename col1 = cov;
run;
PROC TRANSPOSE data=traffic_i80wb out=a4;
  var n1 n2 n3 n4 n5;
  by car treatment;
run;
data a44;
  set a4;
  rename col1 = n;
run;
```

```
PROC TRANSPOSE data=traffic_i80wb out=a3;
  var spd1 spd2 spd3 spd4 spd5;
  by car treatment;
run;
data a33;
  set a3;
  rename col1 = speed;
run;
data combined_i80wb;
  merge a11 a22 a33 a44;
  by car treatment;
  initial = speed/cov;
  rename _name_ = measurement;
run;
/*full model: car treatment car*treatment measurement car*measurement
treatment*measurement*/
PROC GLM data = combined_i80wb;
  class car treatment measurement;
  model spdsl = car treatment measurement treatment*measurement;
  weight n;
  lsmeans car treatment measurement treatment*measurement /pdiff stderr;
run;
/*Remove
       car*measurement               (p=.4770)
       car*treatment                 (p=.1379)
*/
data combined_i80wb_cov;
  set combined_i80wb;
  if (measurement = "n1") then delete;
run;
PROC GLM data = combined_i80wb_cov;
  class car treatment measurement;
  model cov = initial car treatment measurement treatment*measurement / solution;
  weight n;
  lsmeans car treatment measurement treatment*measurement /pdiff stderr;
run;
/*Removed Parameters
       car*measurement                                     (p=.6403)
       car*treatment                               (p=.0486)
*/
/*Analysis for the Nephi Site*/
DATA traffic_nephi;
  INFILE 'd:\consulting\jbowie\smdnephi.csv' dlm = "," firstobs=3 missover;
  INPUT site $ nsl wsl car smd pstat prad pcru spd1 stdev1 n1 spd2 stdev2 n2 spd3 stdev3
n3 spd4 stdev4 n4 spd5 stdev5 n5 spd6 stdev6 n6 spd7 stdev7 n7;
  sp1dsl = spd1/nsl;
  sp2dsl = spd2/wsl;
  sp3dsl = spd3/wsl;
  sp4dsl = spd4/wsl;
  sp5dsl = spd5/wsl;
  sp6dsl = spd6/wsl;
  sp7dsl = spd7/wsl;
  sp1_cov = spd1/spd1;
  sp2_cov = spd2/spd1;
  sp3_cov = spd3/spd1;
  sp4_cov = spd4/spd1;
  sp5_cov = spd5/spd1;
  sp6_cov = spd6/spd1;
  sp7_cov = spd7/spd1;
  police = pstat + 2*pcru;
  if (smd = 0) then if (police = 0) then treatment = "nothing";
             else if (police = 1) then treatment = "p_station";
                    else treatment = "p_crusing";
       else treatment = "smd";
  drop prad pstat pcru site smd police;
run;
PROC SORT data=traffic_nephi;
  by car treatment nsl wsl;
run;
PROC TRANSPOSE data=traffic_nephi out=a1;
  var sp1dsl sp2dsl sp3dsl sp4dsl sp5dsl sp6dsl sp7dsl;
  by car treatment;
run;
data a11;
  set a1;
  rename col1 = spdsl;
run;
```

```
PROC TRANSPOSE data=traffic_nephi out=a2;
  var sp1 cov sp2 cov sp3_cov sp4_cov sp5_cov sp6_cov sp7_cov;
  by car treatment;
run;
data a22;
  set a2;
  rename col1 = cov;
run;
PROC TRANSPOSE data=traffic_nephi out=a4;
  var n1 n2 n3 n4 n5 n6 n7;
  by car treatment;
run;
data a44;
  set a4;
  rename col1 = n;
run;

PROC TRANSPOSE data=traffic nephi out=a3;
  var spd1 spd2 spd3 spd4 spd5 spd6 spd7;
  by car treatment;
run;
data a33;
  set a3;
  rename col1 = speed;
run;

data combined nephi;
  merge a11 a22 a33 a44;
  by car treatment;
  initial = speed/cov;
  rename _name_ = measurement;
run;
/*full model: car treatment car*treatment measurement car*measurement
treatment*measurement*/
PROC GLM data = combined_nephi;
  class car treatment measurement;
  model spdsl = car treatment car*treatment measurement car*measurement
treatment*measurement;
  weight n;
  lsmeans car treatment car*treatment measurement car*measurement treatment*measurement
/pdiff stderr;
*  means car smd police measurement police*measurement / duncan;
run;
/*Removed nothing
*/
data combined nephi cov;
  set combined nephi;
  if (measurement = "n1") then delete;
run;
PROC GLM data = combined nephi cov;
  class car treatment measurement;
  model cov = initial car treatment measurement car*measurement treatment*measurement /
solution;
  weight n;
  lsmeans car treatment measurement car*measurement treatment*measurement /pdiff stderr;
run;
/*Removed Parameters
       car*treatment                                (p=.2049)
*/
```

SAS Output for All Sites, Dependent Variable SPDSL:

```
                          The SAS System                                   1
                                                   14:09 Monday, March 24, 2003

                         The GLM Procedure

                      Class Level Information

      Class            Levels    Values

      site                  5    I-215 NB I-80 EB1 I-80 EB2 I-80 WB Nephi

      car                   2    0 1

      treatment             3    nothing police smd

      measurement           3    n1 n2 n3


                    Number of observations    72

NOTE: Due to missing values, only 70 observations can be used in this analysis.
```

Table C-1. ANOVA Table for All Sites, Dependent Variable SPDSL

The SAS System 2
14:09 Monday, March 24, 2003

The GLM Procedure

Dependent Variable: spdsl

Weight: n

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	1111.606581	52.933647	26.81	<.0001
Error	48	94.787448	1.974739		
Corrected Total	69	1206.394029			

R-Square	Coeff Var	Root MSE	spdsl Mean
0.921429	137.1651	1.405254	1.024498

Source	DF	Type I SS	Mean Square	F Value	Pr > F
site	4	238.3480327	59.5870082	30.17	<.0001
car	1	16.1985197	16.1985197	8.20	0.0062
treatment	2	58.7414208	29.3707104	14.87	<.0001
measurement	2	559.0583623	279.5291811	141.55	<.0001
site*measurement	8	209.1523771	26.1440471	13.24	<.0001
treatment*measuremen	4	30.1078689	7.5269672	3.81	0.0090

Source	DF	Type III SS	Mean Square	F Value	Pr > F
site	4	169.4387071	42.3596768	21.45	<.0001
car	1	2.4291221	2.4291221	1.23	0.2729
treatment	2	59.9934897	29.9967448	15.19	<.0001
measurement	2	0.4080115	0.2040057	0.10	0.9020
site*measurement	8	233.4238629	29.1779829	14.78	<.0001
treatment*measurement	4	30.1078689	7.5269672	3.81	0.0090

The GLM Procedure
Least Squares Means

site	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
I-215 NB	1.03582673	0.00830555	<.0001	1
I-80 EB1	0.74959152	0.19809215	0.0004	2
I-80 EB2	0.86786402	0.04127028	<.0001	3
I-80 WB	0.93690675	0.04397246	<.0001	4
Nephi	0.96637264	0.00778215	<.0001	5

Least Squares Means for effect site
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3	4	5
1		0.1548	0.0002	0.0300	<.0001
2	0.1548		0.5615	0.3603	0.2793
3	0.0002	0.5615		0.2563	0.0228
4	0.0300	0.3603	0.2563		0.5100
5	<.0001	0.2793	0.0228	0.5100	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

car	spdsl LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1= LSMean2 Pr > |t|
0	0.90585231	0.04234817	<.0001	0.2729
1	0.91677236	0.04157840	<.0001	

Table C-2. Treatment Effect for All Sites, Dependent Variable SPDSL

treatment	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	0.94733131	0.04179381	<.0001	1
police	0.87665260	0.04432071	<.0001	2
smd	0.90995309	0.04175050	<.0001	3

Least Squares Means for effect treatment
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3
1		0.0004	<.0001
2	0.0004		0.0704
3	<.0001	0.0704	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

measurement	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
n1	0.91563311	0.03760202	<.0001	1
n2	0.89676238	0.02419477	<.0001	2
n3	0.92154151	0.11648038	<.0001	3

Least Squares Means for effect measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3
1		0.6733	0.9617
2	0.6733		0.8358
3	0.9617	0.8358	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

site	measurement	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
I-215 NB	n1	0.99046883	0.01379234	<.0001	1
I-215 NB	n2	1.02586901	0.01281160	<.0001	2
I-215 NB	n3	1.09114236	0.01280677	<.0001	3
I-80 EB1	n1	0.86338111	0.14466492	<.0001	4
I-80 EB1	n2	0.70301904	0.05439216	<.0001	5
I-80 EB1	n3	0.68237441	0.57377672	0.2402	6
I-80 EB2	n1	0.88717791	0.06764427	<.0001	7
I-80 EB2	n2	0.86414535	0.06887760	<.0001	8
I-80 EB2	n3	0.85226881	0.07700954	<.0001	9
I-80 WB	n1	0.99417841	0.09335582	<.0001	10
I-80 WB	n2	0.81919113	0.07383014	<.0001	11
I-80 WB	n3	0.99735072	0.05631304	<.0001	12
Nephi	n1	0.84295932	0.01427177	<.0001	13
Nephi	n2	1.07158735	0.01305542	<.0001	14
Nephi	n3	0.98457126	0.01194313	<.0001	15

Least Squares Means for effect site*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3	4	5	6	7	8
1		0.0551	<.0001	0.3832	<.0001	0.5939	0.1404	0.0778
2	0.0551		0.0003	0.2685	<.0001	0.5523	0.0488	0.0249
3	<.0001	0.0003		0.1232	<.0001	0.4796	0.0046	0.0021
4	0.3832	0.2685	0.1232		0.3045	0.7610	0.8820	0.9962
5	<.0001	<.0001	<.0001	0.3045		0.9716	0.0387	0.0716
6	0.5939	0.5523	0.4796	0.7610	0.9716		0.7245	0.7545
7	0.1404	0.0488	0.0046	0.8820	0.0387	0.7245		0.8122
8	0.0778	0.0249	0.0021	0.9962	0.0716	0.7545	0.8122	
9	0.0831	0.0304	0.0035	0.9462	0.1194	0.7704	0.7346	0.9089
10	0.9688	0.7376	0.3077	0.4512	0.0096	0.5942	0.3576	0.2675
11	0.0268	0.0071	0.0007	0.7867	0.2055	0.8140	0.5000	0.6576
12	0.9057	0.6221	0.1097	0.3923	0.0005	0.5874	0.2160	0.1403
13	<.0001	<.0001	<.0001	0.8884	0.0161	0.7808	0.5249	0.7642
14	<.0001	0.0019	0.2758	0.1581	<.0001	0.5009	0.0100	0.0048
15	0.7425	0.0184	<.0001	0.4078	<.0001	0.6009	0.1620	0.0909

Least Squares Means for effect site*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	9	10	11	12	13	14	15
1	0.0831	0.9688	0.0268	0.9057	<.0001	<.0001	0.7425
2	0.0304	0.7376	0.0071	0.6221	<.0001	0.0019	0.0184
3	0.0035	0.3077	0.0007	0.1097	<.0001	0.2758	<.0001
4	0.9462	0.4512	0.7867	0.3923	0.8884	0.1581	0.4078
5	0.1194	0.0096	0.2055	0.0005	0.0161	<.0001	<.0001
6	0.7704	0.5942	0.8140	0.5874	0.7808	0.5009	0.6009
7	0.7346	0.3576	0.5000	0.2160	0.5249	0.0100	0.1620
8	0.9089	0.2675	0.6576	0.1403	0.7642	0.0048	0.0909
9		0.2463	0.7576	0.1344	0.9058	0.0071	0.0960
10	0.2463		0.1477	0.9769	0.1158	0.4152	0.9190
11	0.7576	0.1477		0.0607	0.7531	0.0014	0.0316
12	0.1344	0.9769	0.0607		0.0105	0.2043	0.8249
13	0.9058	0.1158	0.7531	0.0105		<.0001	<.0001
14	0.0071	0.4152	0.0014	0.2043	<.0001		<.0001

15	0.0960	0.9190	0.0316	0.8249	<.0001	<.0001

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table C-3. Treatment*Measurement Effect for All Sites, Dependent Variable SPDSL

treatment	measurement	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	n1	0.93866124	0.03814190	<.0001	1
nothing	n2	0.96288608	0.02439586	<.0001	2
nothing	n3	0.94044661	0.11668364	<.0001	3
police	n1	0.91260566	0.04715698	<.0001	4
police	n2	0.79860231	0.03604593	<.0001	5
police	n3	0.91874984	0.11866920	<.0001	6
smd	n1	0.89563244	0.03802961	<.0001	7
smd	n2	0.92879875	0.02390708	<.0001	8
smd	n3	0.90542809	0.11664133	<.0001	9

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3	4	5
1		0.5936	0.9885	0.4673	0.0101
2	0.5936		0.8514	0.3465	<.0001
3	0.9885	0.8514		0.8257	0.2508
4	0.4673	0.3465	0.8257		0.0599
5	0.0101	<.0001	0.2508	0.0599	
6	0.8737	0.7170	0.4592	0.9618	0.3371
7	0.0020	0.1411	0.7164	0.6279	0.0691
8	0.8268	0.0104	0.9224	0.7598	<.0001
9	0.7876	0.6316	0.0111	0.9547	0.3856

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	6	7	8	9
1	0.8737	0.0020	0.8268	0.7876
2	0.7170	0.1411	0.0104	0.6316
3	0.4592	0.7164	0.9224	0.0111
4	0.9618	0.6279	0.7598	0.9547
5	0.3371	0.0691	<.0001	0.3856
6		0.8535	0.9341	0.6350
7	0.8535		0.4616	0.9366
8	0.9341	0.4616		0.8451
9	0.6350	0.9366	0.8451	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

SAS Output for All Sites, Dependent Variable COV:

```
                          The SAS System                                4
                                               14:09 Monday, March 24, 2003

                         The GLM Procedure

                      Class Level Information

      Class            Levels    Values

      site                  5    I-215 NB I-80 EB1 I-80 EB2 I-80 WB Nephi

      car                   2    0 1

      treatment             3    nothing police smd

      measurement           2    n2 n3


                    Number of observations    48

NOTE: Due to missing values, only 46 observations can be used in this analysis.
```

Table C-4. ANOVA Table for All Sites, Dependent Variable COV

The SAS System 5

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The GLM Procedure

Dependent Variable: cov

Weight: n

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	196.9467973	14.0676284	8.06	<.0001
Error	31	54.1140120	1.7456133		
Corrected Total	45	251.0608092			

R-Square	Coeff Var	Root MSE	cov Mean
0.784459	143.5582	1.321217	0.920335

Source	DF	Type I SS	Mean Square	F Value	Pr > F
initial	1	12.11432749	12.11432749	6.94	0.0130
site	4	39.28529155	9.82132289	5.63	0.0016
treatment	2	26.57788488	13.28894244	7.61	0.0020
measurement	1	8.04331788	8.04331788	4.61	0.0398
site*measurement	4	90.49266523	22.62316631	12.96	<.0001
treatment*measurement	2	20.43331026	10.21665513	5.85	0.0070

Source	DF	Type III SS	Mean Square	F Value	Pr > F
initial	1	58.2337948	58.2337948	33.36	<.0001
site	4	29.7777802	7.4444450	4.26	0.0073
treatment	2	44.8078286	22.4039143	12.83	<.0001
measurement	1	0.0690641	0.0690641	0.04	0.8436
site*measurement	4	107.7626368	26.9406592	15.43	<.0001
treatment*measurement	2	20.4333103	10.2166551	5.85	0.0070

Parameter		Estimate	Standard Error	t Value
Intercept		2.442595354 B	0.27435207	8.90
initial		-0.025465289	0.00440895	-5.78
site	I-215 NB	0.109054707 B	0.01398871	7.80
site	I-80 EB1	-0.243262989 B	0.54039014	-0.45
site	I-80 EB2	-0.030003619 B	0.07668269	-0.39
site	I-80 WB	0.182857375 B	0.05430703	3.37
site	Nephi	0.000000000 B	.	.
treatment	nothing	0.059663313 B	0.01687045	3.54
treatment	police	0.023078423 B	0.02657507	0.87
treatment	smd	0.000000000 B	.	.
measurement	n2	0.122300189 B	0.01605339	7.62
measurement	n3	0.000000000 B	.	.
site*measurement	I-215 NB n2	-0.140343573 B	0.01843250	-7.61
site*measurement	I-215 NB n3	0.000000000 B	.	.
site*measurement	I-80 EB1 n2	-0.038207536 B	0.54195996	-0.07
site*measurement	I-80 EB1 n3	0.000000000 B	.	.
site*measurement	I-80 EB2 n2	-0.072706638 B	0.09865469	-0.74
site*measurement	I-80 EB2 n3	0.000000000 B	.	.
site*measurement	I-80 WB n2	-0.262229858 B	0.08838414	-2.97
site*measurement	I-80 WB n3	0.000000000 B	.	.
site*measurement	Nephi n2	0.000000000 B	.	.
site*measurement	Nephi n3	0.000000000 B	.	.
treatment*measurement	nothing n2	0.005188911 B	0.01750680	0.30
treatment*measurement	nothing n3	0.000000000 B	.	.
treatment*measurement	police n2	-0.130688303 B	0.03884073	-3.36
treatment*measurement	police n3	0.000000000 B	.	.
treatment*measurement	smd n2	0.000000000 B	.	.
treatment*measurement	smd n3	0.000000000 B	.	.

Parameter		Pr > |t|
Intercept		<.0001
initial		<.0001
site	I-215 NB	<.0001
site	I-80 EB1	0.6557
site	I-80 EB2	0.6983
site	I-80 WB	0.0020
site	Nephi	.
treatment	nothing	0.0013
treatment	police	0.3918
treatment	smd	.
measurement	n2	<.0001
measurement	n3	.
site*measurement	I-215 NB n2	<.0001
site*measurement	I-215 NB n3	.
site*measurement	I-80 EB1 n2	0.9442
site*measurement	I-80 EB1 n3	.
site*measurement	I-80 EB2 n2	0.4667
site*measurement	I-80 EB2 n3	.
site*measurement	I-80 WB n2	0.0058
site*measurement	I-80 WB n3	.
site*measurement	Nephi n2	.
site*measurement	Nephi n3	.
treatment*measurement	nothing n2	0.7689
treatment*measurement	nothing n3	.
treatment*measurement	police n2	0.0021
treatment*measurement	police n3	.
treatment*measurement	smd n2	.
treatment*measurement	smd n3	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

The GLM Procedure
Least Squares Means

site	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
I-215 NB	0.99287609	0.01680517	<.0001	1
I-80 EB1	0.69162641	0.27169518	0.0161	2
I-80 EB2	0.88763623	0.05047324	<.0001	3
I-80 WB	1.00573561	0.04579553	<.0001	4
Nephi	0.95399316	0.01357421	<.0001	5

Least Squares Means for effect site
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3	4	5
1		0.2786	0.0741	0.7714	0.0005
2	0.2786		0.4818	0.2646	0.3436
3	0.0741	0.4818		0.1060	0.2381
4	0.7714	0.2646	0.1060		0.2510
5	0.0005	0.3436	0.2381	0.2510	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table C-5. Treatment Effect for All Sites, Dependent Variable COV

treatment	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	0.96196725	0.05661411	<.0001	1
police	0.85744376	0.05826128	<.0001	2
smd	0.89970949	0.05609605	<.0001	3

Least Squares Means for effect treatment
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3
1		<.0001	0.0003
2	<.0001		0.0400
3	0.0003	0.0400	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

measurement	cov LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1= LSMean2 Pr > |t|
n2	0.89525827	0.02254861	<.0001	0.8436
n3	0.91748873	0.10947394	<.0001	

site	measurement	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
I-215 NB	n2	0.96293783	0.01820940	<.0001	1
I-215 NB	n3	1.02281434	0.01897036	<.0001	2

I-80 EB1	n2	0.71275617	0.05464214	<.0001	3
I-80 EB1	n3	0.67049665	0.53986955	0.2236	4
I-80 EB2	n2	0.89151644	0.06641057	<.0001	5
I-80 EB2	n3	0.88375602	0.07344235	<.0001	6
I-80 WB	n2	0.91485421	0.07047815	<.0001	7
I-80 WB	n3	1.09661701	0.05508725	<.0001	8
Nephi	n2	0.99422669	0.01687829	<.0001	9
Nephi	n3	0.91375964	0.01481677	<.0001	10

Least Squares Means for effect site*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: cov

i/j	1	2	3	4	5
1		0.0007	0.0003	0.5925	0.3284
2	0.0007		<.0001	0.5194	0.0791
3	0.0003	<.0001		0.9383	0.0377
4	0.5925	0.5194	0.9383		0.6870
5	0.3284	0.0791	0.0377	0.6870	
6	0.3183	0.0859	0.0632	0.6979	0.9368
7	0.4916	0.1349	0.0337	0.6570	0.8146
8	0.0191	0.1823	<.0001	0.4388	0.0280
9	0.0233	0.1006	<.0001	0.5536	0.1592
10	0.0052	<.0001	0.0021	0.6557	0.7535

Least Squares Means for effect site*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	6	7	8	9	10
1	0.3183	0.4916	0.0191	0.0233	0.0052
2	0.0859	0.1349	0.1823	0.1006	<.0001
3	0.0632	0.0337	<.0001	<.0001	0.0021
4	0.6979	0.6570	0.4388	0.5536	0.6557
5	0.9368	0.8146	0.0280	0.1592	0.7535
6		0.7655	0.0306	0.1631	0.6983
7	0.7655		0.0456	0.2641	0.9877
8	0.0306	0.0456		0.0690	0.0020
9	0.1631	0.2641	0.0690		<.0001
10	0.6983	0.9877	0.0020	<.0001	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table C-6. Treatment*Measurement Effect for All Sites, Dependent Variable COV

treatment	measurement	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	n2	0.97436304	0.02452924	<.0001	1
nothing	n3	0.94957146	0.10991438	<.0001	2
police	n2	0.80190094	0.03380232	<.0001	3
police	n3	0.91298657	0.11152043	<.0001	4
smd	n2	0.90951082	0.02277310	<.0001	5
smd	n3	0.88990815	0.10968800	<.0001	6

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3	4	5	6
1		0.8263	<.0001	0.5946	0.0014	0.4593
2	0.8263		0.2091	0.2045	0.7243	0.0013
3	<.0001	0.2091		0.3479	0.0007	0.4487
4	0.5946	0.2045	0.3479		0.9758	0.3918
5	0.0014	0.7243	0.0007	0.9758		0.8620
6	0.4593	0.0013	0.4487	0.3918	0.8620	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

SAS Output for I-80 West Site, Dependent Variable SPDSL:

```
                    The SAS System                            7
                                   14:09 Monday, March 24, 2003

                   The GLM Procedure

                Class Level Information

     Class            Levels    Values

     car                   2    0 1

     treatment             3    nothing police smd

     measurement           5    n1 n2 n3 n4 n5


              Number of observations    30

NOTE: Due to missing values, only 28 observations can be used in this analysis.
```

Table C-7. ANOVA Table for I-80 West, Dependent Variable SPDSL

```
                             The SAS System                                  8
                                              14:09 Monday, March 24, 2003

                           The GLM Procedure

Dependent Variable: spdsl

Weight: n

                                          Sum of
 Source                      DF          Squares    Mean Square   F Value   Pr > F

 Model                       15      12.27637808     0.81842521     57.55   <.0001

 Error                       12       0.17064920     0.01422077

 Corrected Total             27      12.44702728


               R-Square     Coeff Var      Root MSE    spdsl Mean

               0.986290      13.10526      0.119251      0.909946


 Source                      DF        Type I SS    Mean Square   F Value   Pr > F

 car                          1       0.88739527     0.88739527     62.40   <.0001
 treatment                    2       1.11389266     0.55694633     39.16   <.0001
 measurement                  4       8.31883314     2.07970828    146.24   <.0001
 treatment*measurement        8       1.95625702     0.24453213     17.20   <.0001


 Source                      DF      Type III SS    Mean Square   F Value   Pr > F

 car                          1       0.84848036     0.84848036     59.66   <.0001
 treatment                    2       2.06023347     1.03011673     72.44   <.0001
 measurement                  4       8.83850914     2.20962728    155.38   <.0001
 treatment*measurement        8       1.95625702     0.24453213     17.20   <.0001
```

The GLM Procedure
Least Squares Means

car	spdsl LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1=LSMean2 Pr > |t|
0	0.80971848	0.01016169	<.0001	<.0001
1	0.87356891	0.00740196	<.0001	

Table C-8. Treatment Effect for I-80 West, Dependent Variable SPDSL

treatment	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	0.93107222	0.00566300	<.0001	1
police	0.79436625	0.01796000	<.0001	2
smd	0.79949261	0.01230775	<.0001	3

Least Squares Means for effect treatment
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3
1		<.0001	<.0001
2	<.0001		0.8145
3	<.0001	0.8145	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

measurement	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
n1	0.97093643	0.01066438	<.0001	1
n2	0.60354651	0.03369946	<.0001	2
n3	0.84365173	0.00680461	<.0001	3
n4	0.81026823	0.00605955	<.0001	4
n5	0.97981554	0.00673160	<.0001	5

Least Squares Means for effect measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3	4	5
1		<.0001	<.0001	<.0001	0.4688
2	<.0001		<.0001	<.0001	<.0001
3	<.0001	<.0001		0.0018	<.0001
4	<.0001	<.0001	0.0018		<.0001
5	0.4688	<.0001	<.0001	<.0001	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table C-9. Treatment*Measurement Effect for I-80 West, Dependent Variable SPDSL

treatment	measurement	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	n1	0.95449508	0.01545141	<.0001	1
nothing	n2	0.94172074	0.01269744	<.0001	2
nothing	n3	0.91941023	0.00957188	<.0001	3
nothing	n4	0.82968559	0.00790211	<.0001	4
nothing	n5	1.01004944	0.00910798	<.0001	5
police	n1	0.96856326	0.01798299	<.0001	6
police	n2	0.42730555	0.08442432	0.0003	7
police	n3	0.80255220	0.01208903	<.0001	8
police	n4	0.80215330	0.01080807	<.0001	9
police	n5	0.97125694	0.01171798	<.0001	10
smd	n1	0.98975095	0.02000734	<.0001	11
smd	n2	0.44161325	0.05349052	<.0001	12
smd	n3	0.80899277	0.01237032	<.0001	13
smd	n4	0.79896581	0.00989548	<.0001	14
smd	n5	0.95814026	0.01182789	<.0001	15

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3	4	5	6	7	8
1		0.5267	0.0706	<.0001	0.0077	0.5543	<.0001	<.0001
2	0.5267		0.1771	<.0001	0.0007	0.2383	<.0001	<.0001
3	0.0706	0.1771		<.0001	<.0001	0.0296	<.0001	<.0001
4	<.0001	<.0001	<.0001		<.0001	<.0001	0.0005	0.0733
5	0.0077	0.0007	<.0001	<.0001		0.0562	<.0001	<.0001
6	0.5543	0.2383	0.0296	<.0001	0.0562		<.0001	<.0001
7	<.0001	<.0001	<.0001	0.0005	<.0001	<.0001		0.0009
8	<.0001	<.0001	<.0001	0.0733	<.0001	<.0001	0.0009	
9	<.0001	<.0001	<.0001	0.0485	<.0001	<.0001	0.0008	0.9801
10	0.3926	0.1067	0.0042	<.0001	0.0191	0.9001	<.0001	<.0001
11	0.1830	0.0634	0.0075	<.0001	0.3678	0.4408	<.0001	<.0001
12	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.8884	<.0001
13	<.0001	<.0001	<.0001	0.1755	<.0001	<.0001	0.0008	0.7130
14	<.0001	<.0001	<.0001	0.0252	<.0001	<.0001	0.0009	0.8178
15	0.8501	0.3519	0.0219	<.0001	0.0035	0.6283	<.0001	<.0001

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	9	10	11	12	13	14	15
1	<.0001	0.3926	0.1830	<.0001	<.0001	<.0001	0.8501
2	<.0001	0.1067	0.0634	<.0001	<.0001	<.0001	0.3519
3	<.0001	0.0042	0.0075	<.0001	<.0001	<.0001	0.0219
4	0.0485	<.0001	<.0001	<.0001	0.1755	0.0252	<.0001
5	<.0001	0.0191	0.3678	<.0001	<.0001	<.0001	0.0035
6	<.0001	0.9001	0.4408	<.0001	<.0001	<.0001	0.6283
7	0.0008	<.0001	<.0001	0.8884	0.0008	0.0009	<.0001
8	0.9801	<.0001	<.0001	<.0001	0.7130	0.8178	<.0001
9		<.0001	<.0001	<.0001	0.6796	0.8252	<.0001
10	<.0001		0.4355	<.0001	<.0001	<.0001	0.4328
11	<.0001	0.4355		<.0001	<.0001	<.0001	0.1933
12	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
13	0.6796	<.0001	<.0001	<.0001		0.5336	<.0001
14	0.8252	<.0001	<.0001	<.0001	0.5336		<.0001
15	<.0001	0.4328	0.1933	<.0001	<.0001	<.0001	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

SAS Output for I-80 West, Dependent Variable COV:

```
                    The SAS System                                  10
                                        14:09 Monday, March 24, 2003

                   The GLM Procedure

                Class Level Information

        Class           Levels    Values

        car                  2    0 1

        treatment            3    nothing police smd

        measurement          4    n2 n3 n4 n5

             Number of observations    24

NOTE: Due to missing values, only 22 observations can be used in this analysis.
```

Table C-10. ANOVA Table for I-80 West, Dependent Variable COV

```
                          The SAS System                                11
                                                  14:09 Monday, March 24, 2003

                         The GLM Procedure

Dependent Variable: cov

Weight: n

                                      Sum of
 Source                     DF       Squares    Mean Square   F Value   Pr > F

 Model                      13   11.86633044     0.91279465     45.69   <.0001

 Error                       8    0.15984042     0.01998005

 Corrected Total            21   12.02617086


              R-Square     Coeff Var      Root MSE      cov Mean

              0.986709      15.49111      0.141351      0.912464


 Source                     DF      Type I SS    Mean Square   F Value   Pr > F

 initial                     1    0.54213131     0.54213131     27.13   0.0008
 car                         1    1.66486822     1.66486822     83.33   <.0001
 treatment                   2    0.54789103     0.27394551     13.71   0.0026
 measurement                 3    7.41999069     2.47333023    123.79   <.0001
 treatment*measurement        6     1.69144921     0.28190820     14.11   0.0007


 Source                     DF    Type III SS    Mean Square   F Value   Pr > F

 initial                     1    0.18193112     0.18193112      9.11   0.0166
 car                         1    0.21777173     0.21777173     10.90   0.0108
 treatment                   2    1.26499946     0.63249973     31.66   0.0002
 measurement                 3    7.64889085     2.54963028    127.61   <.0001
 treatment*measurement        6     1.69144921     0.28190820     14.11   0.0007
```

Parameter		Estimate	Standard Error	t Value
Intercept		2.621303609 B	0.54721066	4.79
initial		-0.024882864	0.00824604	-3.02
car	0	-0.104608822 B	0.03168589	-3.30
car	1	0.000000000 B	.	.
treatment	nothing	0.032318339 B	0.02448229	1.32
treatment	police	-0.000967414 B	0.02320755	-0.04
treatment	smd	0.000000000 B	.	.
measurement	n2	-0.505527214 B	0.06466250	-7.82
measurement	n3	-0.149092209 B	0.02002748	-7.44
measurement	n4	-0.158173998 B	0.01771733	-8.93
measurement	n5	0.000000000 B	.	.
treatment*measurement	nothing n2	0.436679234 B	0.06714531	6.50
treatment*measurement	nothing n3	0.057399802 B	0.02502785	2.29
treatment*measurement	nothing n4	-0.026733540 B	0.02220912	-1.20
treatment*measurement	nothing n5	0.000000000 B	.	.
treatment*measurement	police n2	-0.036587564 B	0.11982589	-0.31
treatment*measurement	police n3	-0.022224295 B	0.02793025	-0.80
treatment*measurement	police n4	-0.012448141 B	0.02550635	-0.49
treatment*measurement	police n5	0.000000000 B	.	.
treatment*measurement	smd n2	0.000000000 B	.	.
treatment*measurement	smd n3	0.000000000 B	.	.
treatment*measurement	smd n4	0.000000000 B	.	.
treatment*measurement	smd n5	0.000000000 B	.	.

Parameter		Pr > |t|
Intercept		0.0014
initial		0.0166
car	0	0.0108
car	1	.
treatment	nothing	0.2233
treatment	police	0.9678
treatment	smd	.
measurement	n2	<.0001
measurement	n3	<.0001
measurement	n4	<.0001
measurement	n5	.
treatment*measurement	nothing n2	0.0002
treatment*measurement	nothing n3	0.0510
treatment*measurement	nothing n4	0.2631
treatment*measurement	nothing n5	.
treatment*measurement	police n2	0.7679
treatment*measurement	police n3	0.4492
treatment*measurement	police n4	0.6386
treatment*measurement	police n5	.
treatment*measurement	smd n2	.
treatment*measurement	smd n3	.
treatment*measurement	smd n4	.
treatment*measurement	smd n5	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

The GLM Procedure
Least Squares Means

car	cov LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1= LSMean2 Pr > |t|
0	0.78043214	0.02042929	<.0001	0.0108
1	0.88504097	0.01803676	<.0001	

Table C-11. Treatment Effect for I-80 West, Dependent Variable COV

treatment	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	0.93843384	0.01031560	<.0001	1
police	0.77049671	0.02605110	<.0001	2
smd	0.78927912	0.01954959	<.0001	3

Least Squares Means for effect treatment
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3
1		0.0002	0.0003
2	0.0002		0.5839
3	0.0003	0.5839	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

measurement	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
n2	0.63076446	0.03996304	<.0001	1
n3	0.86556075	0.00813064	<.0001	2
n4	0.83169323	0.00726065	<.0001	3
n5	1.00292779	0.00804899	<.0001	4

Least Squares Means for effect measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3	4
1		0.0004	0.0011	<.0001
2	0.0004		0.0093	<.0001
3	0.0011	0.0093		<.0001
4	<.0001	<.0001	<.0001	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table C-12. Treatment*Measurement Effect for I-80 West, Dependent Variable COV

treatment	measurement	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	n2	0.95594784	0.01677922	<.0001	1
nothing	n3	0.93310341	0.01369809	<.0001	2
nothing	n4	0.83988828	0.01283988	<.0001	3
nothing	n5	1.02479582	0.01348522	<.0001	4
police	n2	0.44939529	0.10008006	0.0020	5
police	n3	0.82019356	0.01478715	<.0001	6
police	n4	0.82088793	0.01305528	<.0001	7
police	n5	0.99151006	0.01435122	<.0001	8
smd	n2	0.48695026	0.06420934	<.0001	9
smd	n3	0.84338527	0.01708268	<.0001	10
smd	n4	0.83430348	0.01494910	<.0001	11
smd	n5	0.99247748	0.01700028	<.0001	12

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3	4	5	6
1		0.2505	0.0001	0.0051	0.0011	0.0002
2	0.2505		0.0002	0.0003	0.0014	0.0003
3	0.0001	0.0002		<.0001	0.0047	0.2848
4	0.0051	0.0003	<.0001		0.0004	<.0001
5	0.0011	0.0014	0.0047	0.0004		0.0063
6	0.0002	0.0003	0.2848	<.0001	0.0063	
7	0.0001	0.0002	0.2742	<.0001	0.0061	0.9712
8	0.1202	0.0115	<.0001	0.0951	0.0007	<.0001
9	0.0001	0.0002	0.0007	<.0001	0.7599	0.0010
10	0.0027	0.0065	0.8897	<.0001	0.0047	0.3569
11	0.0013	0.0027	0.8137	<.0001	0.0052	0.5416
12	0.2023	0.0417	0.0002	0.2233	0.0007	<.0001

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	7	8	9	10	11	12
1	0.0001	0.1202	0.0001	0.0027	0.0013	0.2023
2	0.0002	0.0115	0.0002	0.0065	0.0027	0.0417
3	0.2742	<.0001	0.0007	0.8897	0.8137	0.0002
4	<.0001	0.0951	<.0001	<.0001	<.0001	0.2233
5	0.0061	0.0007	0.7599	0.0047	0.0052	0.0007
6	0.9712	<.0001	0.0010	0.3569	0.5416	<.0001
7		<.0001	0.0009	0.3393	0.5281	<.0001
8	<.0001		<.0001	0.0002	<.0001	0.9678
9	0.0009	<.0001		0.0006	0.0006	<.0001
10	0.3393	0.0002	0.0006		0.6376	<.0001
11	0.5281	<.0001	0.0006	0.6376		<.0001
12	<.0001	0.9678	<.0001	<.0001	<.0001	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

SAS Output for I-15 South of Nephi Site, Dependent Variable SPDSL:

```
                    The SAS System                                  13
                                          14:09 Monday, March 24, 2003

                   The GLM Procedure

                Class Level Information

Class            Levels    Values

car                   2    0 1

treatment             4    nothing p_crusi p_stati smd

measurement           7    n1 n2 n3 n4 n5 n6 n7

              Number of observations    56
```

Table C-13. ANOVA Table for I-15 South of Nephi, Dependent Variable SPDSL

The SAS System 14
14:09 Monday, March 24, 2003

The GLM Procedure

Dependent Variable: spdsl

Weight: n

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	669.2187890	18.0869943	307.82	<.0001
Error	18	1.0576628	0.0587590		
Corrected Total	55	670.2764518			

R-Square	Coeff Var	Root MSE	spdsl Mean
0.998422	24.15264	0.242403	1.003628

Source	DF	Type I SS	Mean Square	F Value	Pr > F
car	1	9.6819233	9.6819233	164.77	<.0001
treatment	3	3.2507334	1.0835778	18.44	<.0001
car*treatment	3	0.7209587	0.2403196	4.09	0.0223
measurement	6	555.5383043	92.5897174	1575.75	<.0001
car*measurement	6	1.6597861	0.2766310	4.71	0.0048
treatment*measurement	18	98.3670833	5.4648380	93.00	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
car	1	4.0953631	4.0953631	69.70	<.0001
treatment	3	7.8857980	2.6285993	44.74	<.0001
car*treatment	3	0.3308597	0.1102866	1.88	0.1697
measurement	6	127.7366027	21.2894338	362.32	<.0001
car*measurement	6	1.5333176	0.2555529	4.35	0.0070
treatment*measurement	18	98.3670833	5.4648380	93.00	<.0001

The GLM Procedure
Least Squares Means

car	spdsl LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1=LSMean2 Pr > |t|
0	0.98089903	0.00264381	<.0001	<.0001
1	1.00502687	0.00179633	<.0001	

Table C-14. Treatment Effect for I-15 South of Nephi, Dependent Variable SPDSL

treatment	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	1.02929985	0.00415507	<.0001	1
p_crusi	0.96996058	0.00355191	<.0001	2
p_stati	0.97773575	0.00411457	<.0001	3
smd	0.99485562	0.00121337	<.0001	4

Least Squares Means for effect treatment
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3	4
1		<.0001	<.0001	<.0001
2	<.0001		0.1694	<.0001
3	<.0001	0.1694		0.0009
4	<.0001	<.0001	0.0009	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

car	treatment	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
0	nothing	1.01373294	0.00521717	<.0001	1
0	p_crusi	0.96278060	0.00580652	<.0001	2
0	p_stati	0.96316145	0.00680892	<.0001	3
0	smd	0.98392111	0.00203389	<.0001	4
1	nothing	1.04486676	0.00416615	<.0001	5
1	p_crusi	0.97714055	0.00378117	<.0001	6
1	p_stati	0.99231005	0.00426458	<.0001	7
1	smd	1.00579013	0.00131616	<.0001	8

Least Squares Means for effect car*treatment
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3	4	5	6	7	8
1		<.0001	<.0001	<.0001	<.0001	<.0001	0.0052	0.1563
2	<.0001		0.9664	0.0029	<.0001	0.0475	0.0007	<.0001
3	<.0001	0.9664		0.0091	<.0001	0.0899	0.0016	<.0001
4	<.0001	0.0029	0.0091		<.0001	0.1319	0.0926	<.0001
5	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
6	<.0001	0.0475	0.0899	0.1319	<.0001		0.0158	<.0001
7	0.0052	0.0007	0.0016	0.0926	<.0001	0.0158		0.0073
8	0.1563	<.0001	<.0001	<.0001	<.0001	<.0001	0.0073	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

measurement	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
n1	0.82992334	0.00427383	<.0001	1
n2	1.04271597	0.00356070	<.0001	2
n3	1.09875903	0.00721401	<.0001	3
n4	1.00236221	0.00297191	<.0001	4
n5	1.03830288	0.00311982	<.0001	5
n6	0.97403015	0.00403025	<.0001	6
n7	0.96464708	0.00452963	<.0001	7

Least Squares Means for effect measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3	4	5	6	7
1		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	<.0001	0.3600	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
4	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
5	<.0001	0.3600	<.0001	<.0001		<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001		0.1366
7	<.0001	<.0001	<.0001	<.0001	<.0001	0.1366	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

car	measurement	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
0	n1	0.81545014	0.00579702	<.0001	1
0	n2	1.02146840	0.00540178	<.0001	2
0	n3	1.08766615	0.00833990	<.0001	3
0	n4	0.99142902	0.00446496	<.0001	4
0	n5	1.02288718	0.00472294	<.0001	5
0	n6	0.96846041	0.00558071	<.0001	6
0	n7	0.95893189	0.00611581	<.0001	7
1	n1	0.84439654	0.00441536	<.0001	8
1	n2	1.06396355	0.00365150	<.0001	9
1	n3	1.10985190	0.00724517	<.0001	10
1	n4	1.01329540	0.00311595	<.0001	11
1	n5	1.05371858	0.00328213	<.0001	12
1	n6	0.97959989	0.00419981	<.0001	13
1	n7	0.97036227	0.00453594	<.0001	14

Least Squares Means for effect car*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	1	2	3	4	5	6	7
1		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001		<.0001	0.0003	0.8397	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
4	<.0001	0.0003	<.0001		<.0001	0.0035	0.0003
5	<.0001	0.8397	<.0001	<.0001		<.0001	<.0001
6	<.0001	<.0001	<.0001	0.0035	<.0001		0.2465
7	<.0001	<.0001	<.0001	0.0003	<.0001	0.2465	
8	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001	0.0192	<.0001	<.0001	<.0001	<.0001
10	<.0001	<.0001	0.0016	<.0001	<.0001	<.0001	<.0001
11	<.0001	0.2141	<.0001	0.0003	0.1142	<.0001	<.0001
12	<.0001	<.0001	0.0015	<.0001	<.0001	<.0001	<.0001
13	<.0001	<.0001	<.0001	0.0752	<.0001	0.0668	0.0136
14	<.0001	<.0001	<.0001	0.0045	<.0001	0.7981	0.0652

Least Squares Means for effect car*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: spdsl

i/j	8	9	10	11	12	13	14
1	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001	<.0001	<.0001	0.2141	<.0001	<.0001	<.0001
3	<.0001	0.0192	0.0016	<.0001	0.0015	<.0001	<.0001
4	<.0001	<.0001	<.0001	0.0003	<.0001	0.0752	0.0045
5	<.0001	<.0001	<.0001	0.1142	<.0001	<.0001	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001	0.0668	0.7981
7	<.0001	<.0001	<.0001	<.0001	<.0001	0.0136	0.0652
8		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001		<.0001	<.0001	0.0490	<.0001	<.0001
10	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
11	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001
12	<.0001	0.0490	<.0001	<.0001		<.0001	<.0001
13	<.0001	<.0001	<.0001	<.0001	<.0001		0.1485
14	<.0001	<.0001	<.0001	<.0001	<.0001	0.1485	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table C-15. Treatment*Measurement Effect for I-15 South of Nephi, Dependent Variable SPDSL

treatment	measurement	spdsl LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	n1	0.83116769	0.00421133	<.0001	1
nothing	n2	1.10619867	0.00655797	<.0001	2
nothing	n3	1.08471765	0.02483915	<.0001	3
nothing	n4	1.09502279	0.00391582	<.0001	4
nothing	n5	1.03881826	0.00539108	<.0001	5
nothing	n6	1.00575755	0.00440714	<.0001	6
nothing	n7	1.04341635	0.00799824	<.0001	7
p_crusi	n1	0.81298439	0.01155873	<.0001	8
p_crusi	n2	1.03045587	0.00777788	<.0001	9
p_crusi	n3	1.09481951	0.00878005	<.0001	10
p_crusi	n4	0.97595719	0.00693099	<.0001	11
p_crusi	n5	1.00360468	0.00670418	<.0001	12
p_crusi	n6	0.93245336	0.00979607	<.0001	13
p_crusi	n7	0.93944905	0.00886596	<.0001	14
p_stati	n1	0.83722634	0.01075800	<.0001	15
p_stati	n2	0.95982367	0.00848332	<.0001	16
p_stati	n3	1.10560055	0.01058418	<.0001	17
p_stati	n4	1.02293636	0.00777823	<.0001	18
p_stati	n5	1.03069609	0.00791517	<.0001	19
p_stati	n6	0.93821256	0.01097984	<.0001	20
p_stati	n7	0.94965470	0.01260909	<.0001	21
smd	n1	0.83831492	0.00347999	<.0001	22
smd	n2	1.07438568	0.00329751	<.0001	23
smd	n3	1.10989841	0.00285934	<.0001	24
smd	n4	0.91553249	0.00298807	<.0001	25
smd	n5	1.08009249	0.00298533	<.0001	26
smd	n6	1.01969714	0.00341741	<.0001	27
smd	n7	0.92606822	0.00280551	<.0001	28

Table C-15. Treatment*Measurement Effect for I-15 South of Nephi, Dependent Variable SPDSL (continued)

Least Squares Means for effect treatment*measuremen
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: spdsl

i/j	1	2	3	4	5	6	7
1		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001		0.4127	0.1548	<.0001	<.0001	<.0001
3	<.0001	0.4127		0.6863	0.0872	0.0057	0.1297
4	<.0001	0.1548	0.6863		<.0001	<.0001	<.0001
5	<.0001	<.0001	0.0872	<.0001		0.0001	0.6354
6	<.0001	<.0001	0.0057	<.0001	0.0001		0.0006
7	<.0001	<.0001	0.1297	<.0001	0.6354	0.0006	
8	0.1545	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001	0.0517	<.0001	0.3893	0.0129	0.2610
10	<.0001	0.3131	0.7050	0.9834	<.0001	<.0001	0.0004
11	<.0001	<.0001	0.0005	<.0001	<.0001	0.0020	<.0001
12	<.0001	<.0001	0.0055	<.0001	0.0006	0.7918	0.0013
13	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
14	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
15	0.6034	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
16	<.0001	<.0001	0.0002	<.0001	<.0001	0.0001	<.0001
17	<.0001	0.9622	0.4480	0.3612	<.0001	<.0001	0.0002
18	<.0001	<.0001	0.0290	<.0001	0.1115	0.0713	0.0837
19	<.0001	<.0001	0.0530	<.0001	0.4036	0.0132	0.2736
20	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
21	<.0001	<.0001	0.0001	<.0001	<.0001	0.0005	<.0001
22	0.1949	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
23	<.0001	0.0003	0.6851	0.0008	<.0001	<.0001	0.0022
24	<.0001	0.6114	0.3261	0.0066	<.0001	<.0001	<.0001
25	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
26	<.0001	0.0020	0.8555	0.0075	<.0001	<.0001	0.0005
27	<.0001	<.0001	0.0184	<.0001	0.0080	0.0193	0.0144
28	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: spdsl

i/j	8	9	10	11	12	13	14
1	0.1545	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001	<.0001	0.3131	<.0001	<.0001	<.0001	<.0001
3	<.0001	0.0517	0.7050	0.0005	0.0055	<.0001	<.0001
4	<.0001	<.0001	0.9834	<.0001	<.0001	<.0001	<.0001
5	<.0001	0.3893	<.0001	<.0001	0.0006	<.0001	<.0001
6	<.0001	0.0129	<.0001	0.0020	0.7918	<.0001	<.0001
7	<.0001	0.2610	0.0004	<.0001	0.0013	<.0001	<.0001
8		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001		<.0001	<.0001	0.0160	<.0001	<.0001
10	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
11	<.0001	<.0001	<.0001		0.0091	0.0017	0.0040
12	<.0001	0.0160	<.0001	0.0091		<.0001	<.0001
13	<.0001	<.0001	<.0001	0.0017	<.0001		0.5988
14	<.0001	<.0001	<.0001	0.0040	<.0001	0.5988	
15	0.1401	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
16	<.0001	<.0001	<.0001	0.1590	0.0008	0.0491	0.1145
17	<.0001	<.0001	0.4399	<.0001	<.0001	<.0001	<.0001
18	<.0001	0.5039	<.0001	0.0003	0.0765	<.0001	<.0001
19	<.0001	0.9830	<.0001	<.0001	0.0169	<.0001	<.0001
20	<.0001	<.0001	<.0001	0.0095	<.0001	0.6985	0.9312
21	<.0001	<.0001	<.0001	0.0845	0.0014	0.2958	0.5139
22	0.0488	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
23	<.0001	<.0001	0.0434	<.0001	<.0001	<.0001	<.0001
24	<.0001	<.0001	0.1155	<.0001	<.0001	<.0001	<.0001
25	<.0001	<.0001	<.0001	<.0001	<.0001	0.1163	0.0202
26	<.0001	<.0001	0.1313	<.0001	<.0001	<.0001	<.0001
27	<.0001	0.2223	<.0001	<.0001	0.0468	<.0001	<.0001
28	<.0001	<.0001	<.0001	<.0001	<.0001	0.5393	0.1622

Table C-15. Treatment*Measurement Effect for I-15 South of Nephi, Dependent Variable SPDSL (continued)

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: spdsl

i/j	15	16	17	18	19	20	21
1	0.6034	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001	<.0001	0.9622	<.0001	<.0001	<.0001	<.0001
3	<.0001	0.0002	0.4480	0.0290	0.0530	<.0001	0.0001
4	<.0001	<.0001	0.3612	<.0001	<.0001	<.0001	<.0001
5	<.0001	<.0001	<.0001	0.1115	0.4036	<.0001	<.0001
6	<.0001	0.0001	<.0001	0.0713	0.0132	<.0001	0.0005
7	<.0001	<.0001	0.0002	0.0837	0.2736	<.0001	<.0001
8	0.1401	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001	<.0001	0.5039	0.9830	<.0001	<.0001
10	<.0001	<.0001	0.4399	<.0001	<.0001	<.0001	<.0001
11	<.0001	0.1590	<.0001	0.0003	<.0001	0.0095	0.0845
12	<.0001	0.0008	<.0001	0.0765	0.0169	<.0001	0.0014
13	<.0001	0.0491	<.0001	<.0001	<.0001	0.6985	0.2958
14	<.0001	0.1145	<.0001	<.0001	<.0001	0.9312	0.5139
15		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
16	<.0001		<.0001	<.0001	<.0001	0.1313	0.5064
17	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
18	<.0001	<.0001	<.0001		0.4835	<.0001	<.0001
19	<.0001	<.0001	<.0001	0.4835		<.0001	<.0001
20	<.0001	0.1313	<.0001	<.0001	<.0001		0.4977
21	<.0001	0.5064	<.0001	<.0001	<.0001	0.4977	
22	0.9236	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
23	<.0001	<.0001	0.0116	<.0001	<.0001	<.0001	<.0001
24	<.0001	<.0001	0.6972	<.0001	<.0001	<.0001	<.0001
25	<.0001	0.0001	<.0001	<.0001	<.0001	0.0620	0.0170
26	<.0001	<.0001	0.0328	<.0001	<.0001	<.0001	<.0001
27	<.0001	<.0001	<.0001	0.7078	0.2190	<.0001	<.0001
28	<.0001	0.0014	<.0001	<.0001	<.0001	0.2984	0.0825

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: spdsl

i/j	22	23	24	25	26	27	28
1	0.1949	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
2	<.0001	0.0003	0.6114	<.0001	0.0020	<.0001	<.0001
3	<.0001	0.6851	0.3261	<.0001	0.8555	0.0184	<.0001
4	<.0001	0.0008	0.0066	<.0001	0.0075	<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001	<.0001	0.0080	<.0001
6	<.0001	<.0001	<.0001	<.0001	<.0001	0.0193	<.0001
7	<.0001	0.0022	<.0001	<.0001	0.0005	0.0144	<.0001
8	0.0488	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	0.2223	<.0001
10	<.0001	0.0434	0.1155	<.0001	0.1313	<.0001	<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
12	<.0001	<.0001	<.0001	<.0001	<.0001	0.0468	<.0001
13	<.0001	<.0001	<.0001	0.1163	<.0001	<.0001	0.5393
14	<.0001	<.0001	<.0001	0.0202	<.0001	<.0001	0.1622
15	0.9236	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
16	<.0001	<.0001	<.0001	0.0001	<.0001	<.0001	0.0014
17	<.0001	0.0116	0.6972	<.0001	0.0328	<.0001	<.0001
18	<.0001	<.0001	<.0001	<.0001	<.0001	0.7078	<.0001
19	<.0001	<.0001	<.0001	<.0001	<.0001	0.2190	<.0001
20	<.0001	<.0001	<.0001	0.0620	<.0001	<.0001	0.2984
21	<.0001	<.0001	<.0001	0.0170	<.0001	<.0001	0.0825
22		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
23	<.0001		<.0001	<.0001	0.2133	<.0001	<.0001
24	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
25	<.0001	<.0001	<.0001		<.0001	<.0001	0.0189
26	<.0001	0.2133	<.0001	<.0001		<.0001	<.0001
27	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001
28	<.0001	<.0001	<.0001	0.0189	<.0001	<.0001	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

SAS Output for I-15 South of Nephi Site, Dependent Variable COV:

```
                     The SAS System                                16
                                         14:09 Monday, March 24, 2003

                   The GLM Procedure

                Class Level Information

 Class            Levels    Values

 car                   2    0 1

 treatment             4    nothing p_crusi p_stati smd

 measurement           6    n2 n3 n4 n5 n6 n7

              Number of observations    48
```

Table C-16. ANOVA Table for I-15 South of Nephi, Dependent Variable COV

The SAS System 17
14:09 Monday, March 24, 2003

The GLM Procedure

Dependent Variable: cov

Weight: n

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	271.2581514	9.0419384	178.37	<.0001
Error	17	0.8617421	0.0506907		
Corrected Total	47	272.1198935			

R-Square	Coeff Var	Root MSE	cov Mean
0.996833	25.09923	0.225146	0.897023

Source	DF	Type I SS	Mean Square	F Value	Pr > F
initial	1	3.9289664	3.9289664	77.51	<.0001
car	1	0.3186825	0.3186825	6.29	0.0226
treatment	3	16.3723355	5.4574452	107.66	<.0001
measurement	5	181.8519182	36.3703836	717.50	<.0001
car*measurement	5	0.9694083	0.1938817	3.82	0.0167
treatment*measurement	15	67.8168406	4.5211227	89.19	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
initial	1	1.27460792	1.27460792	25.14	0.0001
car	1	0.41883576	0.41883576	8.26	0.0105
treatment	3	6.11662475	2.03887492	40.22	<.0001
measurement	5	23.33846872	4.66769374	92.08	<.0001
car*measurement	5	0.89408094	0.17881619	3.53	0.0227
treatment*measurement	15	67.81684059	4.52112271	89.19	<.0001

Parameter		Estimate	Standard Error	t Value
Intercept		1.656169784 B	0.17047250	9.72
initial		-0.013384723	0.00266923	-5.01
car	0	-0.008707743 B	0.00708548	-1.23
car	1	0.000000000 B	.	.
treatment	nothing	0.104619311 B	0.00758208	13.80
treatment	p crusi	0.010157960 B	0.00991786	1.02
treatment	p stati	0.022531747 B	0.01178321	1.91
treatment	smd	0.000000000 B	.	.
measurement	n2	0.141417562 B	0.00431302	32.79
measurement	n3	0.162939980 B	0.00405567	40.18
measurement	n4	-0.004634379 B	0.00399908	-1.16
measurement	n5	0.141385249 B	0.00391430	36.12
measurement	n6	0.081447724 B	0.00438729	18.56
measurement	n7	0.000000000 B	.	.
car*measurement	0 n2	-0.024222482 B	0.00706032	-3.43
car*measurement	0 n3	-0.004428061 B	0.00691761	-0.64
car*measurement	0 n4	-0.009131038 B	0.00645130	-1.42
car*measurement	0 n5	-0.014293546 B	0.00665175	-2.15
car*measurement	0 n6	-0.000145590 B	0.00690427	-0.02
car*measurement	0 n7	0.000000000 B	.	.
car*measurement	1 n2	0.000000000 B	.	.
car*measurement	1 n3	0.000000000 B	.	.
car*measurement	1 n4	0.000000000 B	.	.
car*measurement	1 n5	0.000000000 B	.	.
car*measurement	1 n6	0.000000000 B	.	.
car*measurement	1 n7	0.000000000 B	.	.
treatment*measurement	nothing n2	-0.074108989 B	0.00995470	-7.44
treatment*measurement	nothing n3	-0.123329528 B	0.02431916	-5.07
treatment*measurement	nothing n4	0.053781662 B	0.00870248	6.18
treatment*measurement	nothing n5	-0.138359654 B	0.00934437	-14.81
treatment*measurement	nothing n6	-0.114870406 B	0.00902210	-12.73
treatment*measurement	nothing n7	0.000000000 B	.	.
treatment*measurement	p crusi n2	-0.046802433 B	0.01131619	-4.14
treatment*measurement	p crusi n3	-0.020241656 B	0.01182842	-1.71
treatment*measurement	p crusi n4	0.042046576 B	0.01077130	3.90
treatment*measurement	p crusi n5	-0.075773103 B	0.01065349	-7.11
treatment*measurement	p crusi n6	-0.087566619 B	0.01263997	-6.93
treatment*measurement	p crusi n7	0.000000000 B	.	.
treatment*measurement	p stati n2	-0.119924377 B	0.01433872	-8.36
treatment*measurement	p stati n3	-0.024101088 B	0.01542499	-1.56
treatment*measurement	p stati n4	0.072601073 B	0.01395532	5.20
treatment*measurement	p stati n5	-0.063334493 B	0.01398183	-4.53
treatment*measurement	p stati n6	-0.091995619 B	0.01575320	-5.84
treatment*measurement	p stati n7	0.000000000 B	.	.
treatment*measurement	smd n2	0.000000000 B	.	.
treatment*measurement	smd n3	0.000000000 B	.	.
treatment*measurement	smd n4	0.000000000 B	.	.
treatment*measurement	smd n5	0.000000000 B	.	.
treatment*measurement	smd n6	0.000000000 B	.	.
treatment*measurement	smd n7	0.000000000 B	.	.

Parameter		Pr > |t|
Intercept		<.0001
initial		0.0001
car	0	0.2358
car	1	.
treatment	nothing	<.0001
treatment	p crusi	0.3201
treatment	p stati	0.0729
treatment	smd	.
measurement	n2	<.0001
measurement	n3	<.0001
measurement	n4	0.2625
measurement	n5	<.0001
measurement	n6	<.0001
measurement	n7	.
car*measurement	0 n2	0.0032
car*measurement	0 n3	0.5306
car*measurement	0 n4	0.1750
car*measurement	0 n5	0.0463
car*measurement	0 n6	0.9834
car*measurement	0 n7	.
car*measurement	1 n2	.
car*measurement	1 n3	.
car*measurement	1 n4	.
car*measurement	1 n5	.
car*measurement	1 n6	.

```
car*measurement      1 n7               .
treatment*measurement nothing n2       <.0001
treatment*measurement nothing n3       <.0001
treatment*measurement nothing n4       <.0001
treatment*measurement nothing n5       <.0001
treatment*measurement nothing n6       <.0001
treatment*measurement nothing n7         .
treatment*measurement p crusi n2       0.0007
treatment*measurement p crusi n3       0.1052
treatment*measurement p crusi n4       0.0011
treatment*measurement p crusi n5       <.0001
treatment*measurement p crusi n6       <.0001
treatment*measurement p crusi n7         .
treatment*measurement p stati n2       <.0001
treatment*measurement p stati n3       0.1366
treatment*measurement p stati n4       <.0001
treatment*measurement p stati n5       0.0003
treatment*measurement p stati n6       <.0001
treatment*measurement p stati n7         .
treatment*measurement smd n2             .
treatment*measurement smd n3             .
treatment*measurement smd n4             .
treatment*measurement smd n5             .
treatment*measurement smd n6             .
treatment*measurement smd n7             .

NOTE: The X'X matrix has been found to be singular, and a generalized inverse
      was used to solve the normal equations.  Terms whose estimates are
      followed by the letter 'B' are not uniquely estimable.
```

The GLM Procedure
Least Squares Means

car	cov LSMEAN	Standard Error	H0:LSMEAN=0 Pr > |t|	H0:LSMean1= LSMean2 Pr > |t|
0	0.89548943	0.00322502	<.0001	0.0105
1	0.91290063	0.00374854	<.0001	

Table C-17. Treatment Effect for I-15 South of Nephi, Dependent Variable COV

treatment	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	0.94217171	0.00445731	<.0001	1
p_crusi	0.88246864	0.00448137	<.0001	2
p_stati	0.88843955	0.00420223	<.0001	3
smd	0.90370022	0.00234671	<.0001	4

Least Squares Means for effect treatment
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3	4
1		<.0001	<.0001	<.0001
2	<.0001		0.4123	0.0033
3	<.0001	0.4123		0.0009
4	<.0001	0.0033	0.0009	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

measurement	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
n2	0.92438388	0.00330834	<.0001	1
n3	0.97409439	0.00669982	<.0001	2
n4	0.88819394	0.00275352	<.0001	3
n5	0.92015817	0.00289793	<.0001	4
n6	0.86305328	0.00373762	<.0001	5
n7	0.85528651	0.00420893	<.0001	6

Least Squares Means for effect measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3	4	5	6
1		<.0001	<.0001	0.3461	<.0001	<.0001
2	<.0001		<.0001	<.0001	<.0001	<.0001
3	<.0001	<.0001		<.0001	<.0001	<.0001
4	0.3461	<.0001	<.0001		<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001		0.1822
6	<.0001	<.0001	<.0001	<.0001	0.1822	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

<table>
<tr><th>car</th><th>measurement</th><th>cov LSMEAN</th><th>Standard Error</th><th>Pr > |t|</th><th>LSMEAN Number</th></tr>
<tr><td>0</td><td>n2</td><td>0.90791877</td><td>0.00543992</td><td><.0001</td><td>1</td></tr>
<tr><td>0</td><td>n3</td><td>0.96752649</td><td>0.00777478</td><td><.0001</td><td>2</td></tr>
<tr><td>0</td><td>n4</td><td>0.87927455</td><td>0.00481351</td><td><.0001</td><td>3</td></tr>
<tr><td>0</td><td>n5</td><td>0.90865753</td><td>0.00496329</td><td><.0001</td><td>4</td></tr>
<tr><td>0</td><td>n6</td><td>0.85862661</td><td>0.00560402</td><td><.0001</td><td>5</td></tr>
<tr><td>0</td><td>n7</td><td>0.85093264</td><td>0.00571639</td><td><.0001</td><td>6</td></tr>
<tr><td>1</td><td>n2</td><td>0.94084899</td><td>0.00476830</td><td><.0001</td><td>7</td></tr>
<tr><td>1</td><td>n3</td><td>0.98066229</td><td>0.00743240</td><td><.0001</td><td>8</td></tr>
<tr><td>1</td><td>n4</td><td>0.89711333</td><td>0.00445172</td><td><.0001</td><td>9</td></tr>
<tr><td>1</td><td>n5</td><td>0.93165882</td><td>0.00451031</td><td><.0001</td><td>10</td></tr>
<tr><td>1</td><td>n6</td><td>0.86747994</td><td>0.00513031</td><td><.0001</td><td>11</td></tr>
<tr><td>1</td><td>n7</td><td>0.85964038</td><td>0.00527778</td><td><.0001</td><td>12</td></tr>
</table>

Least Squares Means for effect car*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3	4	5	6
1		<.0001	0.0003	0.9096	<.0001	<.0001
2	<.0001		<.0001	<.0001	<.0001	<.0001
3	0.0003	<.0001		<.0001	0.0047	0.0006
4	0.9096	<.0001	<.0001		<.0001	<.0001
5	<.0001	<.0001	0.0047	<.0001		0.3094
6	<.0001	<.0001	0.0006	<.0001	0.3094	
7	0.0006	0.0147	<.0001	0.0010	<.0001	<.0001
8	<.0001	0.0857	<.0001	<.0001	<.0001	<.0001
9	0.2026	<.0001	0.0286	0.1622	0.0002	<.0001
10	0.0098	0.0018	<.0001	0.0070	<.0001	<.0001
11	0.0002	<.0001	0.1711	0.0001	0.2672	0.0683
12	<.0001	<.0001	0.0301	<.0001	0.9088	0.2358

Least Squares Means for effect car*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	7	8	9	10	11	12
1	0.0006	<.0001	0.2026	0.0098	0.0002	<.0001
2	0.0147	0.0857	<.0001	0.0018	<.0001	<.0001
3	<.0001	<.0001	0.0286	<.0001	0.1711	0.0301
4	0.0010	<.0001	0.1622	0.0070	0.0001	<.0001
5	<.0001	<.0001	0.0002	<.0001	0.2672	0.9088
6	<.0001	<.0001	<.0001	<.0001	0.0683	0.2358
7		<.0001	<.0001	0.0573	<.0001	<.0001
8	<.0001		<.0001	<.0001	<.0001	<.0001
9	<.0001	<.0001		<.0001	<.0001	<.0001
10	0.0573	<.0001	<.0001		<.0001	<.0001
11	<.0001	<.0001	<.0001	<.0001		0.1854
12	<.0001	<.0001	<.0001	<.0001	0.1854	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Table C-18. Treatment*Measurement Effect for I-15 South of Nephi, Dependent Variable COV

treatment	measurement	cov LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
nothing	n2	0.98077590	0.00607833	<.0001	1
nothing	n3	0.96297499	0.02306496	<.0001	2
nothing	n4	0.97016033	0.00369143	<.0001	3
nothing	n5	0.92145739	0.00504694	<.0001	4
nothing	n6	0.89208309	0.00415366	<.0001	5
nothing	n7	0.92557857	0.00741566	<.0001	6
p_crusi	n2	0.91362110	0.00783507	<.0001	7
p_crusi	n3	0.97160151	0.00861835	<.0001	8
p_crusi	n4	0.86396389	0.00713934	<.0001	9
p_crusi	n5	0.88958259	0.00698108	<.0001	10
p_crusi	n6	0.82492552	0.00960839	<.0001	11
p_crusi	n7	0.83111721	0.00869744	<.0001	12
p_stati	n2	0.85287295	0.00797483	<.0001	13
p_stati	n3	0.98011586	0.00992656	<.0001	14
p_stati	n4	0.90689218	0.00730499	<.0001	15
p_stati	n5	0.91439498	0.00744514	<.0001	16
p_stati	n6	0.83287031	0.01025718	<.0001	17
p_stati	n7	0.84349100	0.01179020	<.0001	18
smd	n2	0.95026557	0.00366613	<.0001	19
smd	n3	0.98168520	0.00342681	<.0001	20
smd	n4	0.81175936	0.00336346	<.0001	21
smd	n5	0.95519773	0.00335766	<.0001	22
smd	n6	0.90233418	0.00374813	<.0001	23
smd	n7	0.82095925	0.00337869	<.0001	24

Least Squares Means for effect treatment*measuremen
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	1	2	3	4	5	6	7	8
1		0.4646	0.1463	<.0001	<.0001	<.0001	<.0001	0.4100
2	0.4646		0.7616	0.0960	0.0075	0.1400	0.0604	0.7314
3	0.1463	0.7616		<.0001	<.0001	<.0001	<.0001	0.8833
4	<.0001	0.0960	<.0001		0.0003	0.6467	0.4273	0.0001
5	<.0001	0.0075	<.0001	0.0003		0.0009	0.0319	<.0001
6	<.0001	0.1400	<.0001	0.6467	0.0009		0.3003	0.0011
7	<.0001	0.0604	<.0001	0.4273	0.0319	0.3003		<.0001
8	0.4100	0.7314	0.8833	0.0001	<.0001	0.0011	<.0001	
9	<.0001	0.0008	<.0001	<.0001	0.0047	<.0001	<.0001	<.0001
10	<.0001	0.0077	<.0001	0.0023	0.7723	0.0035	0.0202	<.0001
11	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
12	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
13	<.0001	0.0003	<.0001	<.0001	0.0003	<.0001	<.0001	<.0001
14	0.9547	0.5011	0.3522	<.0001	<.0001	0.0003	0.0001	0.5380
15	<.0001	0.0325	<.0001	0.1120	0.0884	0.0836	0.5581	<.0001
16	<.0001	0.0602	<.0001	0.4281	0.0156	0.2904	0.9467	0.0002
17	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
18	<.0001	0.0002	<.0001	<.0001	0.0011	<.0001	0.0002	<.0001
19	0.0002	0.5916	0.0007	0.0001	<.0001	0.0063	0.0010	0.0481
20	0.8926	0.4299	0.0235	<.0001	<.0001	<.0001	<.0001	0.3214
21	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
22	0.0013	0.7416	0.0049	<.0001	<.0001	0.0015	0.0003	0.1152
23	<.0001	0.0184	<.0001	0.0053	0.0589	0.0096	0.2473	<.0001
24	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Table C-18. Treatment*Measurement Effect for I-15 South of Nephi, Dependent Variable COV (continued)

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	9	10	11	12	13	14	15	16
1	<.0001	<.0001	<.0001	<.0001	<.0001	0.9547	<.0001	<.0001
2	0.0008	0.0077	<.0001	<.0001	0.0003	0.5011	0.0325	0.0602
3	<.0001	<.0001	<.0001	<.0001	<.0001	0.3522	<.0001	<.0001
4	<.0001	0.0023	<.0001	<.0001	<.0001	<.0001	0.1120	0.4281
5	0.0047	0.7723	<.0001	<.0001	0.0003	<.0001	0.0884	0.0156
6	<.0001	0.0035	<.0001	<.0001	<.0001	0.0003	0.0836	0.2904
7	<.0001	0.0202	<.0001	<.0001	<.0001	0.0001	0.5581	0.9467
8	<.0001	<.0001	<.0001	<.0001	<.0001	0.5380	<.0001	0.0002
9		0.0096	0.0025	0.0053	0.3403	<.0001	0.0009	0.0003
10	0.0096		<.0001	<.0001	0.0044	<.0001	0.1241	0.0339
11	0.0025	<.0001		0.6163	0.0463	<.0001	<.0001	<.0001
12	0.0053	<.0001	0.6163		0.0951	<.0001	<.0001	<.0001
13	0.3403	0.0044	0.0463	0.0951		<.0001	<.0001	<.0001
14	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001
15	0.0009	0.1241	<.0001	<.0001	<.0001	<.0001		0.4666
16	0.0003	0.0339	<.0001	<.0001	<.0001	<.0001	0.4666	
17	0.0287	0.0004	0.5892	0.9011	0.1335	<.0001	<.0001	<.0001
18	0.1704	0.0048	0.2526	0.4216	0.5097	<.0001	0.0002	<.0001
19	<.0001	<.0001	<.0001	<.0001	<.0001	0.0092	<.0001	0.0003
20	<.0001	<.0001	<.0001	<.0001	<.0001	0.8766	<.0001	<.0001
21	<.0001	<.0001	0.2393	0.0686	0.0001	<.0001	<.0001	<.0001
22	<.0001	<.0001	<.0001	<.0001	<.0001	0.0243	<.0001	<.0001
23	0.0005	0.1626	<.0001	<.0001	<.0001	<.0001	0.5639	0.1423
24	0.0001	<.0001	0.7196	0.3201	0.0011	<.0001	<.0001	<.0001

Least Squares Means for effect treatment*measurement
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: cov

i/j	17	18	19	20	21	22	23	24
1	<.0001	<.0001	0.0002	0.8926	<.0001	0.0013	<.0001	<.0001
2	<.0001	0.0002	0.5916	0.4299	<.0001	0.7416	0.0184	<.0001
3	<.0001	<.0001	0.0007	0.0235	<.0001	0.0049	<.0001	<.0001
4	<.0001	<.0001	0.0001	<.0001	<.0001	<.0001	0.0053	<.0001
5	<.0001	0.0011	<.0001	<.0001	<.0001	<.0001	0.0589	<.0001
6	<.0001	<.0001	0.0063	<.0001	<.0001	0.0015	0.0096	<.0001
7	<.0001	0.0002	0.0010	<.0001	<.0001	0.0003	0.2473	<.0001
8	<.0001	<.0001	0.0481	0.3214	<.0001	0.1152	<.0001	<.0001
9	0.0287	0.1704	<.0001	<.0001	<.0001	<.0001	0.0005	0.0001
10	0.0004	0.0048	<.0001	<.0001	<.0001	<.0001	0.1626	<.0001
11	0.5892	0.2526	<.0001	<.0001	0.2393	<.0001	<.0001	0.7196
12	0.9011	0.4216	<.0001	<.0001	0.0686	<.0001	<.0001	0.3201
13	0.1335	0.5097	<.0001	<.0001	0.0001	<.0001	<.0001	0.0011
14	<.0001	<.0001	0.0092	0.8766	<.0001	0.0243	<.0001	<.0001
15	<.0001	0.0002	<.0001	<.0001	<.0001	<.0001	0.5639	<.0001
16	<.0001	<.0001	0.0003	<.0001	<.0001	<.0001	0.1423	<.0001
17		0.4984	<.0001	<.0001	0.0591	<.0001	<.0001	0.2681
18	0.4984		<.0001	<.0001	0.0164	<.0001	0.0001	0.0729
19	<.0001	<.0001		<.0001	<.0001	0.2462	<.0001	<.0001
20	<.0001	<.0001	<.0001		<.0001	<.0001	<.0001	<.0001
21	0.0591	0.0164	<.0001	<.0001		<.0001	<.0001	0.0266
22	<.0001	<.0001	0.2462	<.0001	<.0001		<.0001	<.0001
23	<.0001	0.0001	<.0001	<.0001	<.0001	<.0001		<.0001
24	0.2681	0.0729	<.0001	<.0001	0.0266	<.0001	<.0001	

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

APPENDIX D

Questionnaire SAS Code and Output

SAS Code for Questionnaire:

```
data SMDSurvey;
       input Q4 $ Qcompare5 $ Count;
       datalines;
       a  5b     68
       a  5c     11
       a  5adef  11
       b  5b    196
       b  5c    126
       b  5adef  91
       cd 5b     28
       cd 5c     35
       cd 5adef  54
       ;
run;
proc freq data=SMDSurvey;
       weight Count;
       table Q4*Qcompare5/chisq expected norow nocol;
run;

data SMDSurvey;
       input Q4 $ Qcompare7 $ Count;
       datalines;
       a  7b     82
       a  7c      5
       a  7ad     3
       b  7b    243
       b  7c    159
       b  7ad    11
       cd 7b     47
       cd 7c     51
       cd 7ad    19
       ;
run;
proc freq data=SMDSurvey;
       weight Count;
       table Q4*Qcompare7/chisq expected norow nocol;
       exact pchi;
run;

data SMDSurvey;
       input Q4 $ Qcompare8 $ Count;
       datalines;
       a  8y     33
       a  8n     57
       b  8y    222
       b  8n    191
       cd 8y     67
       cd 8n     50
       ;
run;
proc freq data=SMDSurvey;
       weight Count;
       table Q4*Qcompare8/chisq expected norow nocol;
run;

data SMDSurvey;
       input Q4 $ Qcompare9 $ Count;
       datalines;
       a  9y     87
       a  9n      3
       b  9y    378
       b  9n     35
       cd 9y     87
       cd 9n     30
       ;
run;
proc freq data=SMDSurvey;
       weight Count;
       table Q4*Qcompare9/chisq expected norow nocol;
       exact pchi;
run;
```

SAS Output for Questionnaire:

Table D-1. Results for Comparison of Questions 4 and 5

```
 The SAS System 11:54 Friday, April 4, 2003

        The FREQ Procedure

     Table of Q4 by Qcompare5

     Q4        Qcompare5

     Frequency|
     Expected |
     Percent  |5adef   |5b      |5c      |  Total
     --------------------------------------------
     a        |     11 |     68 |     11 |     90
              | 22.645 | 42.387 | 24.968 |
              |   1.77 |  10.97 |   1.77 |  14.52
     ---------|--------|--------|--------|
     b        |     91 |    196 |    126 |    413
              | 103.92 | 194.51 | 114.57 |
              |  14.68 |  31.61 |  20.32 |  66.61
     ---------|--------|--------|--------|
     cd       |     54 |     28 |     35 |    117
              | 29.439 | 55.103 | 32.458 |
              |   8.71 |   4.52 |   5.65 |  18.87
     ---------|--------|--------|--------|
     Total         156      292      172      620
                 25.16    47.10    27.74   100.00


        Statistics for Table of Q4 by Qcompare5

 Statistic                     DF       Value      Prob
 ------------------------------------------------------
 Chi-Square                     4     66.0577    <.0001
 Likelihood Ratio Chi-Square    4     66.0416    <.0001
 Mantel-Haenszel Chi-Square     1      3.5617    0.0591
 Phi Coefficient                       0.3264
 Contingency Coefficient               0.3103
 Cramer's V                            0.2308

Sample Size = 620
```

Table D-2. Results for Comparison of Questions 4 and 7

```
 The SAS System 11:54 Friday, April 4, 2003

        The FREQ Procedure

     Table of Q4 by Qcompare7

     Q4        Qcompare7

     Frequency|
     Expected |
     Percent  |7ad     |7b      |7c      |  Total
     ---------|--------|--------|--------|
     a        |      3 |     82 |      5 |     90
              | 4.7903 |     54 |  31.21 |
              |   0.48 |  13.23 |   0.81 |  14.52
     ---------|--------|--------|--------|
     b        |     11 |    243 |    159 |    413
              | 21.982 |  247.8 | 143.22 |
              |   1.77 |  39.19 |  25.65 |  66.61
     ---------|--------|--------|--------|
     cd       |     19 |     47 |     51 |    117
              | 6.2274 |   70.2 | 40.573 |
              |   3.06 |   7.58 |   8.23 |  18.87
     ---------|--------|--------|--------|
     Total          33      372      215      620
                  5.32    60.00    34.68   100.00


        Statistics for Table of Q4 by Qcompare7

 Statistic                     DF       Value      Prob
 ------------------------------------------------------
 Chi-Square                     4     81.0612    <.0001
 Likelihood Ratio Chi-Square    4     83.8990    <.0001
 Mantel-Haenszel Chi-Square     1      7.5315    0.0061
 Phi Coefficient                       0.3616
 Contingency Coefficient               0.3400
 Cramer's V                            0.2557


     Pearson Chi-Square Test
 ----------------------------------
 Chi-Square                 81.0612
 DF                               4
 Asymptotic Pr >  ChiSq      <.0001
 Exact      Pr >= ChiSq   3.474E-13

Sample Size = 620
```

Table D-3. Results for Comparison of Questions 4 and 8

```
 The SAS System 11:54 Friday, April 4, 2003

         The FREQ Procedure

      Table of Q4 by Qcompare8

 Q4        Qcompare8

 Frequency|
 Expected |
 Percent  |8n      |8y      |  Total
 ---------|--------|--------|
 a        |     57 |     33 |     90
          | 43.258 | 46.742 |
          |   9.19 |   5.32 |  14.52
 ---------|--------|--------|
 b        |    191 |    222 |    413
          | 198.51 | 214.49 |
          |  30.81 |  35.81 |  66.61
 ---------|--------|--------|
 cd       |     50 |     67 |    117
          | 56.235 | 60.765 |
          |   8.06 |  10.81 |  18.87
 ---------|--------|--------|
 Total         298      322      620
             48.06    51.94   100.00


         Statistics for Table of Q4 by Qcompare8

 Statistic                    DF       Value      Prob
 ------------------------------------------------------
 Chi-Square                     2     10.2833    0.0058
 Likelihood Ratio Chi-Square    2     10.3567    0.0056
 Mantel-Haenszel Chi-Square     1      7.7552    0.0054
 Phi Coefficient                       0.1288
 Contingency Coefficient               0.1277
 Cramer's V                            0.1288

Sample Size = 620
```

Table D-4. Results for Comparison of Questions 4 and 9

```
 The SAS System 11:54 Friday, April 4, 2003

         The FREQ Procedure

      Table of Q4 by Qcompare9

 Q4        Qcompare9

 Frequency|
 Expected |
 Percent  |9n      |9y      |  Total
 ---------|--------|--------|
 a        |      3 |     87 |     90
          |  9.871 | 80.129 |
          |   0.48 |  14.03 |  14.52
 ---------|--------|--------|
 b        |     35 |    378 |    413
          | 45.297 |  367.7 |
          |   5.65 |  60.97 |  66.61
 ---------|--------|--------|
 cd       |     30 |     87 |    117
          | 12.832 | 104.17 |
          |   4.84 |  14.03 |  18.87
 ---------|--------|--------|
 Total          68      552      620
             10.97    89.03   100.00


         Statistics for Table of Q4 by Qcompare9

 Statistic                     DF       Value      Prob
 ------------------------------------------------------
 Chi-Square                     2     33.7983    <.0001
 Likelihood Ratio Chi-Square    2     29.6138    <.0001
 Mantel-Haenszel Chi-Square     1     28.7052    <.0001
 Phi Coefficient                       0.2335
 Contingency Coefficient               0.2274
 Cramer's V                            0.2335


      Pearson Chi-Square Test
 ----------------------------------
 Chi-Square                 33.7983
 DF                               2
 Asymptotic Pr >  ChiSq      <.0001
 Exact      Pr >= ChiSq   3.437E-07

Sample Size = 620
```