Effects of Automated Speed Enforcement in Maryland Work Zones

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Abstract

The Maryland State Highway Administration has started a pilot program to evaluate the effectiveness of an automated speed enforcement system in work zones. Three sites were selected to measure the spatial and temporal effect of automated speed enforcement on motorists' speeding behavior. In addition to comparing the temporal changes and spatial evolution of mean and 85 percentile speeds, the spatial and temporal change in percentages of three motorist populations, conservative, normal and aggressive drivers, were considered. A total of five datasets were analyzed. For the two data sets that compared the before versus during analysis periods, the enforcement period displayed a general reduction in aggressive motorists while creating a more stable spatial speeding distribution through the work zone. Two of the three data sets comparing the during versus after enforcement periods showed that motorists may learn where enforcement is taking place and adjust their speeds accordingly. This effect was evident even after the enforcement period. Lastly, one dataset displayed increased speeds and less stable spatial speeding patters during the enforcement period, suggesting the need for further investigation of this data set.

I. INTRODUCTION

As well recognized, speeding is one of the main factors in highway crashes. In 2008, speeding contributed to 31 percent of all fatal crashes and 11,674 lives were lost in speeding-related crashes *(1)*. For work zones in particular, the speeding problem is compounded by on-site road re-configuration, lane closures, narrowed lanes, and/or reduced visibility. Thousands of crashes occurring in work zones each year lead to numerous fatalities and injuries. According to the National Highway Traffic and Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS), 720 nationwide fatalities resulted from motor vehicle crashes in work zones in 2008. During the same year, 11 work zone fatalities occurred in the state of Maryland. NHTSA estimates the economic cost to society of speeding related crashes is $40.4 billion per year *(1)*. These statistics emphasize the need to motivate drivers to comply with the speed limit in work zones.

There is a wealth of literature on traditional work zone speed control methods, including, but not limited to flagging, use of marked police vehicles *(2)* and speed display trailers *(3)*. Each method has inherent advantages and disadvantages. For example, the use of police cars is effective in improving motorist compliance with speed limits but the effect is localized both temporally and spatially. In addition, police presence can be costly for long-term projects *(4)*. Recent studies by the Washington Department of Transportation (DOT), the Arizona DOT, Illinois DOT, and the Oregon DOT have shown that the use of automated speed enforcement (ASE) is an effective method to improve motorist compliance with work zone speed limits while increasing overall safety.

Recognizing the potential advantages of ASE, the Maryland State Highway Administration (MD SHA) started a pilot program that involved deployment of two mobile ASE vehicles in October 2009. The pilot sites were located at three highway work zones in the Baltimore-Washington area. During the first 30 days of deployment only warnings were issued to motorists traveling 12 mph more over the posted speed limit. During the same period, promotion and media campaigns were widely broadcasted to raise the awareness of the general public. Following the initial 30 day period, citations were issued to the registered owner of the speeding vehicle. Time stamped speed and volume data was collected in two separate data sets by MD SHA contractors. In each data set the during ASE deployment data was collected well after the warning period had expired. The first data set included the before and during ASE deployment periods, with data collection locations upstream, at and downstream of the ASE vehicle. The before ASE deployment was collected before the installation of advanced warning signs. Due to data deficiencies in the first data set, a second data set was collected. The data deficiencies are discussed in detail in the results and analysis section. The second data set entailed the during and after ASE deployment periods, with data collection locations upstream, at, downstream, and far downstream of the ASE vehicle. The addition of the far downstream data collection location was added to allow for a more in-depth spatial analysis while the after ASE deployment period allowed for a more complete temporal analysis.

II. LITERATURE REVIEW

Over the past decade, speed photo enforcement programs have been implemented on highways, local roads, and work zones in the US. Studies have showed that automated speed enforcement can significantly reduce the average speed, reduce the percentage of speeding vehicles, and increase general traffic safety conditions *(5).*

In 2004, the Illinois DOT deployed automated speed photo-radar enforcement (SPE) in work zones for the first time in US. The results of these efforts are published in a series of papers. The study by Hajbabaie et al. *(6)* included the comparison between SPE and other speed management treatments. The study evaluated the effects separately for cars and trucks in both free-flow and in the general traffic stream for the median and shoulder lanes. The study showed that SPE reduced the mean speed and the percentage of speeding of both cars and trucks in both traffic conditions, in both the median and shoulder lanes.

Using similar measures of effectiveness, Benekohal et al *(7)* found a reduction of 6.3-7.9 mph in the mean speed of cars in the median lane and by 4.1-7.7 mph in the shoulder lane. As for trucks, the reduction in mean speed was reduced by 3.4-6.9 mph in the median lane and 4.0-6.1 mph in the shoulder lane. Additionally, the percent of speeding cars and trucks in both lanes were reduced. A similar study by Benekohal et al *(8)* showed that SPE reduced the average speed of cars by 4.2-7.9 mph, with the average speed of trucks reduced by 3.4 to 6.9 mph. Again, the percentages of speeding cars and trucks were reduced during the SPE deployment period. The halo effects of SPE were also considered in this study. In one work zone the average speed of trucks was reduced by 1.8-2.7 mph. However the halo effect on passenger cars was minimal. The study by Medina et al. *(9)* showed that SPE had a minor reduction in mean speeds of both cars and trucks at a location 1.5 miles downstream of the SPE location.

The Arizona DOT conducted a fixed speed-enforcement camera demonstration program (SEP) in 2006, and deployed their first work zone speed enforcement cameras in early 2008 *(5).* The authors conducted the impact analysis over five time periods (before, warning, program, after and reactivation) with respect to citable speeding behavior (i.e., speeds > 75 mph), average speeds, and traffic safety (i.e. motor vehicle crashes) within the enforcement zone. The study also considered total travel time and expected economic factors. The results showed that the SEP reduced the average speed by 9 mph, reduced speeding vehicles by 26% from the warning to program period.

The Washington DOT undertook a six-month automated enforcement pilot project in 2008-2009 *(10).* The study was conducted at two highway work zones. The before, during, and after enforcement periods were compared in terms of average speed, speed distribution, and percentage of speeding vehicles. The result showed that the ASE program significantly reduced average speed and reduced the percentage of vehicles traveling over 70 mph from 18% before ASE deployment to 8-13% during the enforcement period. After removing the ASE, motorists returned to speeding patterns similar to that of the pre-deployment period.

The Oregon DOT conducted a photo-radar enforcement study from March through September of 2009. The study found a 27% reduction in speeding vehicles during the enforcement period. However, when the enforcement vehicle was removed, motorists returned to the pre-enforcement speeding behaviors *(11).*

Despite the significant progress made by transportation professionals on this vital subject, many critical issues associated with the effectiveness of ASE remain to be explored. For instance, what are the spatial speeding effects of ASE upstream and far downstream of the enforcement area? Does a reduction in mean speeds make the work zone safer? Do regular road users learn where enforcement take place and adjust their spatial speeding pattern accordingly? Does the installment of advanced warning ASE signs alone affect speeding behaviors? Would moving the enforcement location on a regular basis have an effect on speeding behaviors?

III. ANALYSIS METHODS AND AVAILABLE DATA SETS

Data Analysis Methods

While changes in the mean or the 85 percentile speeds is often used as a measure of ASE effectiveness, reductions in such measures do not necessarily result in safer work zones. In fact, a study done by Garber and Gadiraju *(12)* found that crash rates are more strongly correlated with speed variation than with mean speed. Considering these findings, the authors of this paper have identified some additional measures of ASE effectiveness to further analyze the influence ASE on speed variance.

In addition to the comparison of mean speeds and 85 percentile speeds, this study also includes the change in speed distribution for the off peak hours. To compare the change in the general speed distribution, this study has defined three speed bins for convenience of analysis:

1. Conservative drivers: those traveling between 1mph- Posted Speed Limit
2. Normal drivers: those traveling between 1 mph over the Posted Speed Limit – 10 mph over the Posted Speed Limit
3. Aggressive drivers: those traveling more than 10 mph over the Posted Speed Limit

This approach identifies how much each population of motorists was affected by the ASE, and how the distributions of speeds changed both temporally and spatially.

Available Data Sets

Data was collected at three work zone locations, in one direction at each work zone. The first pilot work zone was located at NB I95, near the Inter-County Connector (ICC) project. The posted speed limit before, during, and after ASE deployment was 65 mph for this site. The next work zone was at the SB I95 Express Toll Lane (ETL), southeast of Baltimore, MD. Here, the posted speed limit was 55 mph for the before, during and after ASE deployment periods. The final work zone was located on the WB Baltimore Beltway, I695, north of the city. The posted speed limit for the I695 site was 50 mph for all three analysis periods.

A complete data set would include time stamped, speed binned data at four data collection locations, upstream, at, downstream and far downstream of the enforcement area. The data set would also cover the before, during, and after ASE deployment data. However, due to lack of experience, none of the available data sets collected by SHA consultants meet all of these criteria. In fact, data was collected by SHA consultants in two separate data sets for each of the study sites. The first data set was collected by tube counters and covered the before and during deployment periods. The second data set was collected via microwave sensors and covered the during and after deployment periods, and added the far downstream data collection location. Since both Dataset-1 and Dataset-2 included a during ASE deployment period, it was possible to compare the during ASE deployment data from each data set, and evaluate the speed distribution stability in the two data sets. An independent sample t-test was used to compare the percentages in each of the previously mentioned speed bins, at the upstream, at, and downstream of the ASE vehicle data collection locations for the during ASE deployment data in each data set. Since, none of the work zones exhibited stable speeding patterns; it was decided to analyze these two data sets independently. The data deficiencies associated with each work zone are summarized below:

<u>I695 at Charles St. Data Deficiencies:</u>

1. Dataset-1 was not usable do to incomplete lane coverage
2. Dataset-2 lacks before ASE data

<u>I95/ETL Data Deficiencies:</u>

1. Dataset-1 lacks the after ASE data
2. Dataset-1 lacks the far downstream data location
3. Dataset-1 at ASE location, during ASE deployment data was collected on different dates and days the week than adjacent locations
4. Dataset-2 lacks before ASE data

<u>I95 at ICC Data Deficiencies:</u>

1. Dataset-1 lacks the after ASE data
2. Dataset-1 lacks the far downstream data location
3. Dataset-1 before ASE data was collected on Mon-Wed, Dataset-1 during data was collected Thur-Mon
4. Dataset-2 lacks before ASE data

Due to the aforementioned deficiencies, the data sets available for analysis are presented in Tables 1, 2, and 3. The distance to the data collection locations, relative to the location of the ASE enforcement vehicle are shown in Figure 1:

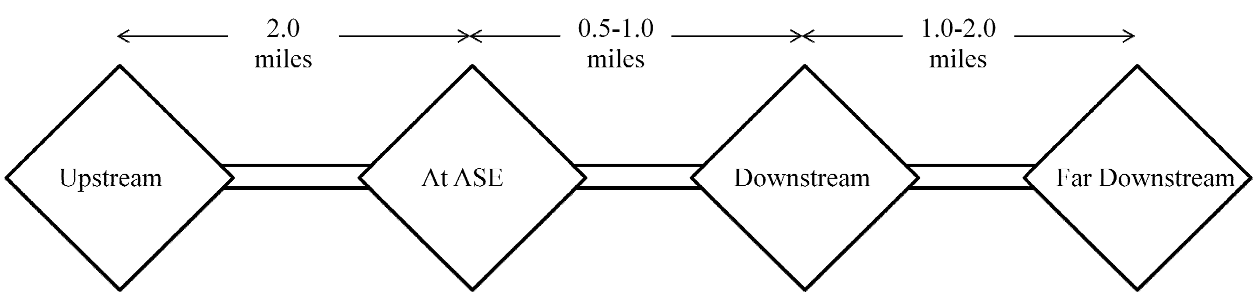

FIGURE1: Relative distances to data collection locations

TABLE 1: WB I695 at Charles St. Data Summary

I695 at Charles St. WB Data		
	During Dataset-2	**After Dataset-2**
Location	Collection Dates	Collection Dates
Upstream	June 2-8, 2010 (Wed-Tues)	June 9-16, 2010 (Wed-Wed)
At	June 2-8, 2010 (Wed-Tues)	June 9-16, 2010 (Wed-Wed)
Downstream	June 2-8, 2010 (Wed-Tues)	June 9-16, 2010 (Wed-Wed)
Far Downstream	June 2-8, 2010 (Wed-Tues)	June 9-16, 2010 (Wed-Wed)

TABLE 2: SB I95/ETL Data Summary

SB I95/ETL Data				
	Before Dataset-1	**During Dataset-1**	**During Dataset-2**	**After Dataset-2**
Location	Collection Dates	Collection Dates	Collection Dates	Collection Dates
Upstream	Oct 21-22, 2009 (Wed–Thurs)	Dec 2-3, 2009 (Wed , Thurs)	June 30 –July 7, 2010 (Wed–Wed)	July 7- 14, 2010 (Wed-Wed)
At	Oct 21-22, 2009 (Wed–Thurs)	**Dec 8-9, 2009 (Tues, Wed)*	June 30 –July 7, 2010 (Wed–Wed)	July 7- 14, 2010 (Wed-Wed)
Downstream	Oct 21-22, 2009 (Wed–Thurs)	Dec 2-3, 2009 (Wed , Thurs)	June 30 –July 7, 2010 (Wed–Wed)	July 7- 14, 2010 (Wed-Wed)
Far Downstream	NA	NA	June 30 –July 7, 2010 (Wed–Wed)	July 7- 14, 2010 (Wed-Wed)

*Data collected on different dates than adjacent data collection sites\

TABLE 3: NB I95 at ICC Data Summary

NB I95 at ICC Data				
	Before Dataset-1	**During Dataset-1**	**During Dataset-2**	**After Dataset-2**
Location	Collection Dates	Collection Dates	Collection Dates	Collection Dates
Upstream	Oct 28- 30, 2009 (Mon–Wed)	Dec 10-14, 2009 (Thurs – Mon)	June16- 23, 2010 (Wed-Wed)	June 23-30, 2010 (Wed-Wed)
At	Oct 28- 30, 2009 (Mon–Wed)	Dec 10-14, 2009 (Thurs – Mon)	June16- 23, 2010 (Wed-Wed))	June 23-30, 2010 (Wed-Wed)
Downstream	Oct 28- 30, 2009 (Mon–Wed)	Dec 10-14, 2009 (Thurs – Mon)	June16- 23, 2010 (Wed-Wed)	June 23-30, 2010 (Wed-Wed)
Far Downstream	NA	NA	June16- 23, 2010 (Wed-Wed)	June 23-30, 2010 (Wed-Wed)

IV. RRESULTS AND ANALYSIS

Based on the both the data quality and availability, this study has conducted the following analysis for each of the demonstration sites:

I695 at Charles St. Analysis:

1. During versus after ASE temporal analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed at each available data collection location across the during and after ASE analysis periods
2. During ASE spatial analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the during ASE time period
3. After ASE spatial analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the after ASE time period

I95/ETL Analysis:

1. Before versus during ASE temporal analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed at each available data collection location across the before and during ASE analysis periods
2. During versus after ASE temporal analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed at each available data collection location across the during and after ASE analysis periods
3. Before ASE spatial analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the before ASE time period

4. During ASE spatial analysis (Dataset-1): comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the during ASE time period
5. During ASE spatial analysis (Dataset-2): comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the during ASE time period
6. After ASE spatial analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the after ASE time period

<u>I95 at ICC Analysis:</u>

1. Before versus during ASE temporal analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed at each available data collection location across the before and during ASE analysis periods
2. During versus after ASE temporal analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed at each available data collection location across the during and after ASE analysis periods
3. Before ASE spatial analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the before ASE time period
4. During ASE spatial analysis (Dataset-1): comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the during ASE time period
5. During ASE spatial analysis (Dataset-2): comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the during ASE time period
6. After ASE spatial analysis: comparing the percentages in each driver population, as well as the mean and 85 percentile speed across the available data collection locations for the after ASE time period

Site Analysis:

Ideally, the before ASE deployment data should be used as the base data set in which the during and after ASE deployment data are compared to. This strategy accounts for "pre-existing" speeding behaviors that should not be attributed to the use of ASE. However, only two of the data sets, the I95/ICC Dataset-1 and the I95/ETL Dataset-1, had before ASE deployment data. Tables 4, 5, and 6 present the distribution of the driving population, along with the mean and 85 percentile speed for each data collection location and analysis period. Each table is followed by a brief summary for each study site.

I695 Site

TABLE 4: I695 Speed Distributions, Mean Speeds, and 85 Percentile Speeds

Period	Bin/Parameter	Upstream	At ASE	Downstream	Downstream
During	Conservative	10.7%	39.6%	3.9%	0.9%
	Normal	44.3%	40.1%	38.7%	12.6%
	Aggressive	**45.0%**	**20.3%**	**57.4%**	**86.6%**
	Mean Speed*	59.0	50.7	61.6	66.3
	85% Speed*	62.9	54.6	65.7	70.4
After	Conservative	19.0%	35.7%	11.0%	6.9%
	Normal	40.8%	38.0%	35.2%	14.1%
	Aggressive	**40.2%**	**26.3%**	**53.9%**	**78.9%**
	Mean Speed*	59.8	52.8	61.3	66.0
	85% Speed*	63.7	56.7	65.4	70.1

* Units of mph

From Table 4, the spatial speeding pattern for both the during and after ASE deployment at the I695 site were similar. In both analysis periods, there is a reduction in aggressive motorists approaching the enforcement location (from 45.0% to 20.3% in the during period, and from 40.2% to 26.3% in the after period), followed by a steady increase in aggressive driving once past the enforcement location. Markedly, the percentage of aggressive motorists grew from 20.3% at the enforcement location to 86.6% at the far downstream location during the enforcement period, and grew from 26.3% to 78.9% after the enforcement period. Similar spatial patterns in the 85 percentile and mean speeds were also discovered. For instance, the mean speed at the enforcement location, during the enforcement period, was 50.7 mph and increased to 66.3 mph at the far downstream location. The temporal changes between the during and after analysis periods were minor at this site.

The I695 work zone reduced speeds as motorists approached the enforcement location; however the speed reduction was localized. At this site, it appears that motorists may learn where enforcement is occurring and adjust their speeds accordingly. Once past the enforcement location is passed, speeds steadily increased, perhaps in an attempt to make up for time lost by slowing down near the enforcement area.

I95/ETL Site

TABLE 5: I95/ETL Speed Distributions, Mean Speeds, and 85 Percentile Speeds

	Period	Bin/Parameter	Upstream	At ASE	Downstream	Far Downstream
Dataset-1	Before	Conservative	41.8%	27.9%	34.7%	NA
		Normal	51.2%	60.0%	55.3%	NA
		Aggressive	**7.0%**	**12.1%**	**10.1%**	NA
		Mean Speed*	**55.2**	**58.6**	**57.8**	NA
		85% Speed*	63.0	63.0	63.0	NA
	During	Conservative	52.9%	50.9%	55.7%	NA
		Normal	43.2%	44.7%	40.4%	NA
		Aggressive	**4.0%**	**4.4%**	**3.9%**	NA
		Mean Speed*	**54.1**	**55.2**	**54.8**	NA
		85% Speed*	63.0	63.0	63.0	NA
Dataset-2	During	Conservative	11.1%	5.7%	9.2%	3.8%
		Normal	54.6%	44.0%	53.8%	21.5%
		Aggressive	**34.3%**	**50.3%**	**37.0%**	**74.7%**
		Mean Speed*	63.4	**65.7**	63.3	68.3
		85% Speed*	67.7	**70.3**	67.3	72.4
	After	Conservative	17.2%	18.8%	16.7%	7.6%
		Normal	57.4%	52.1%	57.6%	29.4%
		Aggressive	**25.4%**	**29.1%**	**25.6%**	**63.0%**
		Mean Speed*	61.1	**61.3**	60.2	65.3
		85% Speed*	65.3	**65.8**	64.0	69.2

* Units of mph

Table 5 shows that the before ASE period of Dataset-1 for the I95/ETL site displayed an increase in both the percentage of aggressive drivers and mean speed, as motorists approach the ASE location. For example, the 55.2 mph mean speed at the upstream location increased by 3.4 mph, to 58.6 mph. However, during ASE deployment in Dataset-1, both parameters became steadier as motorists progressed through the work zone. Here the mean speed increased by 1.1 mph, from 54.1 mph at the upstream location to 55.2 mph at the enforcement location. It is worth noting that while the mean speed increased at the enforcement location during the enforcement period, the percentage of aggressive motorists approaching the enforcement location became more stable, thus reducing spatial speed variation. Had this analysis only considered the mean speed, the conclusion on the spatial effect of ASE at this site would have been different. From a temporal perspective, aggressive driving decreased at all three data collection locations, with the largest reduction, from occurring at the enforcement location. The reduction in aggressive driving during the enforcement period was paired with a reduction in mean speeds and an increase in conservative driving at all three data collection locations.

Conversely, the spatial speeding pattern became unstable for the during ASE deployment period of Dataset-2 for the I95/ETL site. Here, aggressive driving increased 16.0%, from 34.3% at the upstream location to 50.3% at the enforcement location, then decreased by 13.2%, to 37.0% at the downstream location, only to increase by 37.7%, to 74.7% at the far downstream location. The mean and 85% speeds displayed a parallel pattern. A similar but less dramatic spatial speeding pattern was observed in the after ASE period. The after analysis period showed a spatial aggressive driving evolution of 25.4 % upstream, to 29.1% at ASE, decreasing to 25.6% downstream, finally increasing to 63.0% far downstream. Considering the temporal effects, aggressive driving and the mean speeds at all for data collection locations were reduced after the ASE was removed. The counter intuitive results discovered in Dataset-2 for the I95/ETL site may indicate an equipment calibration error or other issues with the collected data. As such, no further analysis will be discussed on this data set.

Dataset-1 for the I95/ETL showed ASE reduced the percentage of aggressive driving and mean speeds at all three data collection locations. These reductions occurred while making the spatial speed patterns more stable. As previously mentioned, the results of Dataset-2 suggest some potential errors in the dataset. The sources of errors are not known, but may be related to equipment calibration or low enforcement rates at this site.

I95 at ICC Site

TABLE 6: I95 at ICC Speed Distributions, Mean Speeds, and 85 Percentile Speeds

	Period	Bin/Parameter	Upstream	At ASE	Downstream	Far Downstream
Dataset-1	Before	Conservative	55.4%	62.1%	**34.7%**	NA
		Normal	40.4%	34.9%	**53.0%**	NA
		Aggressive	4.2%	3.0%	**12.3%**	NA
		Mean Speed*	64.3	63.2	67.7	NA
		85% Speed*	73.0	68.0	73.0	NA
	During	Conservative	70.8%	66.8%	**61.3%**	NA
		Normal	26.5%	29.1%	**32.9%**	NA
		Aggressive	2.7%	4.1%	**5.8%**	NA
		Mean Speed*	58.9	61.3	62.7	NA
		85% Speed*	68.0	68.0	73.0	NA
Dataset-2	During	Conservative	57.7%	86.4%	49.1%	32.5%
		Normal	37.7%	12.8%	42.4%	55.1%
		Aggressive	**4.6%**	**0.7%**	**8.5%**	**12.5%**
		Mean Speed*	63.2	57.8	63.4	67.8
		85% Speed*	67.6	61.6	67.0	71.7
	After	Conservative	51.8%	83.3%	42.7%	25.6%
		Normal	42.1%	16.0%	45.9%	57.5%
		Aggressive	**6.1%**	**0.7%**	**11.4%**	**16.8%**
		Mean Speed*	62.5	59.6	63.3	68.6
		85% Speed*	66.8	63	67.1	72.6

* Units of mph

Table 6 summarizes the analysis results for the I96at ICC work zone. The before ASE analysis period in Dataset-1 for the I95 at ICC site showed a fairly stable spatial speeding pattern until motorists reached the downstream location. Here, conservative driving reduced by 27.4% relative to the enforcement location, from 86.4% to 49.1%. Normal driving increased by from 34.9% to 53%, a change of 18.1%. Similarly aggressive driving rose 9.4%, from 3.0% to 12.3%. In contrast, the during deployment period for Dataset-1 created a stable spatial speeding pattern at all three data collection locations. In fact, the largest change in driver population percentage between adjacent locations for this period was 5.6%, occurring in the conservative driver bin, comparing the at ASE locations (66.8%) versus downstream location (61.3%). The temporal analysis of Dataset-1 shows a reduction in mean speeds of 5.4 mph (from 64.3 mph to 58.9 mph), 2.0 mph (from 63.2 mph to 61.3 mph) and 5.0 mph (from 67.7 mph to 62.7 mph) for the upstream, at ASE, and downstream locations, respectively. Interestingly, aggressive driving was reduced at the upstream and downstream locations, while the aggressive driving at ASE location remained about the same with a slight increase of 1.1%.

Both analysis periods for Dataset-2 for the I95 at ICC work zone displayed a reduction in aggressive motorists approaching the enforcement location. However, the percentage of aggressive motorists increased downstream, and then again far downstream of the ASE location. Temporally, three of the four data collection location saw an a slight increase in aggressive driving. These increased were 1.5%, 2.9%, and 4.4% for the upstream, downstream, and far downstream locations, respectively. The at ASE location showed no change in the percentage of aggressive motorists.

Dataset-1 for the I95 at ICC work zone showed a reduction in aggressive driving in the upstream and downstream data collection locations as well as a more stable spatial speeding pattern through the work zone. Similar to the results at the I695 site, Dataset-2 for the I95 at ICC site displayed a potential learning behavior as motorists reduced speeds near the enforcement area. Upon passing the enforcement location, speeds increased with distance from the enforcement area. Again, one plausible explanation may be motorists attempting to make for time lost by slowing near the enforcement area.

V. CONCLUSIONS AND FUTURE WORK

Due to the data quality and availability, the effects of ASE on the speeding behavior are not consistent across the three work zones. The I695 site showed that motorists tend to reduce speeds at the enforcement location, then speed back up once past that location. This pattern was evident in both the during and after analysis periods. However, since there was no before ASE data for this site, it cannot be determined if this spatial speeding behavior was caused entirely by the ASE system. Dataset-1 for the I95/ETL site showed a reduction in aggressive driving at all three data collection locations during ASE, while creating a more stable spatial speed distribution as motorists progressed through the work zone. Dataset-2 for the I95/ETL site displayed abnormal results for both the spatial and temporal considerations. Such results may indicate erroneous data and thus no clear conclusions can be made. Lastly, Dataset-1 for the I95 at ICC site showed increased spatial speed stability during the deployment period. While aggressive driving remained the same at the ASE location, the upstream and downstream locations exhibited reductions in aggressive driving. Interestingly, Dataset-2 for the I95 at ICC site observed motorists slowing down while approaching the enforcement location, then speeding back up beyond that location. The after enforcement period showed slight increases in the percentage of aggressive motorists at three of the four data collection locations.

In summary, for the two data sets that compared the before versus during analysis periods, the enforcement period displayed a general reduction in aggressive motorists while creating a more stable spatial speeding distribution through the work zone. Two of the three data sets comparing the during versus after ASE deployment periods showed that motorists may learn where enforcement is taking place and adjust their speeds accordingly. This effect was evident even after the enforcement period. Lastly, the irregular results from Dataset-2 for the I95/ETL site suggest the need for further investigation of this data set.

Future Work

The MD SHA has begun data collection at a new work zone in the Baltimore-Washington region. This data set will include a before, during and after ASE deployment periods at upstream, at ASE, downstream, and far downstream locations. Data will be collected for a full week for each of the three periods. The results of this analysis should produce more definitive conclusions on the spatial and temporal effects of ASE on motorists' speeding behaviors in Maryland work zones.

Given the potential discovery of a learning pattern, future considerations may include the impact of ASE on commuters and non-commuters using license plate reading cameras. It would also be interesting to see if moving the enforcement location on regular basis would mitigate the potential learning pattern, thus promoting a more stable spatial speeding pattern. Another strategy may be to study the effect of only the advanced warning ASE warning signs on motorists speeding behaviors.

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