AGGRESSIVE DRIVING VIDEO AND NON-CONTACT ENFORCEMENT

(ADVANCE)

Productivity Analysis Results

Final Report

Submitted to

Maryland State Police

By

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TABLE OF CONTENTS

Page

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LIST OF ACRONYMS

ADVANCE	-	Aggressive Driving Video And Non-Contact Enforcement
ATC	-	Aberdeen Test Center
CVED	-	Commercial Vehicle Enforcement Division
FHWA	-	Federal Highway Administration
FMCSA	-	Federal Motor Carrier Safety Administration
JPL	-	Jet Propulsion Laboratory
MDSHA	-	Maryland State Highway Administration
MSP	-	Maryland State Police
UDA	-	Unsafe Driver Action
USDOT	-	United States Department of Transportation
VASCAR	-	Visual Average Speed Computer and Recorder

"ADVANCE" SYSTEM PRODUCTIVITY ANALYSIS

INTRODUCTION

Aggressive driving involves deliberate, unsafe driver actions (UDAs) such as driving over the speed limit, following too closely, and unsafe lane changing. Aggressive driving has been recognized as a major contributing factor to freeway crashes in the U.S. In an effort to reduce aggressive driving, the Maryland State Police (MSP) – in collaboration with the Maryland State Highway Administration (MDSHA), the Federal Motor Carrier Safety Administration (FMCSA), and the U.S. Army Aberdeen Test Center (ATC) – embarked on an effort to develop the Aggressive Driving Video And Non-Contact Enforcement (ADVANCE) system. ADVANCE is an integration of state of the practice, off-the-shelf technologies – which include video, speed measurement, distance measurement, and digital imaging – that detects UDAs in the traffic stream and subsequently notifies violators by mail of their UDA. The system is capable of obtaining sharp digital images of vehicle registration numbers, United States Department of Transportation (USDOT) registration numbers, vehicle paths, and UDAs. The system is permanently installed in a vehicle and operated by a trained officer. Field records of violators are saved on computer discs for later processing by an information system in the office. This ADVANCE system is being modified to access motor vehicle records at the roadside to identify the owners of the violating vehicles to whom violation notices are sent by mail.

The purpose of this Productivity Analysis is to determine whether or not the ADVANCE system can provide a significant advantage in detecting traffic violators and issuing warnings over the traditional method of using troopers. To fulfill this purpose, productivity data collected from operations that used the ADVANCE system and those collected from the MSP in Rockville (Barrack N), College Park (Barrack Q), and Forestville (Barrack L) were analyzed and compared. All data were collected by MSP and provided to Daniel Consultants, Inc. for analyses. This paper contains a summary of the analysis results.

The results of the Productivity Analysis are summarized in this document according to the following headings:

1. Input Data Analysis and Observations
2. Cost Comparisons
3. Qualitative Comparisons
4. Conclusion

INPUT DATA ANALYSIS AND OBSERVATIONS

This section summarizes the analysis of the data for the Barrack Activities and the ADVANCE Activities and the resulted observations that are relevant to the Productivity Analysis. The focus of this analysis is to assess the reasonableness of the data, and

identify any conditions that may affect the conclusion of the alternative comparison – e.g., inclement weather conditions, traffic incidents, evidence of the learning curve, etc.

Barrack Activities Data

The provided Barracks Activities data (refer to Table 1 and Figure 1) contains the following items that may affect the ability to obtain a fair comparison:

1. Three samples were taken during weekends that usually have different traffic patterns.

2. One sample was taken during a snow event and at a location where a multiple-vehicle accident occurred during the data collection period.

3. One sample was taken during which time it was raining on and off.

4. One sample was taken at a location that was not on the Beltway.

5. One sample was taken during the early evening hours (6:00 p.m. to 8:00 p.m.), which may be at the tail end of the peak period.

6. Comments from police officers have indicated that during heavy traffic, it is more difficult to pull violators off the road. In such a situation, the perceived productivity of the officers is reduced. Heavy traffic, on the contrary, is a target-rich environment for the ADVANCE system.

Because of the limited availability of the data samples, it was decided to retain all samples except two. The first sample excluded was the one that involved a multi-vehicle accident; the other was the one that was not on the Beltway. After these exclusions, 15 data samples remained.

The data shown earlier in Figure 1 shows that there are eight data samples in which the number of vehicles stopped by police officers is greater than ten (10) vehicles during two hours. One of these cases has 24 vehicles that were stopped and 24 citations issued. Although the provided data did not show the number of troopers involved in each operation, consultation with MSP confirmed that these eight cases were very likely to be the result of Stopping Team operations. The following assumptions were used to adjust the troopers' labor hours and cruiser hours:

- If the number of vehicles stopped is between 10 and 15, assume two (2) troopers and two (2) police vehicles were involved in the operation.
- If the number of vehicles stopped is between 15 and 25, assume three (3) troopers and three (3) police vehicles were involved in the operation.
- If the number of vehicles stopped is greater than 25, assume four (4) troopers and four (4) police vehicles were involved in the operation.

Table 1. Summary of Unadjusted Barrack Activities Data

Date	Day of the Week	Start Time	End Time	Hours Worked	Vehicles Stopped	Citations Issued	Trooper's Comments
19-Jan	Wednesday	12:00	14:00	2	4	2	
20-Jan	Thursday	7:00	9:00	2	0	1	Multi-veh. accident & snow
9-Feb	Wednesday	10:00	12:00	2	5	5	
13-Feb	Sunday	15:30	17:30	2	16	16	
23-Feb	Wednesday	11:30	13:30	2	6	5	Rain on & off
23-Feb	Wednesday	10:00	12:00	2	12	12	
24-Feb	Thursday	10:00	12:00	2	24	24	Productivity seems high
25-Feb	Friday	10:00	12:00	2	6	5	Accident in VA, traffic heavy
1-Mar	Wednesday	10:00	12:00	2	5	7	
3-Mar	Friday	10:00	12:00	2	13	10	
6-Mar	Monday	11:30	13:30	2	5	6	Heavy traffic
23-Mar	Thursday	11:00	13:00	2	6	4	
28-Mar	Tuesday	18:00	20:00	2	15	13	Early Evening
29-Mar	Wednesday	10:15	12:15	2	7	6	Not on the Beltway
29-Mar	Wednesday	12:00	14:00	2	11	10	
1-Apr	Saturday	11:30	13:30	2	19	19	
2-Apr	Sunday	12:30	14:30	2	16	12	
TOTAL				34	170	157	

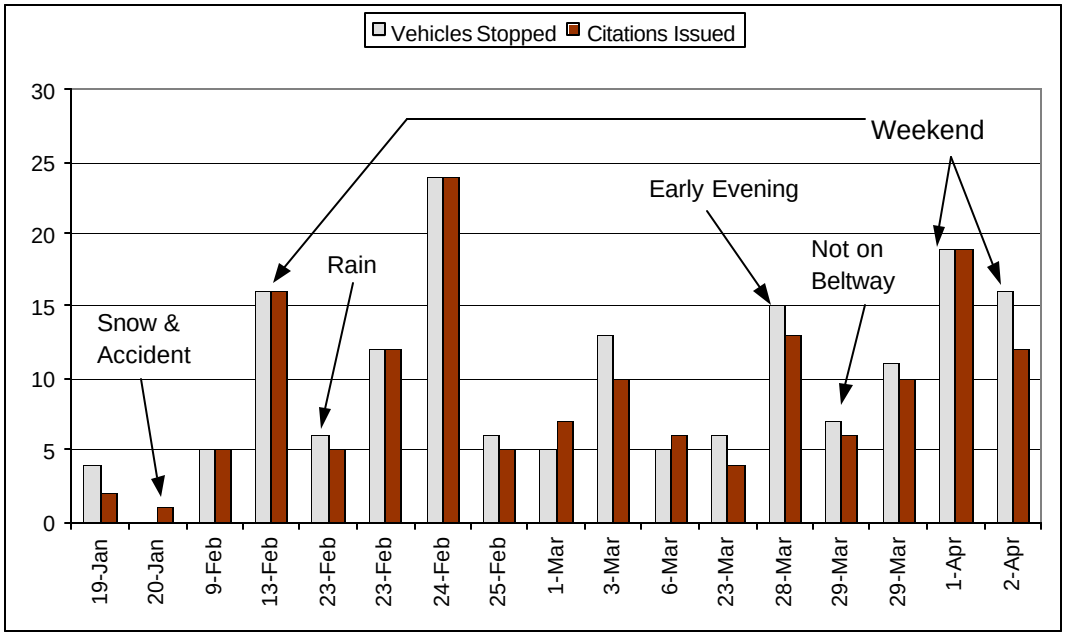


Figure 1 – Number of Vehicles Stopped and Citations Issued by the Three Barracks

The Barrack Activities Data were adjusted to reflect the above observations and assumptions as shown in Table 2. These adjustments increase the labor hours from 34 to 56, reduce the number of vehicles stopped from 170 to 163, and reduce the number of citations issued from 157 to 150.

Table 2. Adjusted Barrack Activities Data to Reflect the Use of Stopping Teams

Date	Day of Week	Start Time	End Time	Traffic Monitoring Time (hrs)	No. of Troopers	Total Labor Hrs	No. of Veh. Used*	Vehicle Hours	Vehicles Stopped	Citations Issued	Barrack Location
19-Jan	Wednesday	12:00	14:00	2.00	1	2.00	1	2	4	2	Q
9-Feb	Wednesday	10:00	12:00	2.00	1	2.00	1	2	5	5	Q
13-Feb	Sunday	15:30	17:30	2.00	3	6.00	3	6	16	16	L
23-Feb	Wednesday	11:30	13:30	2.00	1	2.00	1	2	6	5	N
23-Feb	Wednesday	10:00	12:00	2.00	2	4.00	2	4	12	12	Q
24-Feb	Thursday	10:00	12:00	2.00	3	6.00	3	6	24	24	Q
25-Feb	Friday	10:00	12:00	2.00	1	2.00	1	2	6	5	N
1-Mar	Wednesday	10:00	12:00	2.00	1	2.00	1	2	5	7	Q
3-Mar	Friday	10:00	12:00	2.00	2	4.00	2	4	13	10	Q
6-Mar	Monday	11:30	13:30	2.00	1	2.00	1	2	5	6	N
23-Mar	Thursday	11:00	13:00	2.00	1	2.00	1	2	6	4	Q
28-Mar	Tuesday	18:00	20:00	2.00	3	6.00	3	6	15	13	L
29-Mar	Wednesday	12:00	14:00	2.00	2	4.00	2	4	11	10	L
1-Apr	Saturday	11:30	13:30	2.00	3	6.00	3	6	19	19	L
2-Apr	Sunday	12:30	14:30	2.00	3	6.00	3	6	16	12	L
TOTAL				30.00		56.00		56	163	150	

The Barrack Activities data does not indicate any variability by day of the week or by time of day as shown in Figure 2. It seems to depend on the number of troopers in the Stopping Team.

ADVANCE System Activities Data

The total labor hours expended in the ADVANCE System operation consists of the following:

1. Pre-and post-deployment time, which is approximately one hour each.

2. Traffic monitoring (or deployment) time, which is calculated from the system data. This calculation was necessary to exclude the times that either the operator was on a short break or the equipment needed adjustments.

3. Image and warning processing time, which is recorded as the number of hours worked by the troopers or other staff members at the Commercial Vehicle Enforcement Division (CVED).

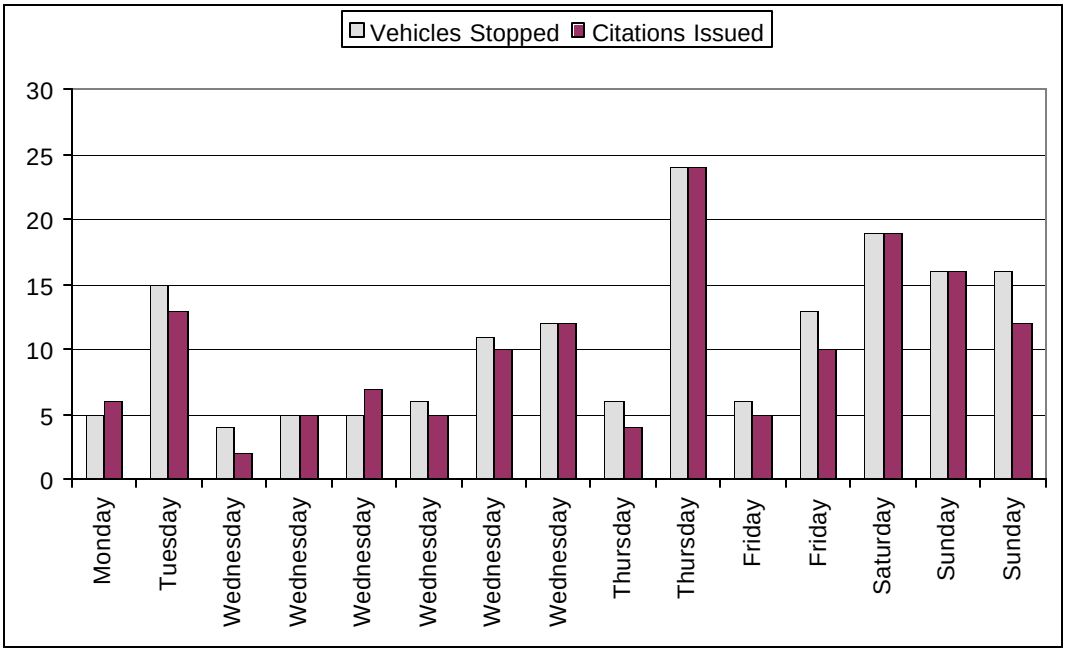


Figure 2. Barrack Activities data shows no variability from one day of the week to another – changes seemed to be caused by the number of Troopers in the Stopping Team

The recorded labor hours and the corresponding images processed and warnings mailed out are summarized in Table 3. As shown in this table, the troopers spent 34 hours for pre- and post-deployment activities; 38.08 hours for traffic monitoring; and 26 hours out of 116 hours for data processing and issuing warnings. (The office staff spent the remaining 90 hours of data processing and issuing warnings.) Table 3 also shows that all samples were collected during weekdays and between mid-morning and early afternoon.

The total number of images processed and the number of warnings mailed out during the study period are shown in Figure 3. Also shown are the same statistics on an hourly basis to avoid any bias that may be caused by different durations of traffic monitoring activities.

Out of the 1,504 images captured by the ADVANCE System, about 52% of the images contain violations that lead to warnings to be issued. Figure 4 shows the percentage of warnings for each of the traffic monitoring sessions recorded.

The available data on traffic violations from the ADVANCE System does not exhibit any trend for day of the week or monitoring locations, as shown in Figure 5 and Figure 6, respectively.

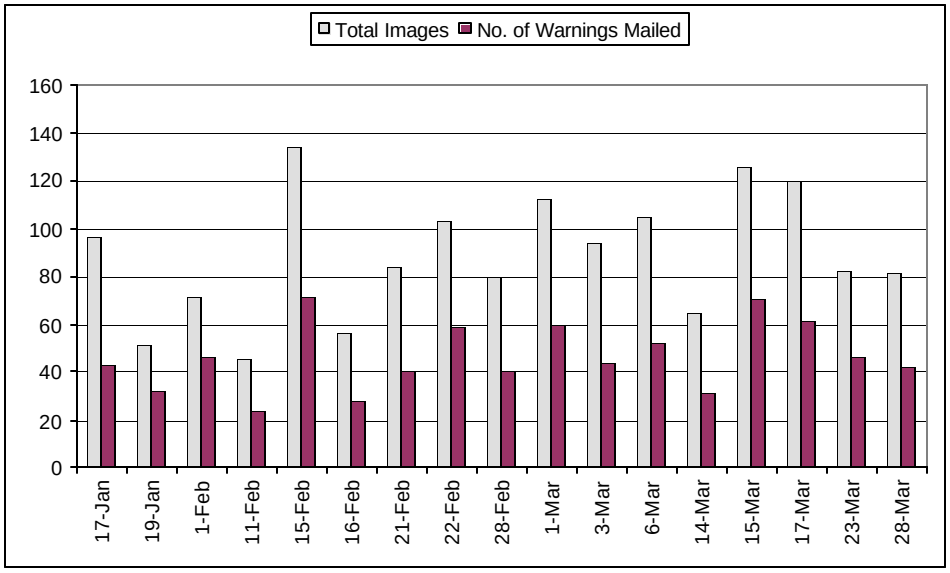
Although the data does not seem to show any trend regarding day of the week and monitoring locations, the efficiency of the troopers to capture images using the ADVANCE system seems to improve over time. The fitting of a straight line through the image-per-hour data using the least-square method shows evidence of this trend, as shown in Figure 7.

Table 3. ADVANCE System Activities Data

Date	Day of Week	Start Time*	End Time*	Pre- & Post Deploy Hrs	Calculated Deploy Hrs	Reported** Process Hrs	Total Images	Warnings Mailed	Barrack Location
17-Jan	Monday	11:15	14:00	2.00	2.47		96	43	Q
19-Jan	Wednesday	10:30	11:45	2.00	1.13		51	32	Q
24-Jan	Monday					5.00			
27-Jan	Thursday					5.00			
1-Feb	Tuesday	10:40	13:00	2.00	2.25		71	46	Q
3-Feb	Thursday					2.00			
4-Feb	Friday					2.00			
4-Feb	Friday					3.00			
6-Feb	Sunday					3.00			
7-Feb	Monday					2.00			
8-Feb	Tuesday					2.00			
9-Feb	Wednesday					2.00			
11-Feb	Friday	10:30	13:00	2.00	2.53		45	24	L
14-Feb	Monday					3.00			
15-Feb	Tuesday					3.00			
15-Feb	Tuesday	11:30	13:45	2.00	2.12		134	71	N
16-Feb	Wednesday					4.00			
16-Feb	Wednesday	10:45	13:00	2.00	2.12		56	28	N
17-Feb	Thursday					8.00			
18-Feb	Friday					2.00			
21-Feb	Monday					2.00			
21-Feb	Monday	9:30	12:00	2.00	2.12		84	40	Q
22-Feb	Tuesday	10:00	13:00	2.00	2.95		103	59	Q
23-Feb	Wednesday					6.00			
24-Feb	Thursday					6.00			
28-Feb	Monday	11:15	13:45	2.00	2.57		80	40	N
28-Feb	Monday					2.00			
29-Feb	Tuesday					4.00			
1-Mar	Wednesday	11:45	13:45	2.00	1.95		112	60	Q
2-Mar	Thursday					5.00			
3-Mar	Friday	11:00	13:30	2.00	2.40		94	44	Q
6-Mar	Monday	11:00	13:30	2.00	2.32		105	52	Q
7-Mar	Tuesday					7.00			
14-Mar	Tuesday	10:30	12:45	2.00	2.13		65	31	N
14-Mar	Tuesday					2.00			
15-Mar	Wednesday	11:15	14:15	2.00	2.75		125	70	N
16-Mar	Thursday					4.00			
17-Mar	Friday	11:30	14:00	2.00	2.40		120	61	N
17-Mar	Friday					4.00			
19-Mar	Sunday					7.00			
22-Mar	Wednesday					8.00			
23-Mar	Thursday	13:45	15:30	2.00	1.72		82	46	N
24-Mar	Friday					2.00			
28-Mar	Tuesday	11:30	13:45	2.00	2.17		81	42	L
29-Mar	Wednesday					6.00			
29-Mar	Wednesday					5.00			
TOTAL				34.00	38.08	116.00	1504	789	

* Rounded to the nearest 15 minutes for presentation purposes only

** Troopers processed data from 1/17/00 to 2/9/00; Office Staff processed data from 2/14/00 and beyond



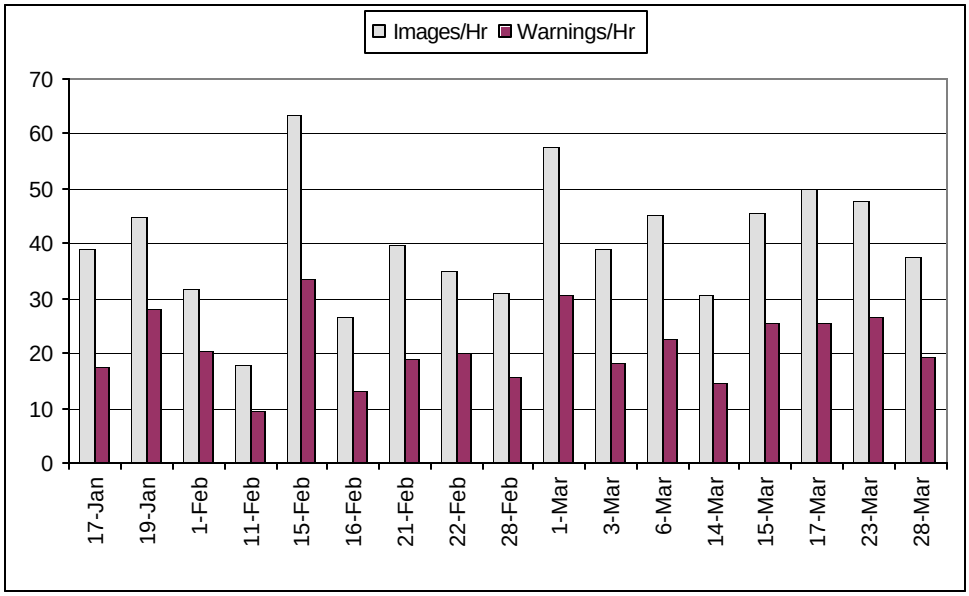


Figure 3. Total and Hourly Images and Warnings Produced Using the ADVANCE System

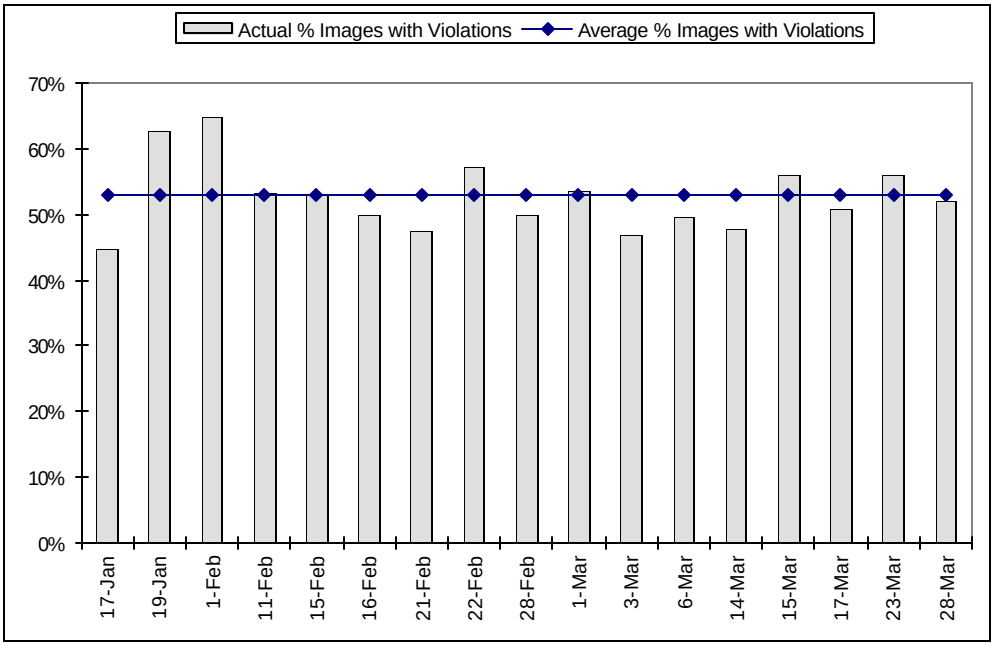


Figure 4. About 52% of the Images Captured by ADVANCE Contain Violations

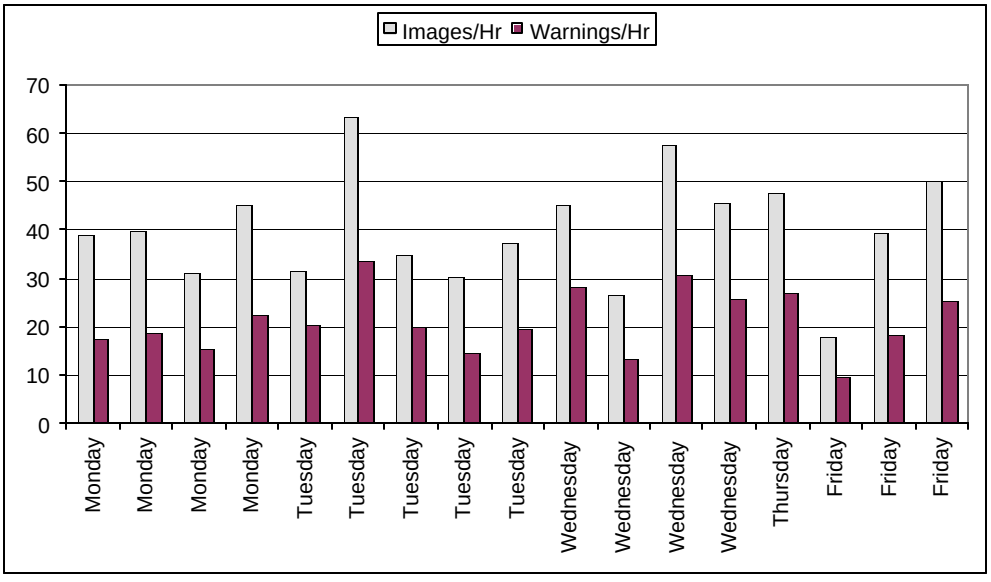


Figure 5. The Captured Images Do Not Exhibit Any Trend for Day of the Week

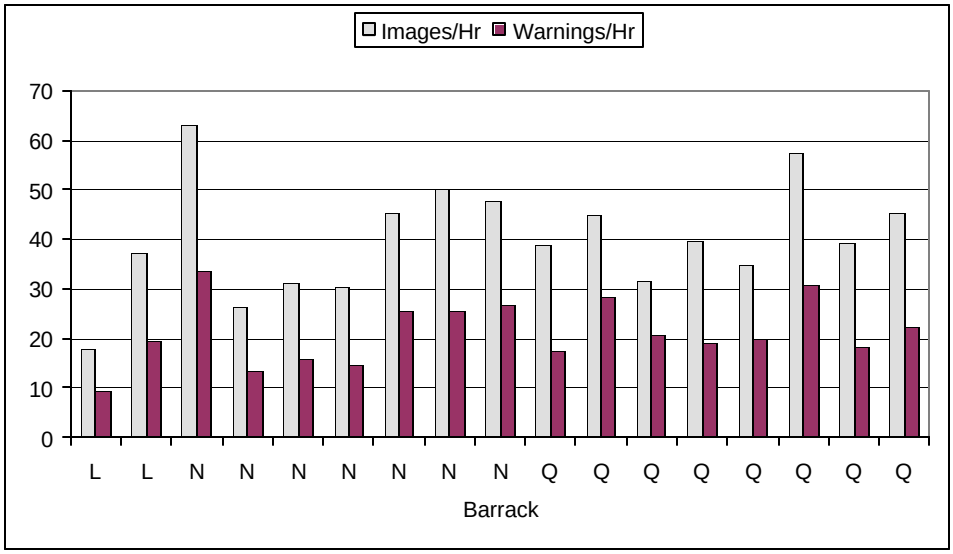


Figure 6. The Captured Images Do Not Exhibit Any Trend for Monitoring Locations *(represented by the coverage area of each Barrack)*

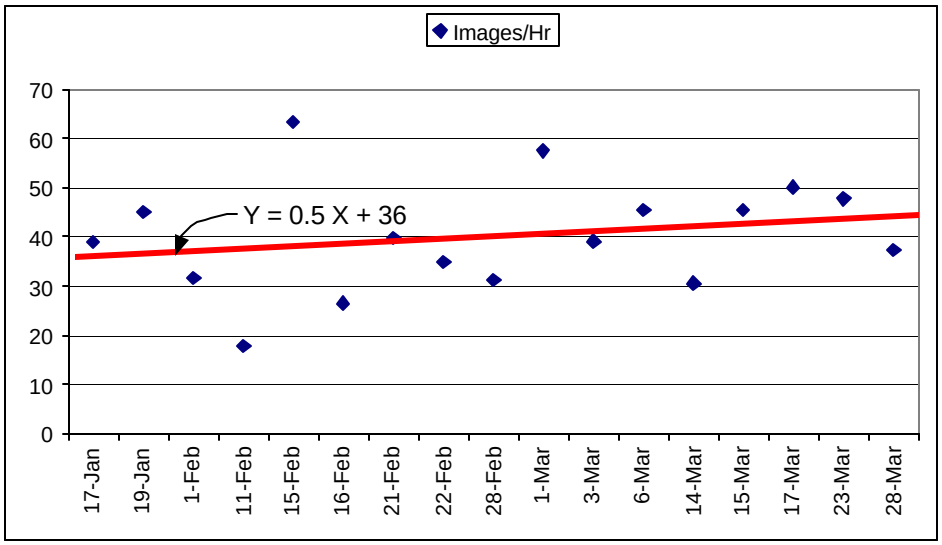


Figure 7. Trend of Efficiency Improvement in Capturing Images Using ADVANCE

Efficiency improvements over time are also observed in the image processing and the warning generation activities. Recall the ADVANCE Activities data presented earlier in Table 3. From this table, one can identify (by examining the dates of image processing and the dates between traffic-monitoring activities) four data-processing periods:

- Period 1 that goes from 1/17/2000 to 2/9/2000
- Period 2 that goes from 2/11/2000 to 2/21/2000
- Period 3 that goes from 2/21/2000 to 2/29/2000
- Period 4 that goes from 3/1/2000 to 3/29/2000

If the number of labor minutes per warning mailed out is used as a measure of productivity, a trend of improvement could clearly be observed as shown in Figure 8.

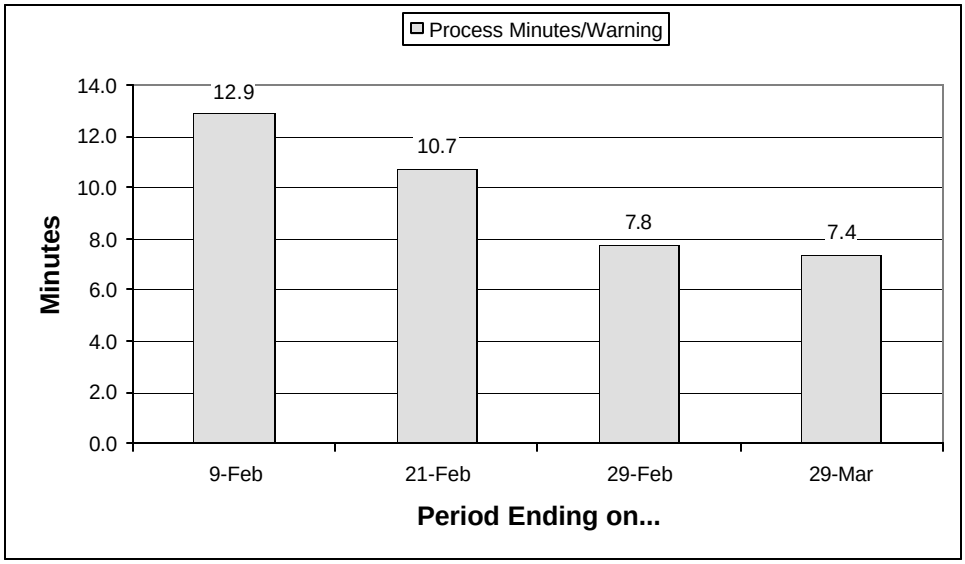


Figure 8. Trend of Efficiency Improvement in Processing ADVANCE Images

With the above analysis of the data provided by MSP, the method and results of comparing the productivity of the two alternatives are presented in the next section.

COST COMPARISONS

Approach

For the ease of referencing, the following names are used to describe the two alternatives:

- *Trooper Monitoring Method* refers to the traditional ways MSP detects traffic violators.

- *ADVANCE Method* refers to the use of the ADVANCE System to detect traffic violators.

Since the purpose of employing each of these methods is to detect and issue citations or warnings to traffic violators, it is reasonable to use the number of citations or warnings issued as a measure of productivity of each method. Furthermore, since the data collection periods for the two methods were not the same (75 days for the Trooper Monitoring Method and 72 days for the ADVANCE Method), the annual number of citations/warnings that are likely to be issued by each method is a more appropriate measure for comparison.

In addition to the number of citations/warnings per year, the corresponding resources expended must be determined in order to assess the cost effectiveness of each method. The relevant elements of resources required by each method are as shown in Table 4.

Table 4. Cost Elements Considered in the Productivity Analysis

	UNIT OF MEASUREMENT	
RESOURCE ITEMS	TROOPER MONITORING	ADVANCE METHOD
Trooper' Labor	Hours	Hours
Staff Processing Labor	--	Hours
Police Cruiser	Hours of Use (i.e., veh hrs)	--
ADVANCE Vehicle (i.e., Bronco)	--	Hours of Use (i.e., veh hrs)
Existing Speed Sensor	Hours of Use	--
ADVANCE Equipment Cost (capital)	--	$ (Annualized)
ADVANCE Equipment Cost (O&M)	--	$ Per year

The hours of use for the vehicles are considered for this analysis because these vehicles may be used for other purposes other than traffic monitoring.

Using the provided data, one can determine the values of the cost and productivity items as shown in Table 5.

Table 5. Resource Requirements and Productivity Estimates for the Study Period

RESOURCE AND PRODUCTIVITY MEASURES	TROOPER MONITORING	ADVANCE METHOD
Trooper's Hours	55.00	72.08*
Staff Processing Hrs	-	116
Police Cruiser Hrs	56.00	-
ADVANCE Vehicle (Bronco) Hrs	-	72.08
Existing Speed Sensor Hrs	56.00	-
Number of Citations/Warnings	150	789
Trooper's Minutes per Citation/Warning	22.40	5.48
Staff Minutes per Warning	-	8.82
Days of data collection	75	72
ADVANCE Equipment Cost (capital)	--	TBD*
ADVANCE Equipment Cost (O&M)	--	TBD

* Including pre- and post-deployment time
** TBD – To Be Determined

Using the number of days in the data collection period for each method, one can calculate the number of labor hours and vehicle hours, as well as the estimated number of citations/warnings per year for each alternative. In order to more accurately estimate the number of trooper's hours per year allocated to traffic monitoring in the traditional method, 4 hours should be added to the 56 hours indicated for the study because these hours belong to the two biased samples eliminated earlier. With this note, the estimated annual resource requirements and productivity are shown in Table 6.

Even on an annual basis, there still has not been a common reference for the two alternatives to be compared. To put the productivity of both alternatives on the same level, one may determine the amount of resource required to produce the same number of citations/warnings. The approach taken was to determine the resource requirements for the Trooper Monitoring Method to produce the same number of warnings as that of the ADVANCE System Method (that is, 4000 citations). Table 7 shows the resource requirements under this assumption.

Table 6. Estimated Annual Resource Requirement and Productivity

RESOURCE AND PRODUCTIVITY MEASURES	TROOPER MONITORING	ADVANCE METHOD
Trooper's Hours	292	365
Staff Processing Hrs	-	588
Police Cruiser Hrs	292	-
ADVANCE Vehicle (Bronco) Hrs	-	365
Existing Speed Sensor Hrs	292	-
Number of Citations/Warnings	782	4000
ADVANCE Equipment Cost (capital)	--	TBD
ADVANCE Equipment Cost (O&M)	--	TBD

Table 7. Resource Requirements for the Trooper Monitoring Method to Generate the Same Number of Warnings as that of the ADVANCE Method

RESOURCE AND PRODUCTIVITY MEASURES	TROOPER MONITORING	ADVANCE SYSTEM	DIFFERENCE
Trooper's Hours	1493	365	1128
Staff Processing Hrs	0	588	-588
Police Cruiser Hrs	1493		1493
ADVANCE Vehicle (Bronco) Hrs		365	-365
Existing Speed Sensor Hrs	1493		1493
Number of Citations/Warnings	4000	4000	0
ADVANCE Equipment Cost (capital)	--	TBD	TBD
ADVANCE Equipment Cost (O&M)	--	TBD	TBD

At this point, cost data may be applied to the above measures to arrive at a common reference for the alternative comparison. Because the complete operational cost

estimates for the ADVANCE system are not available at this time, reasonable assumptions were used as described next.

Assumptions

The following assumptions were used in comparing the two alternatives.

1. The hourly cost of the police cruiser is the same as that of the ADVANCE vehicle. This cost includes all costs throughout the life cycle of the vehicle. The vehicle usage cost is $11.00 per hour of use.

2. The cost of the existing speed measuring devices in the cruiser – e.g., radar, VASCAR (Visual Average Speed Computer and Recorder), Video Cams, and other speed measuring devices) is included in the hourly vehicle cost and, therefore, will not be considered in the comparison.

3. The trooper's labor cost is $39.00 per hour.

4. Processing Staff's labor cost is $28.00 per hour.

5. The ADVANCE system has a life span of four (4) years.

6. The annual maintenance cost of the ADVANCE system is 5% of the initial capital cost (see rationale in Appendix A)

7. The discount rate for computing the annualized initial system cost is 5%.

8. The research and development cost of the ADVANCE system is not considered because there is no information on how many systems will be produced after this Federal project is completed. It would not be reasonable to attribute 100% of the R&D money (which is approximately $270,000) to MSP in this analysis.

9. The cost of mailing out the warnings is not considered.

10. The revenues generated from the citations are not considered.

11. The cost of the trooper's time in court (as a result of the violator's request for a court appearance in the Trooper Monitoring Method) is not considered. This cost can be substantial because about 5% of all the citations issued are challenged in court by the violators. And the trooper must sometimes wait for hours before the judge hears his or her case.

Based on these assumptions, the comparison results for two scenarios are summarized next.

Comparison of Results

The comparison of the two methods was performed for two scenarios. Scenario #1 is without the learning curve effects, and Scenario #2 is with the learning curve effects (that is, the efficiency of the ADVANCE system users improves over time). Under each scenario, a set of assumed initial system costs, ranging from $50,000 to $175,000 with an increment of $25,000, was used to estimate the cost advantage of the ADVANCE Method over the Trooper Monitoring Method. The reasons for using this set of assumed cost include: (a) the rapid changes in technology cost that may make today's estimate obsolete in the near future; and (b) the need to understand the sensitivity of the ADVANCE system's cost advantage to the initial system cost.

Scenario #1: Without the Learning Curve Effects

Table 8 shows the cost difference between the Trooper Monitoring Method and the ADVANCE Method. The labor costs and vehicle cost are based on the estimated differences in hours as shown earlier in Table 7. The costs of the ADVANCE system were calculated based on the assumptions described above and a set of assumed initial system costs. Based on the results summarized in Table 8, the "break-even" point for the initial cost of the ADVANCE system is about $120,300 (rounding) as shown in Figure 9.

Table 8. Comparison results for a set of assumed ADVANCE System initial costs

Cost Differences*	Assumed Initial Cost of the ADVANCE System					
	$ 50,000	**$ 75,000**	**$ 100,000**	**$ 125,000**	**$ 150,000**	**$ 175,000**
Trooper's labor cost difference	$43,989	$43,989	$43,989	$43,989	$43,989	$43,989
Police cruiser cost difference	$12,407	$12,407	$12,407	$12,407	$12,407	$12,407
Staff labor cost difference for ADVANCE Method	$(16,466)	$(16,466)	$(16,466)	$(16,466)	$(16,466)	$(16,466)
Annualized ADVANCE system capital cost	$(14,101)	$(21,151)	$(28,201)	$(35,251)	$(42,302)	$(49,352)
ADVANCE system annual maintenance cost	$(2,500)	$(3,750)	$(5,000)	$(6,250)	$(7,500)	$(8,750)
(Trooper Monitoring Method cost) - (ADVANCE Method cost)	$23,329	$15,029	$6,729	$(1,571)	$(9,872)	$(18,172)

* Cost Difference = Trooper Method Cost – ADVANCE method Cost

The original developer of the ADVANCE system – Aberdeen Army Test Center – has provided a cost estimate of a new system at $90,115 (as shown in Appendix B). This gives the ADVANCE system an annual cost advantage of about $10,000.

Scenario #2: With the Learning Curve Effects

As described earlier in the *Input Data Analysis and Observations* section of this document, the data suggest that the image-capturing efficiency of the trooper in the field improves over time. This is also true for the image and violation-warning processing efficiency of the staff at CVED office. The purpose of this scenario is to show the effects of the efficiency improvement on the comparison results.

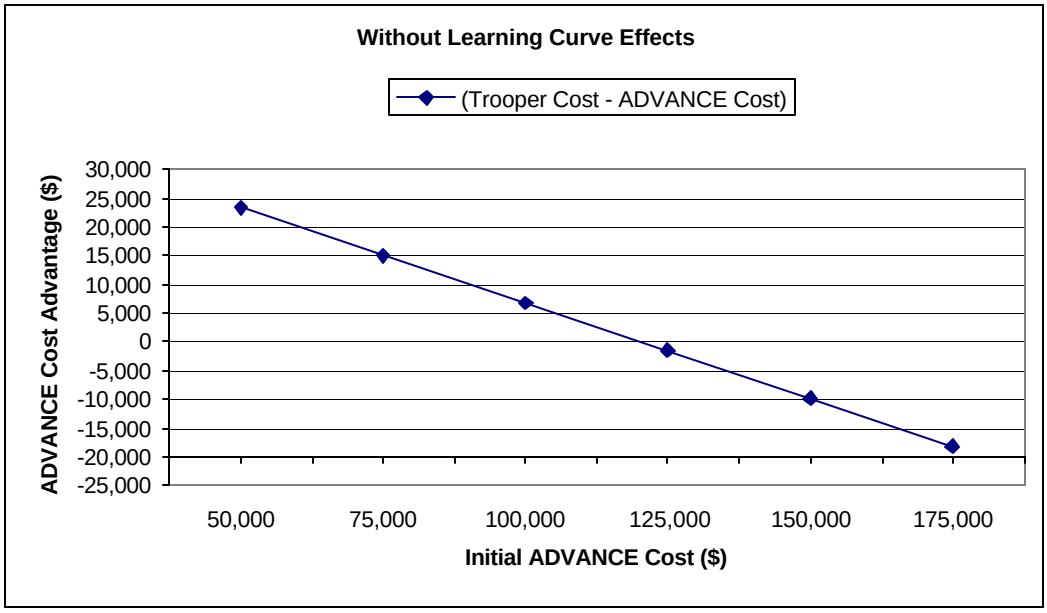


Figure 9. Without the Learning Curve Effects, the Cost Advantage of ADVANCE Diminishes if the Initial System Cost Exceeds Approximately $120,300

The efficiency of the trooper in capturing images may be estimated using the equation shown earlier in Figure 7. That is:

$$Y = 0.5X + 36$$

Where Y = number of images captured per hour
X = the X^{th} ADVANCE operation (the last operation in the study was the 17^{th})

For this scenario, assume that X = 18, giving Y = 45 images/hour. Let's further assume that the trooper's efficiency remains at that Y value of 45 images/hour throughout the analysis period.

The analysis of the data shown earlier (see Figure 4) also shows that, on the average, 52% of the images captured contain traffic violations that lead to the generation of warnings. Thus, with the improved trooper's efficiency of 45 images per hour, 23.4 warnings per hour (that is, 45 x 0.52) may be expected, or equivalently 2.56 minutes per warning (as opposed to the average of 5.48 minutes per warning as shown earlier in Table 5).

For Staff's efficiency, the data shows that it goes from 12.9 minutes per warning to 7.4 minutes per warning (see Figure 8 shown earlier). The improved Staff's efficiency of 7.4 minutes per warning was used.

Using the trooper's efficiency of 2.56 minutes per warning and the monitoring period of 72.08 hours reported for this study, one can find the number of warnings as 1687, and the required staff time for processing as 208.03 hours. Table 9 shows a summary of these calculations using the improved efficiency values for a 72-day period and for a 365-day period.

Table 9. Resource Requirements and Productivity of the ADVANCE System under the Assumed Efficiency Improvements

RESOURCE AND PRODUCTIVITY MEASURES	72 Days	365 Days
Trooper's Hours	72.08	365.42
Staff Processing Hrs	208.03	1054.61
ADVANCE Vehicle (Bronco) Hrs	72.08	365.42
Number of Warnings	1687	8551
Trooper's Minutes/Warning	2.56	2.56
Staff's Minutes/Warning	7.40	7.40

In order to provide a common reference for comparison, the resource requirements for the Trooper Monitoring Method to produce the same number of citations (i.e., 8,551 citations) were calculated. The results of the calculation are summarized in Table 10, along with the resource requirements of the ADVANCE Method. The differences in resource requirements between the two methods were used to calculate the cost advantages of the ADVANCE system as shown in Table 11 and Figure 10. As shown in Table 11 and Figure 10, the ADVANCE system still maintains a cost advantage of more than $53,000 per year at an initial system cost of $175,000. For the estimated cost of $90,115, the cost advantage of the system is about $ 81,000 per year.

Table 10. Resource Requirements for the Trooper Monitoring Method to Generate as many Warnings as that of the ADVANCE Method with Improved Efficiency

RESOURCE AND PRODUCTIVITY MEASURES	TROOPER MONITORING	ADVANCE SYSTEM	DIFFERENCE
Trooper's Hours	3192	365	2827
Staff Processing Hrs	0.0	1055	-1055
Vehicle Hrs	3192	365	2827
Number of Citations/Warnings	8551	8551	0
ADVANCE Equipment Cost (capital)	--	TBD	TBD
ADVANCE Equipment Cost (O&M)	--	TBD	TBD

Table 11. Comparison Results for a Set of Assumed Initial Costs of the ADVANCE System with Improved Efficiency

Cost Differences*	Assumed Initial Cost of the ADVANCE System					
	$50,000	$75,000	$100,000	$125,000	$150,000	$175,000
Trooper's labor cost difference	$110,249	$110,249	$110,249	$110,249	$110,249	$110,249
Police cruiser cost difference	$31,096	$31,096	$31,096	$31,096	$31,096	$31,096
Staff labor cost difference for ADVANCE Method	$(29,529)	$(29,529)	$(29,529)	$(29,529)	$(29,529)	$(29,529)
Annualized ADVANCE system capital cost	$(14,101)	$(21,151)	$(28,201)	$(35,251)	$(42,302)	$(49,352)
ADVANCE system annual maintenance cost	$(2,500)	$(3,750)	$(5,000)	$(6,250)	$(7,500)	$(8,750)
(Trooper Monitoring Method cost) - (ADVANCE Method cost)	$95,216	$86,915	$78,615	$70,315	$62,015	$53,714

* Cost Difference = Trooper Method Cost – ADVANCE method Cost

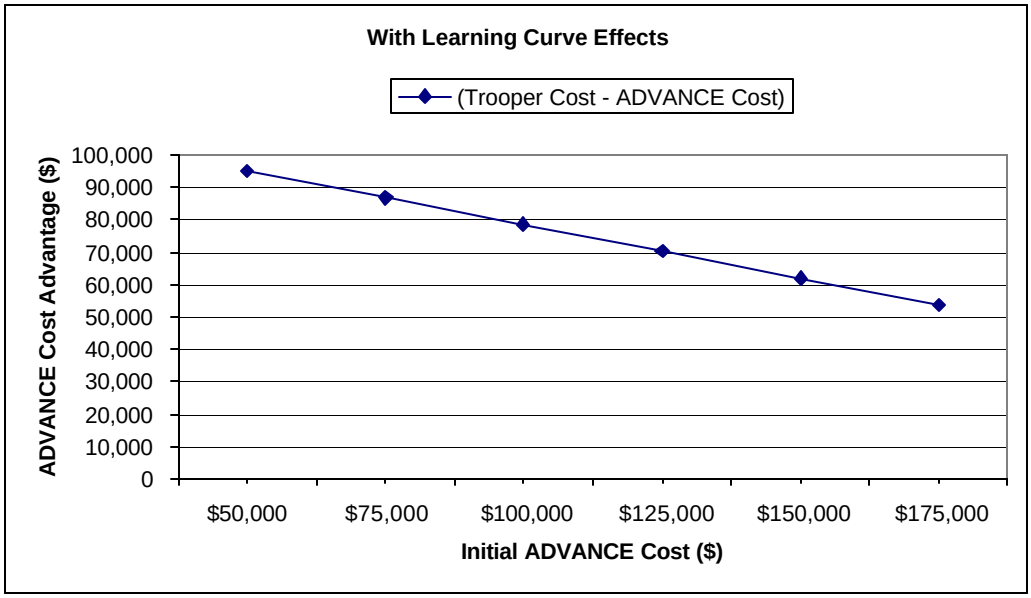


Figure 10. The ADVANCE System with Improved Staff Efficiency is Likely to Maintain a Cost Advantage Even at an Initial Cost of $175,000

In addition to the cost comparison of the two methods of enforcement, other qualitative measures may also be compared as described in the next section.

QUALITATIVE COMPARISONS

This section attempts to show the qualitative differences (or advantages and disadvantages) between the two methods of enforcement, with a focus on trooper and motorist safety, traffic impacts, effectiveness, and contact enforcement opportunities.

Trooper and Motorist Safety

It is well known that troopers are in more danger when working on the side of a high-speed roadway to stop violators. This is because the troopers and/or their vehicles are more susceptible to being collided with other vehicles in the roadway. In addition to the danger of fast moving traffic, the troopers may also be susceptible to being harmed by criminals in stopped vehicles. The ADVANCE Method will eliminate the potential dangers from stopped vehicles and significantly reduce the potential collisions between the police vehicles and/or personnel with the general traffic. (There is always some level of risk associated with a parked vehicle on the side of a freeway.)

Traffic Impacts

The presence of troopers in the Trooper Monitoring Method can be both positive and negative to the traffic flow. On the positive side, their presence is a warning for people to

slow down and become less aggressive in their driving behaviors. This effect, however, may be localized. On the negative side, the troopers' presence and their activities may become a spectacle, causing people to slow down more than necessary to "rubber neck" and, in turn, resulting in traffic backups.

With the ADVANCE Method, the presence of an unmarked vehicle on the side of the road may not attract much, if any, attention from the motorists. When this method is employed, interruption to traffic flows is less likely to occur.

Effectiveness

The operational effectiveness of the Trooper Monitoring Method depends on the traffic conditions at the site. Comments from troopers who provided data for this study have indicated that it was very difficult for the troopers to pull vehicles off the road in heavy traffic. This means that their productivity decreases as the traffic becomes heavy. Heavy traffic, on the other hand, presents a target-rich environment for the ADVANCE system, resulting in increased productivity.

The system effectiveness may also be measured in terms of the effect of each enforcement method on changing the drivers' behavior. In this regard, the ADVANCE system can warn many more people of their aggressive driving behaviors than the Trooper Monitoring Method. The data in this study suggests a 5 to 1 ratio (4000 warnings/year for the ADVANCE Method versus 782 citations/year for the Trooper Monitoring Method). This ratio will likely be higher if the learning curve effect is considered.

Contact Enforcement Opportunities

The ADVANCE Method reduces the number of opportunities that the troopers may have for contact enforcement while monitoring traffic violations. Although this reduction can enhance the safety of the troopers, it may result in some missed opportunities for the troopers to detect other types of offense such as driving while intoxicated (DWI), fugitives, possession of contraband (e.g., illegal drugs, weapons, stolen vehicles), illegal driver's license, and defective vehicle equipment.

CONCLUSION

This analysis shows that the ADVANCE system offers higher productivity than the traditional Trooper Monitoring Method of enforcement. The analysis results also show that the ADVANCE system may still be economically feasible even at an initial cost that is close to the development cost of the system.

Although economic justifications are important in considering the deployment of the ADVANCE system, other qualitative benefits and/or shortcomings of the system should also be considered in the decision making process. As highlighted in the *Contact*

Enforcement Opportunities section above, any consideration for long-term deployment of the ADVANCE system should be to supplement, rather than supplant, traditional enforcement practices.

APPENDIX A

Rationale for the Assumed Annual Maintenance Cost Estimate of 5% of the Total System Cost

Aberdeen Test Center (ATC) has provided the historical development cost data (from June 1998 to June 2000) for the ADVANCE system. Table A-1 shows the cost summary of the "based" system. During the development and field operational test phases of this project, ATC performed various maintenance activities that were identified from the provided cost data. These maintenance activities included only labor cost, which is equal to $5,201 (or 9.12% of the total labor cost). Table A-2 shows the various maintenance activities performed during the two years.

Table A-1. Development Cost Summary of the Based System

ITEM	LABOR	MATERIALS	TRAVEL	TOTAL
Front View Violator ID Methodology Study	$17,832.50	$ -	$28.35	$17,860.85
Front View Violator ID Implementation & Data Storage Enhancement	$9,482.50	$6,713.25	$191.25	$16,387.00
Research, Maintenance, Meetings, Field Tests, etc.	$13,468.50	$1,104.55	$ -	$14,573.05
Manual Override Enhancement	$766.50	$ -	$ -	$766.50
User Interface Enhancements	$1,806.75	$ -	$ -	$1,806.75
LIDAR Pan and Tilt System	$5,640.35	$1,255.00	$ -	$6,895.35
Video Monitor Swivel Mount	$5,323.38	$ -	$ -	$5,323.38
Following Too Close Enhancement	$2,573.25	$1,761.00	$ -	$4,334.25
Streamlining Violation Processing	$109.50	$ -	$ -	$109.50
Total Development Cost	$57,003.23	$10,833.80	$219.60	$68,056.63

For the enhanced system, an estimated amount of $20,000 was spent on system enhancement and maintenance activities. If we assume that the maintenance portion of this expenditure remains at 9.12% then an amount of $1,825 (that is, 9.12% of $20,000) should be added to the total system maintenance cost shown earlier in Table A-2. Thus, the total estimated maintenance cost is $7,026 (that is, $5,201 plus $1,825). Since this expenditure is over a two-year period, the annual maintenance cost estimate becomes $3,513.

The above annual maintenance cost equates to 3.9% of the total cost of the new system, which is $90,685 as shown in Appendix B. Since this maintenance cost includes only labor, 1.1% of the total system cost is assumed as the annual cost of parts and other materials. Thus, the assumed annual maintenance cost is $4,534, which is 5% of the total cost of the new system.

Table A-2. Summary of Maintenance Activities for the Based System

Date	Hours Worked	Labor Rate/Hr.	Maintenance Activity Description	Labor Cost
7/1/98	5	$54.75	Maintenance	$273.75
8/18/98	9	$54.75	Maintenance - LIDAR camera lens	$492.75
12/22/98	4	$54.75	Maintenance	$219.00
12/23/98	9	$54.75	Maintenance	$492.75
12/29/98	9	$54.75	Maintenance	$492.75
12/30/98	5	$54.75	Maintenance	$273.75
1/7/99	5	$54.75	Maintenance	$273.75
1/11/99	6	$54.75	Maintenance	$328.50
1/14/99	2	$54.75	Maintenance	$109.50
3/10/99	2	$54.75	Maintenance on removable SCSI drive at CVED	$109.50
3/15/99	2	$54.75	Maintenance on removable SCSI drive at CVED	$109.50
3/16/99	2	$54.75	Maintenance on removable SCSI drive at CVED	$109.50
9/3/99	3	$54.75	Set Focus on LIDAR Camera	$164.25
9/9/99	3	$54.75	Repair LIDAR Camera Lens	$164.25
9/9/99	2	$54.75	Repair LIDAR Camera Lens	$109.50
5/15/00	4	$54.75	Repair Corrupted SCSI Database File	$219.00
5/16/00	4	$54.75	Repair Corrupted SCSI Database File	$219.00
5/24/00	4	$54.75	Repair database	$219.00
5/31/00	7	$54.75	Repair problem with SCSI data drives	$383.25
6/1/00	8	$54.75	Replace SCSI controller card in Bronco	$438.00
			TOTAL	$5,201.25

APPENDIX B
COST ESTIMATE FOR A NEW ADVANCE SYSTEM

(Source: Aberdeen Army Test Center)

MECHANICAL FABRICATION

LABOR CATEGORY	HOURS	RATE/HR	AMOUNT
Chief Engineer	40	$63.50	$2,540.00
Senior Engineer #1	80	$63.50	$5,080.00
Machinist	320	$46.00	$14,720.00
Subtotal			$22,340.00
MATERIALS CATEGORY	**QUANTITY**	**PRICE EACH**	**PRICE TOTAL**
Camera Mounts	3	$150.00	$450.00
Base Mounting Plate	1	$700.00	$700.00
Video Component Rack	1	$100.00	$100.00
Computer Mounting Brackets	4	$25.00	$100.00
Accessory Mounting Brackets	5	$25.00	$125.00
Spare Tire Mounting Bracket	1	$80.00	$80.00
Computer Keyboard Pedestal/Tray	1	$50.00	$50.00
Autosense Mounting Bracket	1	$50.00	$50.00
Operator Seat Mounting Bracket	1	$35.00	$35.00
LIDAR/CAMERA Mount	1	$25.00	$25.00
Operator Seat	1	$670.00	$670.00
Bumper Interface Box	1	$100.00	$100.00
Subtotal			$2,485.00

CATEGORY SUBTOTAL $24,825.00

SOFTWARE & ELECTRICAL COMPONENTS

LABOR CATEGORY	HOURS	RATE/HR	AMOUNT
Chief Engineer	320	$63.50	$20,320.00
Senior Engineer #1	240	$63.50	$15,240.00
Subtotal			$35,560.00
MATERIALS CATEGORY	**QUANTITY**	**PRICE EACH**	**PRICE TOTAL**
Panasonic Video Camera	3	$650.00	$1,950.00
Camera Lenses	3	$200.00	$600.00
Matrox Meteor II Frame Grabber Board	1	$600.00	$600.00
Matrox Imaging Library 6.0 (Software)	1	$4,000.00	$4,000.00
Data Translation "Broadway" Frame Grabber Board	1	$800.00	$800.00
Autosense II Laser	1	$11,000.00	$11,000.00
Dell Dimension XPS B Series Computer	1	$3,200.00	$3,200.00
18 GB Removable SCSI Data Drive	1	$1,600.00	$1,600.00
Microsoft Office 2000 (Software)	1	$600.00	$600.00
Visual Basic 6.0 (Software)	1	$600.00	$600.00
Crystal Reports 7.0 (Software)	1	$400.00	$400.00
Video Monitor	1	$2,000.00	$2,000.00
Deep Cycle Battery	1	$500.00	$500.00
Battery Charger	1	$400.00	$400.00
Power Inverter	1	$550.00	$550.00
RS-422 to RS-232 Converter	1	$200.00	$200.00
Pelco Motorized LIDAR Pan and Tilt System	1	$1,300.00	$1,300.00
Subtotal			$30,300.00

CATEGORY SUBTOTAL $65,860.00

TOTAL SYSTEM COST **$90,685.00**