



**1 ABSTRACT**

2 This paper presents work conducted as part of North Carolina's evaluation of its Highway Patrol  
3 TACT III operation (Ticketing Aggressive Cars and Trucks). TACT is a federally-funded effort  
4 to develop a model program of enhanced enforcement, education/media, and program evaluation  
5 that can be implemented at the state level. The goal of TACT is to reduce the contribution of  
6 aggressive driving behaviors to commercial motor vehicle (CMV)-involved crashes. In the  
7 present study, camera-based detection methods were used to detect the incidence of following-  
8 too-close (FTC) within the context of prevailing CMV and passenger vehicle volumes, speeds,  
9 and lane position both "before" and "during" TACT enforcement operations. The data suggest  
10 that TACT enforcement may have a differential effect upon car and truck following distances.  
11 An increase in CMV following distances was observed in the rightmost lane of the interstate  
12 facility. A slight decrease in CMV speeds was also observed during the enforcement period. No  
13 significant changes, however, in speeds or vehicle following times were observed for passenger  
14 vehicles. The results indicate that the developed methodology is sensitive to detecting changes in  
15 driver behavior, and may thus become a potential alternative evaluation strategy for the TACT  
16 program in the future. The use of roadside instrumentation further enables future applications for  
17 automated driver feedback, in that FTC and speed violations may be automatically detected and  
18 relayed to the driver in an infrastructure-to-vehicle context like that used by dynamic speed  
19 signs. It is even possible that automated methods developed under this research could be used  
20 for automated enforcement in future applications.

21

## 1 INTRODUCTION

2 The TACT program (Ticketing Aggressive Cars and Trucks) represents the Federal Motor  
3 Carrier Safety Administration's (FMCSA) attempt to develop an *enhanced (traffic) enforcement*  
4 model program, similar to the National Highway Traffic Safety Administration's (NHTSA)  
5 *Click-it-or-Ticket (1)* and *Booze-It-and-Lose-It (2)* programs. The focus of TACT is on  
6 reducing aggressive driver behaviors for both commercial motor vehicles (CMV) and passenger  
7 vehicles that are believed to increase the risk of serious CMV-involved collisions with smaller  
8 vehicles(3).

9 Crash data (4) show that well over half of all multiple-vehicle CMV-involved crashes are  
10 attributable to the behavior of the smaller vehicle operator, including cases where:

- 11 • one vehicle is following another too closely;
- 12 • the smaller vehicle cuts off the larger vehicle in the course of a passing maneuver,  
13 causing the larger vehicle to unexpectedly brake;
- 14 • the smaller vehicle rear ends the larger vehicle when the larger vehicle has to suddenly  
15 brake in response to unexpected events,
- 16 • the smaller vehicle driver accepts too-small a gap when attempting to cross the path of  
17 the larger vehicle; or
- 18 • the smaller vehicle fails to accelerate upon entering the travel lane of the larger vehicle,  
19 etc.).

20 The likelihood of these types of behaviors is high on rural two-lane roads where access is less  
21 controlled, but also occurs on interstate facilities. A previous assessment of North Carolina crash  
22 data showed that the likelihood of a fatal CMV-involved crash on a non-Interstate roadway (NC,  
23 US, and state routes) is 2-3 times greater than on an interstate roadway (5). Similar trends are  
24 documented at the national level (6). Such data provide the justification for FMCSA's desire to  
25 increase the TACT focus on rural roads.

26 One of the challenges that arise from a broad enforcement and media campaign such as TACT is  
27 performance assessment, and particularly the question of whether a measurable change in driver  
28 behavior can be achieved. Traditionally, the evaluation of the TACT program has been restricted  
29 to officer-based measures (e.g. the number of citations issued) and more qualitative observations  
30 of aggressive maneuvers from officers positioned within CMVs. This paper looks at more  
31 quantitative evaluation methods of TACT and has worked to develop portable roadside  
32 instrumentation technologies that are currently being field-tested on TACT-enforced corridors in  
33 North Carolina.

## 34 BACKGROUND

35 It is implied in the title and purpose of TACT that some crashes are attributable to driver  
36 behaviors that are "aggressive". The term *aggressive driving* is usually reserved for occasions  
37 where two or more serious traffic violations are observed over a brief period of time and space,  
38 including excessive speed or erratic lane changing (7). However, since these events are rare and

1 sometimes difficult to observe, it is hypothesized that it is more productive to focus on  
 2 *observable traffic stream parameters* that increase the likelihood of these behaviors.

3 The most frequent CMV crash types generally fall in the categories “rear end, slow, or stop,”  
 4 “failure to reduce speed”, and “side swipes in either the same or opposite direction” (5,6).  
 5 Operationally, these behaviors can be derived from observable traffic parameters, including  
 6 speed distributions and vehicle gaps. For example, the forward field of view of a passenger  
 7 vehicle operator following close behind a tractor trailer (short gap) may be significantly  
 8 restricted. Consequently the driver may have difficulty reacting to unforeseen maneuvers  
 9 associated with downstream events, such as an abrupt lane change into a very small gap, or a  
 10 vehicle entering the roadway from an uncontrolled intersection. While a rear-end collision may  
 11 or may not occur, a risky (short) gap maneuver increases the likelihood of a collision. The  
 12 hypothesis of this research is that an assessment of the speed and gap distribution on a facility  
 13 before, during, and after enforcement are adequate surrogate measures for risk, and ultimately,  
 14 vehicle collisions. Figure 1 illustrates some examples of commonly observed *following-too-close*  
 15 (*FTC*) events on interstate facilities, as well as an *aggressive lane change* (*ALC*) event (right-  
 16 most image). Images are taken from video captured during actual TACT operations in North  
 17 Carolina.



Figure 1: Images illustrating Following Too Close (FTC) Behavior

18  
 19 Whether these behaviors are deliberately aggressive or simply the result of poor judgment, they  
 20 are expected to increase the *likelihood* of a crash. What can be done to reduce the likelihood of  
 21 such situations? NHTSA presents many countermeasures aimed at reducing aggressive driving  
 22 behaviors, including: increased high visibility enforcement (8), automated enforcement of  
 23 speeds and other behaviors (9, 10), unmanned speed display devices (11, 12, 13, 14), in-vehicle  
 24 driver warning systems (15,16), and drone radar (17). Accordingly, TACT suggests that the  
 25 solution is in part a public awareness/education issue and in part an enforcement issue. This  
 26 paper focuses on the quantitative evaluation of such efforts using surrogate measures based on  
 27 speeds and gaps.

## 28 The Need to Document TACT Effectiveness

29 TACT can be thought of as an attempt to increase the degree of system control over vehicle  
 30 speeds, lane placement and lane keeping, and vehicle following distance through increased  
 31 enforcement and public awareness. To that extent, an evaluation of the TACT program should  
 32 document measurable changes in the parameters of vehicle speeds and vehicle following  
 33 distances (in particular, the latter). Documentation of how many speeding tickets from past

1 evaluation efforts are issued during a TACT enforcement phase does not constitute evidence that  
2 vehicle speeds and following distances have been affected by enforcement presence. Neither do  
3 measures of TACT “media recognition” constitute evidence that TACT efforts have resulted in  
4 measurable changes in critical driver behaviors. Instead, data should be defensible and based on  
5 the effect of the treatment being employed, in this case public awareness/education campaigns  
6 and focused enforcement.

### 7 **Challenges in Quantifying Critical TACT-Related Driver Behaviors**

8 TACT has significant differences from other campaigns such as *Booze-it-and-Lose-It* and *Click-*  
9 *it-or-Ticket*, in that the behaviors targeted by the enforcement are not as easily observed as a  
10 driver's blood alcohol content (BAC) level, or whether the driver is wearing his/her seatbelt. For  
11 the most part, the latter two behaviors are effectively identified through the use of police check  
12 points where the behavior can be directly observed and measured.

13 The behaviors targeted by TACT are traditionally observed under natural driving conditions by  
14 enforcement personnel who are either stationary at the roadside or in a moving vehicle. In either  
15 case, their ability to observe the behaviors of interest is limited to what can be observed in their  
16 direct (limited) field of view. Behaviors outside their immediate field of view or those that occur  
17 while a citation is being issued go undetected. This same limitation applies to other TACT  
18 evaluation approaches, such as the one in Washington State that positions law enforcement  
19 officers in the cab of large trucks (as observers/spotters) in addition to roving patrol vehicles  
20 (18). For maximum enforcement effectiveness, surveillance needs to be continuous and corridor-  
21 wide in its coverage, in addition to its ability to produce measurable detection evidence of the  
22 behaviors in question.

### 23 **The North Carolina TACT Response**

24 The TACT program in North Carolina is experimenting with the use of video-based, automated  
25 detection of critical TACT behaviors and the operational context in which these behaviors occur.  
26 To do this, the NC TACT program, with the help of researchers at NC State University's  
27 Institute for Transportation Research and Education (ITRE), have strategically instrumented  
28 selected interstate and rural enforcement sites with continuously running video detection  
29 capabilities.

30 Using commercially available Autoscope video processing software from Econolite© (19),  
31 researchers have designed the capability to continuously capture data on: (a) vehicle counts by  
32 lane, (b) vehicle type (CMVs versus passenger vehicle), (c) vehicle speeds by class of vehicle in  
33 each lane under observation, and (d) vehicle following distances by vehicle class, by lane. It is  
34 important to note before going further that this type of instrumentation is being deployed to  
35 *augment* - not to replace - other means of TACT program evaluation. If shown to be successful,  
36 the method described can assist existing evaluation approaches and work towards a broader  
37 assessment of the TACT effort in NC, or even other states.

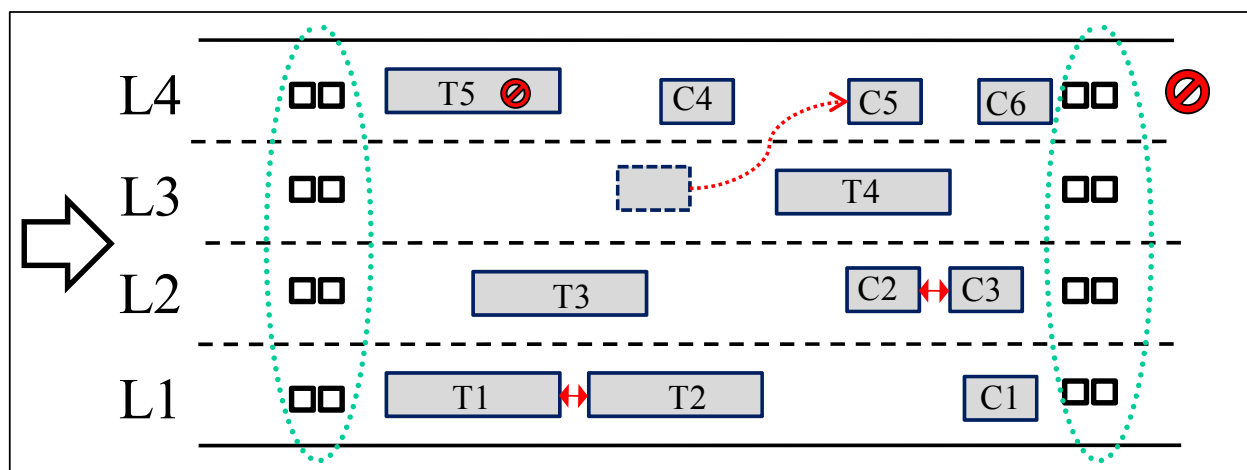
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39

# 1 METHODOLOGY

## 2 Evaluation Approach

3 In this paper, the focus of TACT program evaluation is shifted from an enforcement-based  
 4 approach, to an observational assessment at a fixed location. The evaluation framework rests on  
 5 the assumption that continuous observations at a representative location can provide an effective  
 6 sample of the traffic behavior of a facility. While monitoring over extended segments is  
 7 theoretically preferable, range limitations of roadside or overhead monitoring technology make  
 8 measurements over an extended distance practically infeasible. This section first discusses the  
 9 evaluation concept, followed by a comparison of different automated and manual monitoring  
 10 approaches. Figure 2 presents a schematic of the evaluation concept.



11  
12 Figure 2: Schematic of TACT Evaluation Approach

13 Figure 2 illustrates a snap shot in time of the relative position of various vehicles on a  
 14 hypothetical four-lane freeway segment with a mix of passenger cars (C1-C6) and CMVs (T1-  
 15 T5). The elliptical shapes denote sensor locations, which could take the form of in-road,  
 16 overhead, or roadside sensing technologies. The relative position of CMVs and passenger cars,  
 17 highlight several "aggressive" maneuvers, which will be recorded as surrogate measures to  
 18 describe the general level of safety in the traffic stream:

- 19 • Following-too-Close (FTC), an event where the time gap between two successive  
 20 vehicles is too short to allow for appropriate driver reaction time, illustrated between  
 21 CMVs T1 and T2 and cars C2 and C3.
- 22 • Aggressive Lane Changing (ALC), an event where a vehicle changes lanes in a manner  
 23 that forces reactive deceleration or swerving by one or more other vehicles, illustrated by  
 24 vehicle C5 swerving in front of vehicle C4 in an attempt to overtake a slower-moving  
 25 CMV (T4)
- 26 • Restricted Lane Violation (RLV), an event where a CMV operates in a restricted lane  
 27 ("no trucks this lane"), illustrated by vehicle T5.

- 1 • Violation of Posted Speed (VPS), an event where a vehicle travels more than 9mph over  
2 the posted speed limit (this event is not directly illustrated in Figure 2).

3 With the exception of ALC events, the remaining three measures can readily be observed at fixed  
4 observation locations. More importantly, all three measures are primarily based on speed and  
5 relative position data of one or more vehicles, which can feasibly be recorded using automated  
6 sensing technologies. The automated collection of TACT performance measures is desirable,  
7 because it has the potential to a) greatly decrease analysis time, b) increase sample size, c)  
8 improve reliability across multiple sites, and d) eliminate human observer bias. It is critical for  
9 the adoption of TACT as a model program of effective enforcement that the behaviors in  
10 question be *observable* and *quantifiable*, and that a change in their frequency or rate can be  
11 shown to be associated with the presence of enforcement. In addition, the automated detection  
12 of such measures may prove beneficial in future efforts such as the use of Intelligent  
13 Transportation Systems (ITS) to provide real time feedback to drivers when aggressive driving  
14 maneuvers are taking place.

### 15 **Video-Based Evaluation**

16 Several technologies are available to measure the driver behavior patterns of interest to TACT,  
17 including 1) in-road traffic sensors (magnetic inductance loops), 2) side-fire radar/microwave  
18 sensors, and 3) overhead video observations. In the team's assessment, options 1 and 2 have  
19 significant potential for long-term instrumentation, but are associated with the significant  
20 disadvantage that the results cannot be confirmed visually. Consequently, the team selected a  
21 video-based evaluation of the TACT performance measures, and deferred testing the feasibility  
22 of alternative instrumentation methods for future research. A video-based evaluation allows the  
23 unique opportunity to perform both manual and automated observations. For manual  
24 observations, video is played back (in slow motion if necessary) with a time-stamp overlay to  
25 record critical events. Alternatively, automated video-image processing software is commercially  
26 available that can be used to deliver lane-by-lane volumes, speeds, and classification data, and  
27 can further be adopted to identify short gaps (i.e. FTC events). The project team selected the  
28 Autoscope software by Econolite© (19), but the results are not necessarily tied to the selected  
29 product.

30 In the application of the video-based evaluation approach, overhead mounted traffic cameras are  
31 used to gather video data, which are recorded to a Digital Video Recorder (DVR). For automated  
32 processing with video-detection, cameras need to be placed at an elevated vantage point;  
33 preferably on a bridge or overpass, but could also be mounted on nearby poles if necessary. The  
34 vantage point from an overpass is preferable since it minimizes the potential for occlusion, for  
35 example where a (tall) vehicle in one lane might block the view of a vehicle in adjacent lanes.  
36 The research team used a mobile data collection trailer that was equipped with cameras,  
37 batteries, and DVR recording technology in order to assess multiple TACT enforcement sites in  
38 potentially remote locations.

### 39 **Performance Measures**

40 For the purposes of this study, recorded video were post-processed in the lab for evaluation.  
41 From the four performance measures described above, only three were included in this  
42 assessment. The fourth measure, aggressive lane changing (ALC) proved to be highly subjective

1 in manual observation and infeasible to extract in an automated fashion. Consequently, the three  
2 primary TACT performance measures are:

- 3 • RLV - Restricted Lane Violations: RLV events are strictly defined by a count of CMV  
4 vehicles in a restricted lane (if applicable). The performance measure is defined in terms  
5 of an absolute count of events, as well as a rate of RLV events over time (e.g. violations  
6 per hour).
- 7 • VPS - Violation of Posted Speed: VPS events are defined as a count of vehicles (CMV or  
8 passenger car) observed to travel more than 9 miles per hour in excess of the posted  
9 speed limit. The performance measure is again reported as a count of events (per lane),  
10 and a rate of violations over time.
- 11 • FTC - Following-Too Close: An FTC event occurs when one vehicle (CMV or car)  
12 follows the vehicle in front of it at a specified time gap that does not allow adequate  
13 reaction time if the leading vehicle were to unexpectedly apply its brakes. An FTC event  
14 is especially critical for a CMV following another vehicle, because large trucks generally  
15 cannot decelerate as quickly as passenger cars due to their larger mass. The exact  
16 definition for what constitutes "too close" is explored in the following discussion.

17 The automated video processing algorithms determine the vehicle following times and distances  
18 based on an overlay of *virtual detectors* that are superimposed on a calibrated background video  
19 image. These detectors note the presence of a vehicle by measuring changes in the light  
20 sensitivity at the pixel level within the image according to proprietary and software-specific  
21 algorithms. Multiple detectors can be used to estimate speed by measuring the time between  
22 actuations of two closely-spaced detectors, if the distance between them is known. Calibration of  
23 the image occurs from site-specific knowledge of lane widths and length of lane markings (and  
24 spaces between markings).

25 To estimate FTC events, a logic statement known as *extend time* was used to determine if one  
26 vehicle arrived at a detector within  $x$  seconds of the previous vehicle leaving that same detector.  
27 The value of  $x$  is user-calibrated and can further be used in a sensitivity analysis to explore its  
28 impact on the observed rate of FTC events. For example, for FTC events in Figure 3, two  
29 detectors (shown as lines) were placed a distance of 15 feet apart. The two detectors have  
30 *detector functions* attached to them, which respond to the presence of a vehicle. Other functions  
31 use *if-then* logic to check for user-specified criteria.



1  
2 **Figure 3: Screenshot of Autoscope Video Algorithm for one of the Test Sites**  
3

4 In Figure 3, the left lane shows an example of what constitutes an FTC event. For instance, at  
5 freeway speeds of 100 ft/s (68mph, 109 km/h) an observed following distance of 50 feet  
6 corresponds to a gap time of only 0.5 seconds, which leaves virtually no reaction time in the case  
7 of an unforeseen event. The screenshot in Figure 3 also includes speed and classification  
8 detectors, which can record individual vehicle speeds, and a vehicle classification based on  
9 length. Data points can be paired to obtain speed profiles by vehicle class.  
10

## 11 **IMPLEMENTATION**

12 The methodology was applied to two different test sites to test the feasibility of the approach.  
13 Site A was a pilot installation on an eight-lane section of Interstate I-40 in Wake County, NC. It  
14 was primarily used to develop and test the methodology. While not part of the TACT  
15 enforcement program, per se, results are presented here because they provide valuable insight  
16 regarding the proposed methodology. Site B was located towards the end of a 10-mile TACT  
17 enforcement corridor on a four-lane section of Interstate I-85 in Durham County, North Carolina.  
18 The evaluation was done just outside of this 10-mile corridor to remove the immediate effects of  
19 on-looker delays as police enforcement was taking place.

1 At Site A, cameras were installed on a freeway overpass looking at four lanes of travel at a time.  
2 Because it was a pilot test, the initial goal was to learn what the optimal camera angle would be  
3 to collect the surrogate data, and ultimately, to determine whether the data could feasibly be  
4 collected using automated detection algorithms. After several trials, it was determined that the  
5 optimum angle for data collection of FTC events was to have the camera pointing straight down  
6 at the lanes from a vertical mounting position. This is especially important when multiple lanes  
7 must be detected to avoid occlusion of other vehicles in adjacent lanes. In addition, it was  
8 determined that a secondary camera facing oncoming traffic and with a larger field of view was  
9 needed to accurately capture vehicle speeds and VPS events. RLV data could be captured in  
10 either view.

11 Video set-up for Site B followed the same procedure as for Site A. However, when analyzing the  
12 video in-house, the FTC camera exhibited video “glitches”, which were attributed to the use of  
13 wireless video transmission used at this site. Consequently, data for FTC events at this site were  
14 analyzed manually while speeds were still collected autonomously (from the second camera).  
15 Both sites had video recorded from Tuesday to Thursday, to avoid weekend travel patterns and  
16 unpredictable peak volume periods associated with Mondays and Fridays. For site A, video was  
17 recorded on an as need basis, usually in 1 or 2 hour bins to test various camera locations and to  
18 compare manual for video detection based data collection methods. For Site B (with TACT  
19 enforcement), video was recorded from 9 AM to 5PM, which encompassed the period of TACT  
20 enforcement operations (10AM to 3:30PM). The before enforcement videos were recorded one  
21 week prior to enforcement to establish a baseline of driver behavior prior to the actual TACT  
22 enforcement effort. More video was then recorded during the week of enforcement to determine  
23 the immediate effect of the TACT effort.

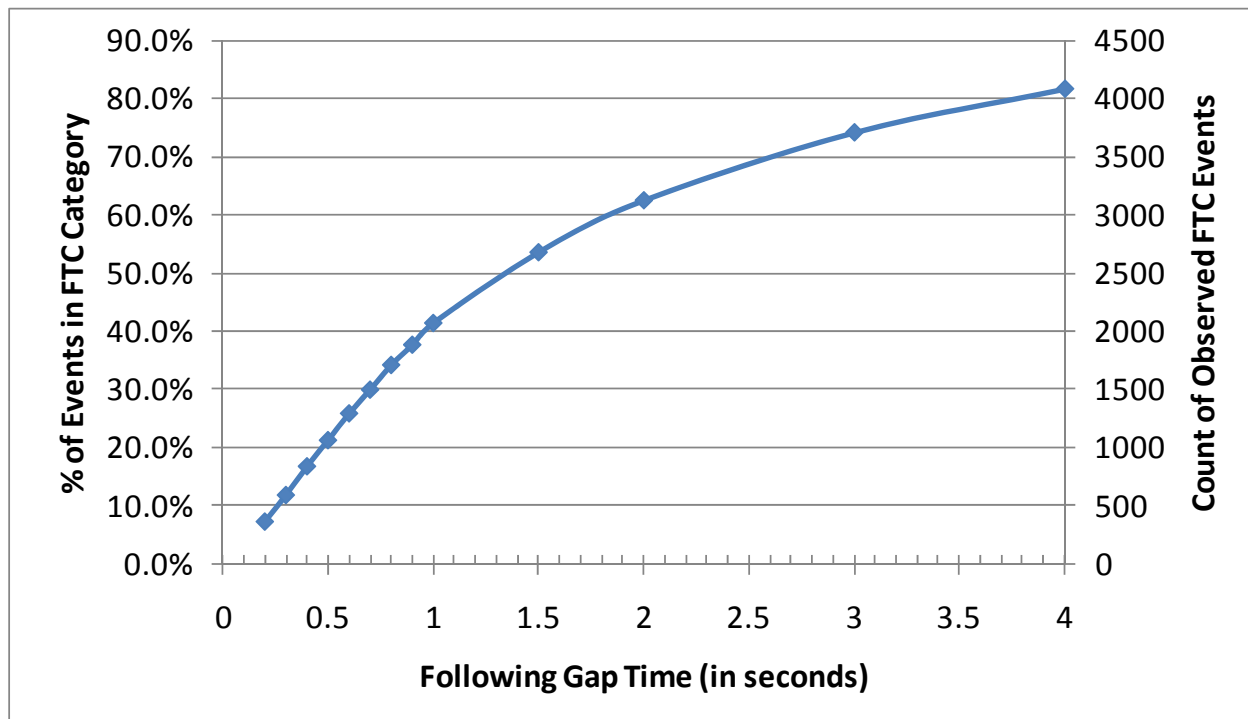
## 24 **RESULTS**

25 The results are presented in two separate sections. First, the feasibility of the evaluation  
26 methodology and a comparison between automated and manual analysis approaches are explored  
27 using data recorded at Site A. The findings and lessons learned from that site are then followed  
28 by assessment of actual TACT interstate enforcement at Site B using automated and manually  
29 extracted data collection methods.

### 30 **Observed Vehicle Following Times at Site A**

31 The video data collected at Site A were analyzed with respect to the distribution of observed  
32 vehicle following times with respect to an FTC measure. From previous research, the team was  
33 quite comfortable with the accuracy of speed and classification data from video, but no previous  
34 attempts at FTC data have been made. The clear challenge was to identify a suitable threshold  
35 for distinguishing FTC events from regular following times, which can be quite small under  
36 heavy vehicular flows. In fact the Highway Capacity Manual (23) predicts a theoretical freeway  
37 capacity of 2,400 passenger-cars per hour per lane, which corresponds to an average headway of  
38 1.5 seconds over an hour (3600 seconds). Using a well established reaction time of 1 second, we  
39 would theoretically predict that following distances of 0.5 seconds would be risky (1.5s headway  
40 - 0.5s reaction time). To explore this relationship further, the threshold for identifying FTC  
41 events was systematically varied from 0.2 sec to 4.0 sec (Figure 4). The data show, for example,  
42 that 62.5 percent of all vehicles observed at the site exhibited following distances of 2-seconds or  
43 less, under reasonably high traffic volumes.. Similarly, 81.7 percent of all vehicles exhibited

1 following distances of 4-seconds or less. The selected FTC threshold from this analysis was  
 2 selected at 0.5 seconds, which was significantly below the 1.5 seconds capacity threshold, but  
 3 corresponded well when accounting for reaction time, and therefore represents a sub-section of  
 4 following times that clearly falls into the aggressive range. The automatic data from Site A was  
 5 then used to infer the effective FTC threshold adopted by the observer in the manual analysis of  
 6 FTC frequency at the Site B enforcement location.



7  
 8 **Figure 4: Percent of Vehicles with Following Distances of x-seconds or less**  
 9

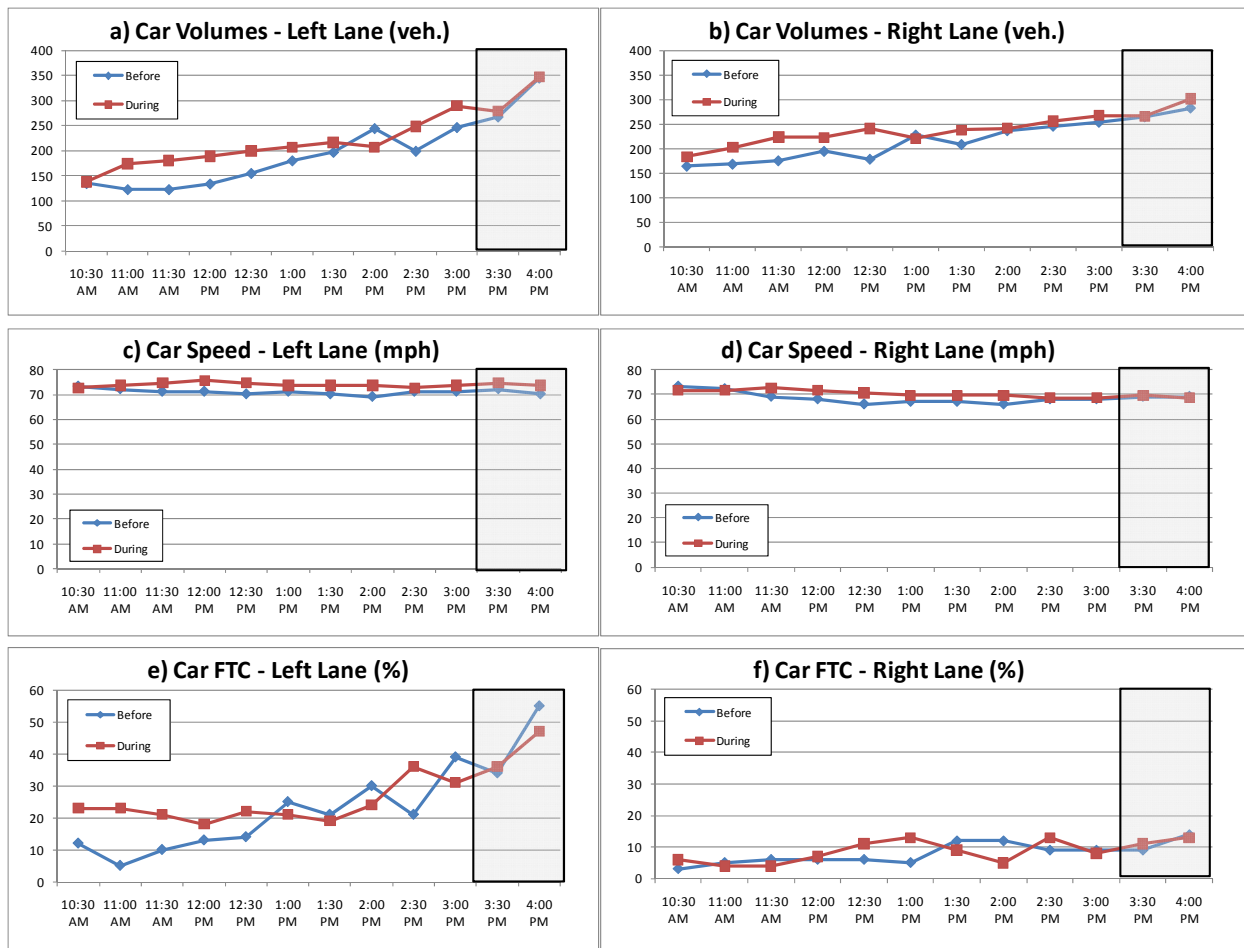
### 10 **Manual Evaluation of Interstate Enforcement Site B**

11 With the general feasibility of the evaluation approach demonstrated, the methodology was  
 12 applied to one direction (two lanes) of interstate Site B, which was observed before and during  
 13 enforcement. At the time of this paper, the “after” data was not available for evaluation, so no  
 14 inference can be made about whether or not the enforcement program had a sustained effect at  
 15 this location. As we noted previously, speed, counts, and classification were all able to be  
 16 obtained through automated methods; however, FTC events had to be collected manually  
 17 because of video loss at the FTC camera. The FTC threshold used by the individual conducting  
 18 the manual evaluation of FTC can be inferred from the automated FTC analysis at Site A.

19 Assuming comparable following distance attributes of the traffic at the two interstate sites (A and  
 20 B), the observer’s threshold was consistent with the 0.5 second threshold selected above. While  
 21 the value of the threshold can be debated, **it is most critical for the TACT program evaluation**  
 22 **that it is applied consistently** to “before” and “during” enforcement periods.

23 At Site B, the analysis focuses on lane-by-lane volumes, speeds, and FTC events. Restricted lane  
 24 compliance (RLC) was not possible because the interstate facility was only two lanes wide at the  
 25 data collection location. The results are shown separately for passenger cars (Figure 5) and

1 CMVs (Figure 6). In both cases, measurements were aggregated to twelve 30-minute periods  
 2 from 10:30am to 4:30pm, although the TACT enforcement effort ended at 3:30pm. The last two  
 3 time periods are therefore grayed out in both figures. Comparisons between before and during  
 4 enforcement periods, and between left and right lanes were performed using a paired-sample t  
 5 test.



6

7 **Figure 5: Manual Evaluation of Before and During Enforcement Periods for Passenger Cars**

8 Results for passenger cars in Figure 5 show that volumes increased towards an afternoon peak,  
 9 with slightly higher volumes in the right lane. These trends are intuitive and give confidence in  
 10 the validity of the data. The observed speeds are generally consistent throughout the observation  
 11 period, with speeds slightly higher in the left lane. As volumes increase toward the afternoon,  
 12 FTC events appear to increase proportionally with volume, which is expected since density along  
 13 the freeway increases as volume increases. As car volumes increased over the period of the day,  
 14 FTC also increased, most notably in the left lane.

15 Comparing before and during enforcement data of passenger cars, AM traffic volumes were  
 16 higher during the enforcement period with both lanes showing a p-value less than 0.01 in a  
 17 paired-sample t-test. Accordingly, speeds were higher during enforcement (both lanes p less than  
 18 .001). The average speed in the left lane increased slightly from 71.0 to 73.9 mph with

1 enforcement, and in the right lane from 68.5 to 70.5 mph. Interestingly, no significant difference  
2 in FTC was evident comparing before and during enforcement behavior for cars (p-values of  
3 0.297 in the left and 0.959 in the right lane. These data are based on a measurement of 4,953 and  
4 5,541 passenger cars before and during enforcement, respectively. The results suggest that the  
5 presence of enforcement did not significantly affect the average speeds and or average following  
6 distances of passenger vehicle drivers.

7 It should be noted here that, in theory, increases in vehicle speed during actual enforcement  
8 suggest that enforcement is not working. However, little is known about other factors that may  
9 actually increase average speed, such as the effect of trucks staying in the right-most lane (noted  
10 later). The team looked at the aggressive passenger car driver population (defined as > 85<sup>th</sup>  
11 percentile speeds) and determined that the average 85<sup>th</sup> percentile speeds did not change  
12 significantly with enforcement, suggesting that although the average speeds increased, the more  
13 aggressive population of drivers had no change in behavior due to enforcement. In future  
14 research, it should be explored if such speed harmonization effect can be verified.



1

2 **Figure 6: Manual evaluation of Before and During Enforcement Periods for CMVs**

3 Results for CMVs in Figure 6 show a relatively constant truck volume throughout the  
 4 observation period, with approximately four to five times as many trucks using the right lane as  
 5 the left lane. At this site, neither lane had a truck restriction, so the difference in volumes appears  
 6 to be a function of general driving habits of CMV operators. CMV volumes are not statistically  
 7 different for the before and during observation periods (p-values of 0.2202 and 0.4043 for left  
 8 and right lane, respectively).

9 The observed CMV speeds are generally consistent throughout the observation period and across  
 10 both lanes. Similar to passenger car observations, speeds were observed to increase in the during  
 11 enforcement period from 69.4 to 72.7 in the left lane (p=0.037) and from 66.6 to 70.9mph in the  
 12 right lane (p=0.001).

1 The truck FTC events exhibited a very interesting pattern. For the left lane, the average FTC  
2 percentage decreased from 13.2 to 7.3% (indicating an increase in CMV following times), which  
3 was statistically significant at  $p=0.0403$ . In the right lane, the FTC percentage decreased even  
4 more drastically from an average 8.1% to 3.3% ( $p=0.0284$ ). Graphically, this difference is  
5 particularly noteworthy in the morning hours for the right lane (Figure 7-f), where a large  
6 difference between the two periods was evident. The FTC rate dropped most drastically from the  
7 10:30am to the 11:00am time period, which largely coincides with the beginning of TACT  
8 enforcement. Similarly, there was an apparent increase in FTC (i.e., an increase in shorter  
9 following times) after enforcement ended at 3pm.

10 While these data were unique to this particular site on the particular day(s) observed, they  
11 suggest a significant impact of the TACT effort on CMV drivers' vehicle following-behavior.  
12 The difference between car and CMV observations may be explained by the ability and general  
13 practice of truck drivers communicating amongst each other via CB radio. In other words, the  
14 presence of additional Highway Patrol vehicles and the enforcement activities may have been  
15 communicated between CMV drivers as they approached the enforcement corridor, while a  
16 similar capability does not exist for most drivers of passenger vehicles. This apparent differential  
17 enforcement effect on CMV and non-CMV drivers is something that deserves attention in such  
18 future efforts.

## 19 **DISCUSSION**

20 Caution is urged in drawing conclusions regarding possible program effects from data which  
21 represent single-day snap shots of system performance associated with the "before" and "during"  
22 enforcement periods at a single site. The emphasis of this paper thus is on the methodology for  
23 evaluating the TACT effort, rather than the limited results themselves. In ongoing efforts in  
24 North Carolina, more data are being collected at additional sites using the same methods, which  
25 will ultimately provide the desired quantitative evaluation of TACT across the state. Particular  
26 effort is being made to derive the system performance data in a *totally automated* fashion, since  
27 the ability to do so is critical for the proposed next step of TACT in North Carolina; i.e., using  
28 the real time data to provide a *driver feedback link* for providing guidance to drivers via roadside  
29 or overhead message signs (i.e. a threshold-based approach for selecting *what* message to display  
30 and *when*). This can be thought of as a possible precursor to future attempts to provide such  
31 information to drivers via an infrastructure to vehicle (I2V) link. The I2V approach would itself  
32 be a precursor to using vehicle-to-vehicle (V2V) methods to communicate risky situations and  
33 guidance to vehicles further upstream.

34 With caution, we can say that in the present case where enforcement performance was sampled  
35 using a before/during treatment approach, the percentage of trucks considered as FTC was  
36 approximately one half of what it was in the before enforcement period (5.6% versus 10.4%  
37 averaged over both lanes). The magnitude of these differences is dependent upon the threshold  
38 established for FTC, which was applied consistently throughout all analyses. A similar reduction  
39 was not observed for passenger vehicles. The apparent CMV effect was most prominent in the  
40 morning, diminishing over the afternoon period of data collection as the program ceased around  
41 3:30 PM.

1 A possible explanation for the truck effect is that trucks were aware of the TACT operation miles  
2 in advance through their extensive trucker-to-trucker communication network, whereas most  
3 passenger vehicle drivers do not have the benefit of that advanced information. Truckers  
4 (especially those in interstate commerce) have a clear incentive to maintain an unblemished  
5 safety record with FMCSA, which includes traffic violations, as well as involvement in crashes  
6 and out of service inspection conditions (19). Additional data for the during enforcement period  
7 need to be analyzed to determine if a similar effect is observed on other days of the during  
8 enforcement period. Clearly, more analyses are required to substantiate whether this FTC  
9 difference (for trucks) is a reliable performance measure or simply an indication of a fluctuation  
10 in performance over time.

11 It is suggested that future analyses concentrate on trying to determine if there are reliable and  
12 predictable relationships between the likelihood of FTC, the likelihood of erratic lane changing  
13 behavior, and changes in the basic traffic attributes of vehicle mix, vehicle lane volumes,  
14 changes in lane speeds, etc. The long term objective is to bring about desired changes in  
15 performance through efforts to control/manipulate the more basic attributes of the traffic stream,  
16 similar to the UK rationale of 'active traffic management' exhibited on the M25 "Controlled"  
17 Motorway (21,22).

18 It can be hypothesized that unbalanced lane volumes and differences in vehicle speeds across  
19 lanes (conditions which may often be precursors to congestion) may prompt a decrease in lane  
20 control and an increase in erratic lane change behavior and FTC as density increases on the  
21 roadway. In other words we don't believe that the type of 'risky' or 'aggressive' behaviors that  
22 are the target of TACT are solely the product of individual driver motivation. It is hypothesized  
23 that traffic conditions play a large role in the likelihood and timing of such (aggressive)  
24 behaviors, and that a reasonable strategy for reducing the likelihood of these behaviors may be  
25 through more effective control of the traffic conditions which, in some large part, determine their  
26 occurrence. The bottom line is that effective treatments for the types of risky behavior targeted  
27 by TACT may be as much a traffic management/control issue as an enforcement issue.

28 Lastly, there are important policy questions raised by the present work, with respect to the most  
29 appropriate temporal description of FTC. In the present study, the threshold for FTC was  
30 selected at 0.5 seconds, which is well below the traditional safety following guidance of 2  
31 seconds for cars and 4 seconds for large trucks. The lower (observed) value is however  
32 consistent with contemporary data from other interstate free-flow settings (23). Is the lower value  
33 'safe' from the standpoint of vehicle braking requirements - probably not. While the more  
34 traditional 2 or 4 second values may be safer, their adoption would have serious impacts on  
35 facility throughput. If FMCSA expects motor carrier enforcement personnel to cite FTC  
36 violations (commonly referred to as a 392.2FC violation), a position must be taken on a  
37 definitive value fully recognizing that such a value may also have ramifications for system  
38 operation.

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