Is TACT Effective in Changing Driver Behavior: Evidence from North Carolina TACT III Effort

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ABSTRACT

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

INTRODUCTION

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

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

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

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

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

BACKGROUND

It is implied in the title and purpose of TACT that some crashes are attributable to driver behaviors that are "aggressive". The term *aggressive driving* is usually reserved for occasions where two or more serious traffic violations are observed over a brief period of time and space, including excessive speed or erratic lane changing *(7)*. However, since these events are rare and sometimes difficult to observe, it is hypothesized that it is more productive to focus on *observable traffic stream parameters* that increase the likelihood of these behaviors.

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

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

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

The Need to Document TACT Effectiveness

TACT can be thought of as an attempt to increase the degree of system control over vehicle speeds, lane placement and lane keeping, and vehicle following distance through increased enforcement and public awareness. To that extent, an evaluation of the TACT program should document measurable changes in the parameters of vehicle speeds and vehicle following distances (in particular, the latter). Documentation of how many speeding tickets from past evaluation efforts are issued during a TACT enforcement phase does not constitute evidence that vehicle speeds and following distances have been affected by enforcement presence. Neither do measures of TACT "media recognition" constitute evidence that TACT efforts have resulted in measurable changes in critical driver behaviors. Instead, data should be defensible and based on the effect of the treatment being employed, in this case public awareness/education campaigns and focused enforcement.

Challenges in Quantifying Critical TACT-Related Driver Behaviors

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

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

The North Carolina TACT Response

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

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

METHODOLOGY

Evaluation Approach

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

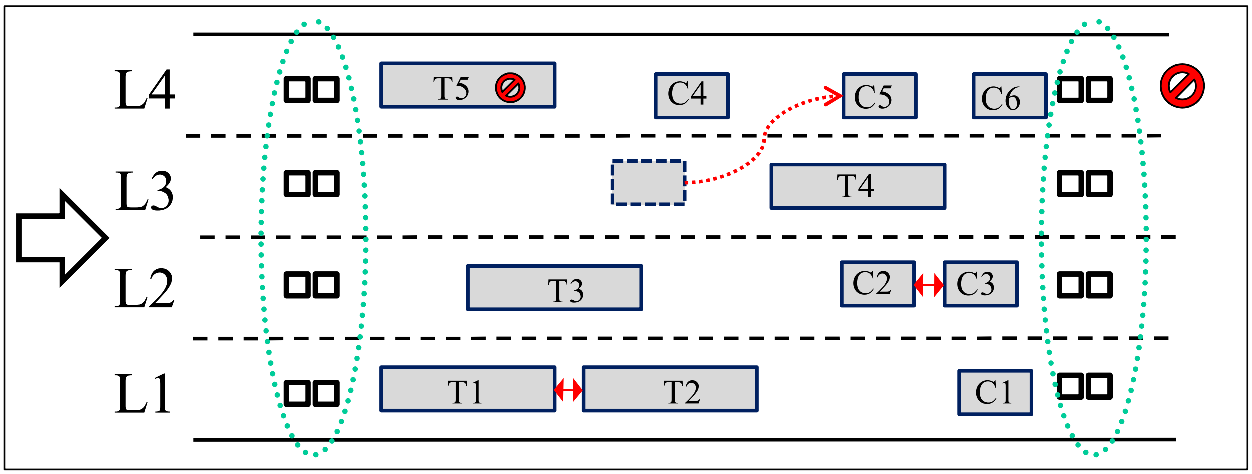

Figure 2: Schematic of TACT Evaluation Approach

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

- Following-too-Close (FTC), an event where the time gap between two successive vehicles is too short to allow for appropriate driver reaction time, illustrated between CMVs T1 and T2 and cars C2 and C3.

- Aggressive Lane Changing (ALC), an event where a vehicle changes lanes in a manner that forces reactive deceleration or swerving by one or more other vehicles, illustrated by vehicle C5 swerving in front of vehicle C4 in an attempt to overtake a slower-moving CMV (T4)

- Restricted Lane Violation (RLV), an event where a CMV operates in a restricted lane ("no trucks this lane"), illustrated by vehicle T5.

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

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

Video-Based Evaluation

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

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

Performance Measures

For the purposes of this study, recorded video were post-processed in the lab for evaluation. From the four performance measures described above, only three were included in this assessment. The fourth measure, aggressive lane changing (ALC) proved to be highly subjective in manual observation and infeasible to extract in an automated fashion. Consequently, the three primary TACT performance measures are:

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

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

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

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

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

IMPLEMENTATION

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

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

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

RESULTS

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

Observed Vehicle Following Times at Site A

The video data collected at Site A were analyzed with respect to the distribution of observed vehicle following times with respect to an FTC measure. From previous research, the team was quite comfortable with the accuracy of speed and classification data from video, but no previous attempts at FTC data have been made. The clear challenge was to identify a suitable threshold for distinguishing FTC events from regular following times, which can be quite small under heavy vehicular flows. In fact the Highway Capacity Manual (*23*) predicts a theoretical freeway capacity of 2,400 passenger-cars per hour per lane, which corresponds to an average headway of 1.5 seconds over an hour (3600 seconds). Using a well established reaction time of 1 second, we would theoretically predict that following distances of 0.5 seconds would be risky (1.5s headway - 0.5s reaction time). To explore this relationship further, the threshold for identifying FTC events was systematically varied from 0.2 sec to 4.0 sec (Figure 4). The data show, for example, that 62.5 percent of all vehicles observed at the site exhibited following distances of 2-seconds or less, under reasonably high traffic volumes.. Similarly, 81.7 percent of all vehicles exhibited following distances of 4-seconds or less. The selected FTC threshold from this analysis was selected at 0.5 seconds, which was significantly below the 1.5 seconds capacity threshold, but corresponded well when accounting for reaction time, and therefore represents a sub-section of following times that clearly falls into the aggressive range. The automatic data from Site A was then used to infer the effective FTC threshold adopted by the observer in the manual analysis of FTC frequency at the Site B enforcement location.

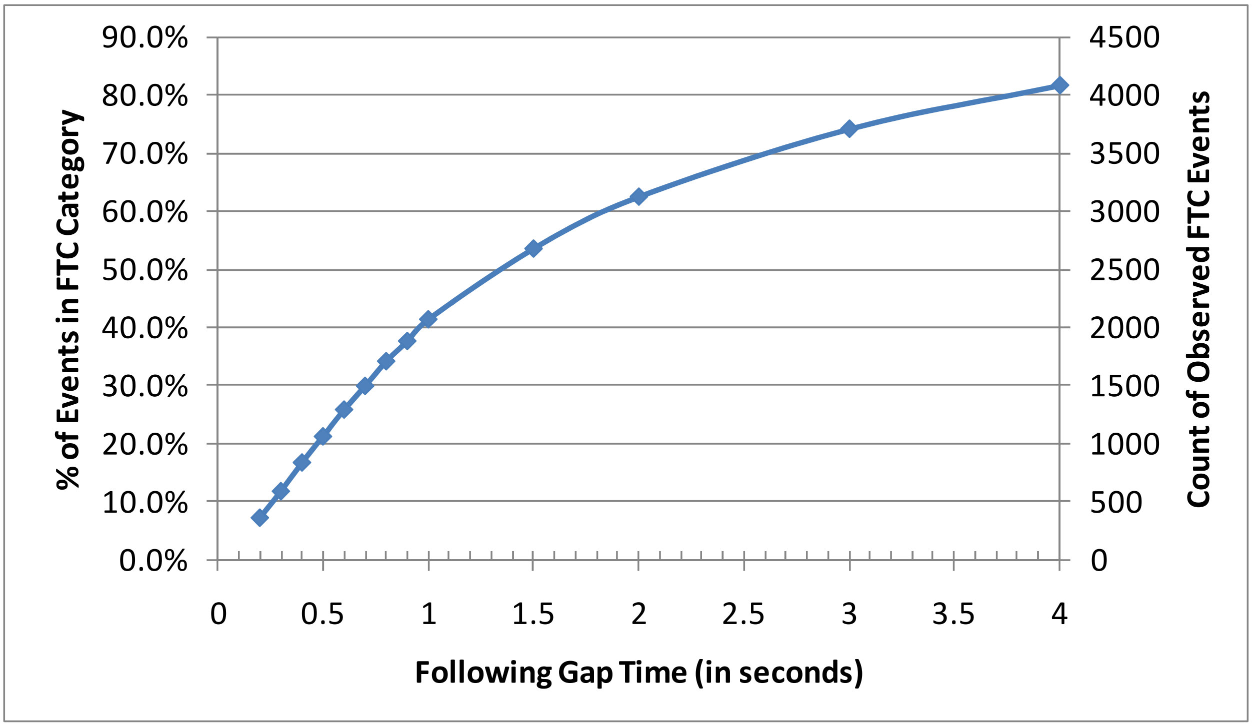

Figure 4: Percent of Vehicles with Following Distances of x-seconds or less

Manual Evaluation of Interstate Enforcement Site B

With the general feasibility of the evaluation approach demonstrated, the methodology was applied to one direction (two lanes) of interstate Site B, which was observed before and during enforcement. At the time of this paper, the "after" data was not available for evaluation, so no inference can be made about whether or not the enforcement program had a sustained effect at this location. As we noted previously, speed, counts, and classification were all able to be obtained through automated methods; however, FTC events had to be collected manually because of video loss at the FTC camera. The FTC threshold used by the individual conducting the manual evaluation of FTC can be inferred from the automated FTC analysis at Site A. Assuming comparable following distance attributes of the traffic at the two interstate sites (A and B), the observer's threshold was consistent with the 0.5 second threshold selected above. While the value of the threshold can be debated, **it is most critical for the TACT program evaluation that it is applied consistently** to "before" and "during" enforcement periods.

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

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

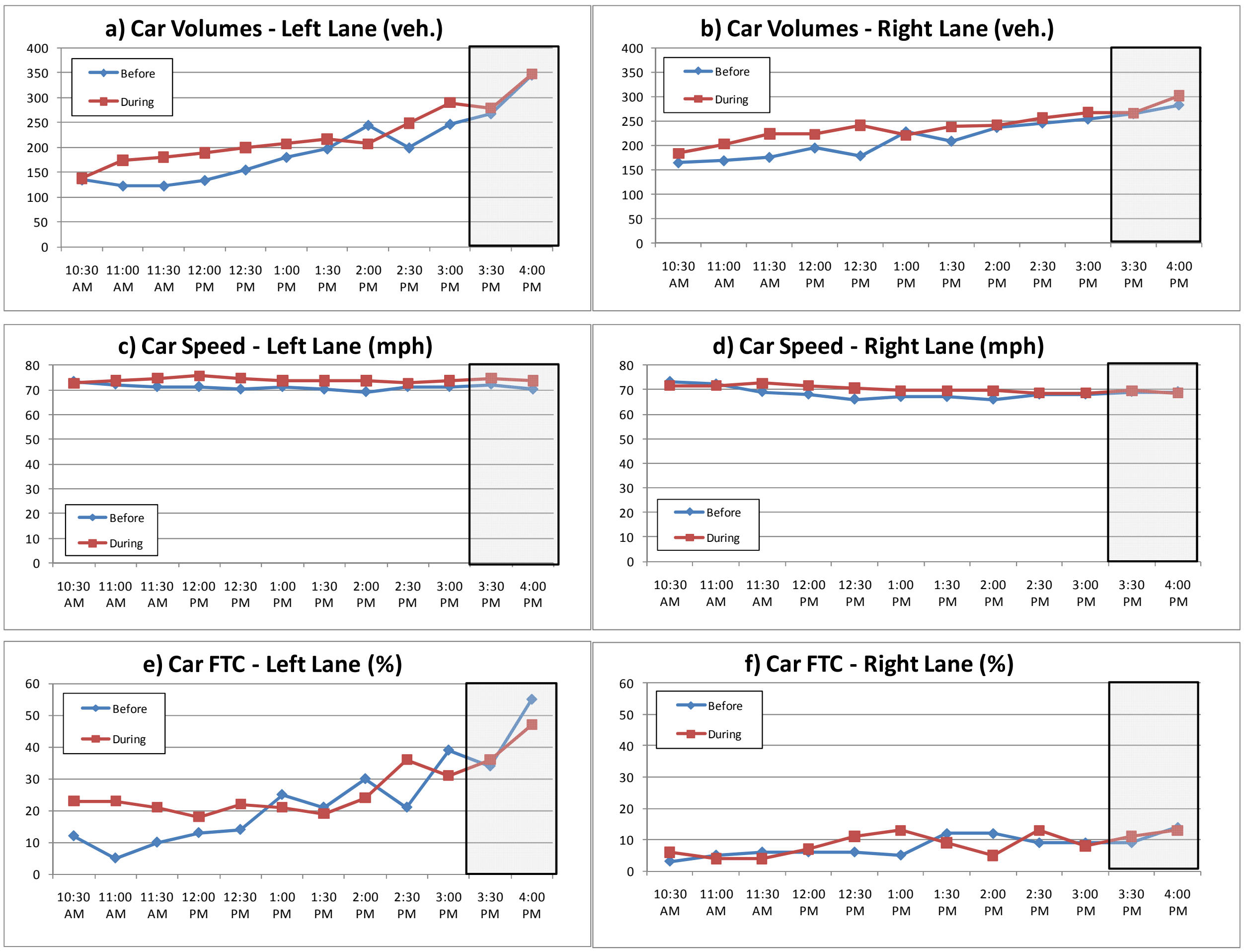

Figure 5: Manual Evaluation of Before and During Enforcement Periods for Passenger Cars

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

Comparing before and during enforcement data of passenger cars, AM traffic volumes were higher during the enforcement period with both lanes showing a p-value less than 0.01 in a paired-sample t-test. Accordingly, speeds were higher during enforcement (both lanes p less than .001). The average speed in the left lane increased slightly from 71.0 to 73.9 mph with enforcement, and in the right lane from 68.5 to 70.5 mph. Interestingly, no significant difference in FTC was evident comparing before and during enforcement behavior for cars (p-values of 0.297 in the left and 0.959 in the right lane. These data are based on a measurement of 4,953 and 5,541 passenger cars before and during enforcement, respectively. The results suggest that the presence of enforcement did not significantly affect the average speeds and or average following distances of passenger vehicle drivers.

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

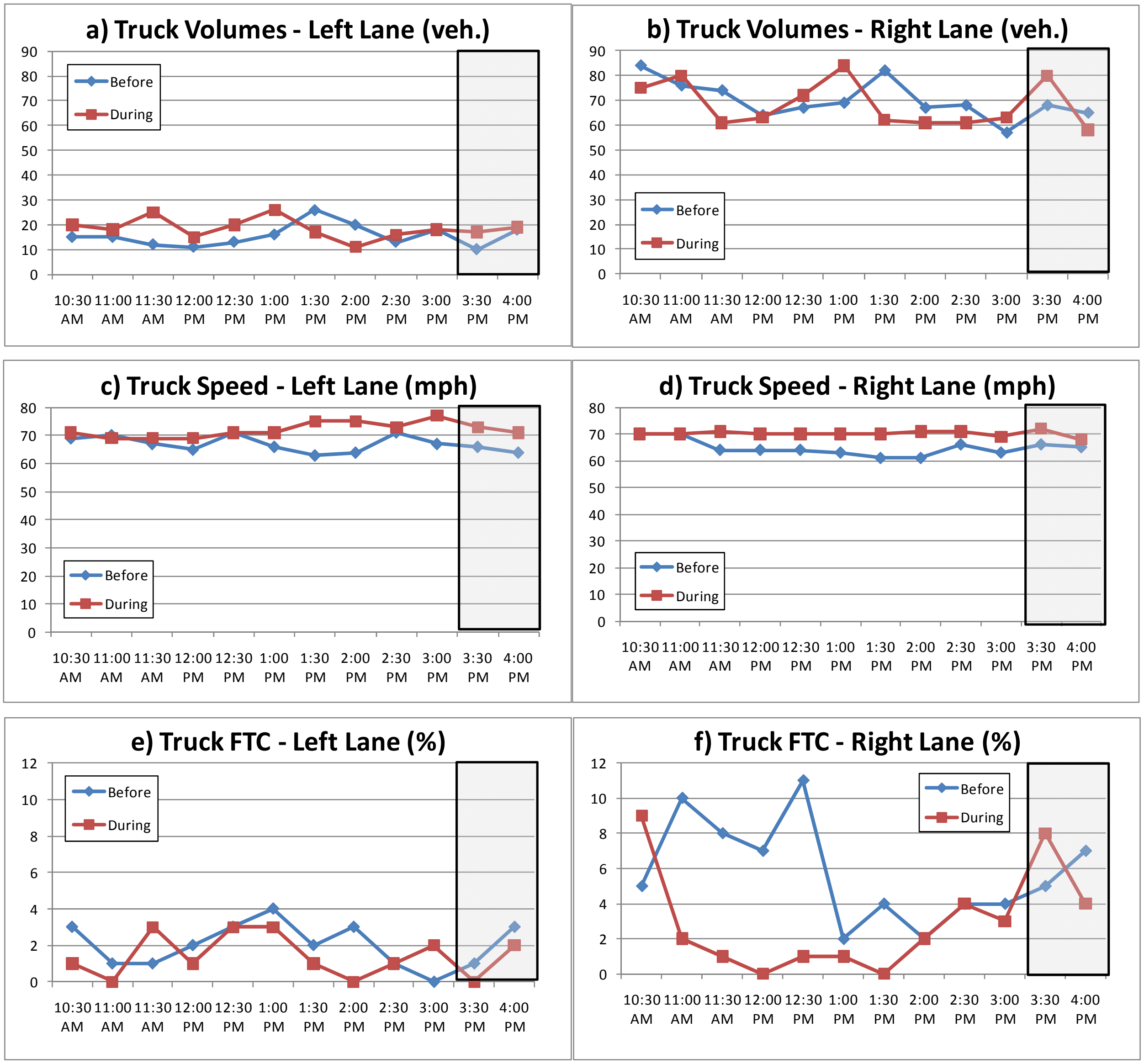

Figure 6: Manual evaluation of Before and During Enforcement Periods for CMVs

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

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

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

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

DISCUSSION

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

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

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

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

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

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

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REFERENCES

1. "Click-it-or-Ticket." National Highway Traffic Safety Administration (NHTSA). http://www.nhtsa.gov/CIOT. Last accessed on July 27, 2010.

2. "Booze-it-and-Lose-it." National Highway Traffic Safety Administration (NHTSA), Washington, DC. http://www.ncdot.gov/programs/GHSP/initiatives/default.html. Last accessed on July 27, 2010.

3. FMCSA Ticketing Aggressive Cars and Trucks (TACT). Federal Motor Carrier Safety Administration (FMCSA). http://www.fmcsa.dot.gov/safety-security/tact/index.htm. Last accessed on July 27, 2010.

4. NHTSA. *Traffic Safety Facts – 2008 Traffic Safety Annual Assessment.* National Highway Traffic Safety Administration (NHTSA). http://www-nrd.nhtsa.dot.gov/pubs/811172.pdf. Last accessed on July 27, 2010.

5. Commercial Motor Vehicle Enforcement/CMV Crash Data. Reported on NCSU-ITRE website at: http://www.itre.ncsu.edu/VAMS/cmv/crashdata.html. North Carolina State University, Raleigh, NC. Last accessed on July 27, 2010.

6. Large Truck Crash Causation Study (LTCCS). US Department of Transportation. Federal Motor Carrier Safety Administration, Washington DC, July 2007.

7. Aggressive Driving. Michigan State Police. On line at: http://www.michigan.gov/msp/0,1607,7-123-1593_3504_22760-13544--,00.html. Last accessed on July 28, 2010.

8. NHTSA. *Speed Enforcement Program Guidelines.* Publication No. DOT HS 810 915. Washington, DC: National Highway Traffic Safety Administration, 2008.

9. *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 1: A Guide for Addressing Aggressive-Driving Collisions*. Washington, DC: Transportation Research Board.

10. USDOT (2008). Speed Enforcement Camera Systems: Operational Guidelines. Publication No. DOT HS 810 916. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration and Federal Highway Administration, 2008.

11. Wrapson, W.; Harre, N.; and P. Murrell. Reductions in Driver Speed using Posted Feedback of Speeding Information: Social Comparison or Implied Surveillance? *Accident Analysis and Prevention, 28*, 1119-1126. 2006.

12. Brewer, M.A., Pesti, G., and W. Schneider. Improving Compliance with Work Zone Speed Limits. *Transportation Research Record, 1948,* 67-76. 2006.

13. Mattox, J.H.; Sarasua, W.A.; Ogle, J.H.; Eckenrode, R.T.; and A.E. Dunning. *Development and Evaluation of a Speed-Activated Sign to Reduce Speeds in Work Zones.* Transportation Research Board 86th Annual Meeting, Transportation Research Board. 18p. 2007.

14. Lee, C.; Lee, S.; Choi, B.; and Y. Oh. Effectiveness of Speed-Monitoring Displays in Speed Reduction in School Zones. *Transportation Research Record, 1973,* 27-35. 2006.

15. Sivak, M.; Luoma, J.; Flannagan, M.J.; Bingham, C.R.; Eby, D.W.; and J.T. Shope. Traffic Safety in the U.S.: Re-examining Major Opportunities. Journal of Safety Research, 38, 337-355. 2007.

16. Young, K.L. and M.A. Regan. Use of Manual Speed Alerting and Cruise Control Devices by Car Drivers, *Safety Science, 45*, 473-485. 2007.

17. Eckenrode, R.T.; Sarasua, W.A.; matox, J.H., Ogle, J.H.; and M.A. Chowdhury. *Revisiting the Use of Drone Radar to Reduce Speed in Work Zones; South Carolina's Experience.* Transportation Research Board 86th Annual meeting cd-rom, Transportation Research Board.

18. Nerup, P.; Salzberg, P; VanDyk, J.; Porter, L.; Blomberg, R.; Thomas, F.D.; and L. Cosgrove. *Ticketing Aggressive Cars and Trucks in Washington State: High Visibility Enforcement Applied to Share the Road Safely.* Final Report, US DOT HS 810 603, May 2006. Also reported on FMCSA website at http://www.fmcsa.dot.gov/safety-security/tact/stateOverView.htm. Last accessed on July 27, 2010

19. Autoscope Products. See http://autoscope.com/products/. Last accessed on July 27, 2010.

20. Harford, B, and Jones, J. Variable Speed Limit Enforcement: The M25 Controlled Pilot Scheme. Institute of Electrical Engineers, Savoy Place, London WC2R 0BL, UK, 1966.

21. M25 Controlled Motorway Summary Report. European Commission: Directorate General Energy and Transport. February 2006.

22. SafeStat. Federal Motor Carrier Safety Administration. US Department of Transportation, (https://ai.fmcsa.dot.gov/SafeStat/disclaimer.asp?RedirectedURL=/SafeStat/SafeStatMain.asp) Last accessed on July 27, 2010.

23. Highway Capacity Manual 2000. Transportation Research Board. National Academies of Science. April 2004. Washington, DC.