CAN EDUCATION AND ENFORCEMENT AFFECT BEHAVIOR OF CAR AND TRUCK DRIVERS ON URBAN FREEWAYS?

Andrew P. Tarko
Professor of Civil Engineering, School of Civil Engineering, Purdue University,
550 Stadium Mall Drive, West Lafayette, 47907 IN, USA, (765) 494-5027, tarko@purdue.edu.

Panagiotis Ch. Anastasopoulos
Visiting Assistant Professor, School of Civil Engineering, Purdue University
550 Stadium Mall Drive, West Lafayette, 47907 IN, USA, (512) 810-3226, panast@purdue.edu.

Ana María Pérez Zuriaga
PhD Candidate, Department of Transportation, Universitat Politècnica de València
Camino de Vera s/n, 46071 Valencia, Spain, +34 (96) 3877-374, anpezu@tra.upv.es

Presented at the 3rd International Conference on Road Safety and Simulation, September 14-16, 2011, Indianapolis, USA

ABSTRACT

More than 5,000 people died in large truck crashes in the United States in 2006. Recognizing the seriousness of this situation, the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Traffic Safety Administration (NHTSA) developed the Ticketing Aggressive Cars and Trucks (TACT) program, a traffic enforcement program that uses communication, enforcement, and evaluation activities to reduce crashes with involvement of commercial motor vehicles (CMV) and resulted fatalities and injuries. FMCSA encourages states to apply the TACT program to roads that are experiencing an excessive number of injuries and fatalities from crashes between cars and trucks. This paper presents the analysis results of the TACT project in order to investigate its effectiveness. Traffic data and information regarding aggressive driving behavior in Indianapolis were collected. There were three phases: the pre-TACT phase, the phase when a media campaign was conducted and the police enforcement took place, and the after the campaign and enforcement phase. The data were extracted from video images and included traffic volumes, speeds, time headways, and several types of aggressive driving behavior. Furthermore, a total of 1,047 surveys were collected by the police officers during the police enforcement phase of the project. The survey data were analyzed to assess the effect that TACT may have had on aggressive behavior characterized by noting the distance left by the drivers when they passed other vehicles. The results showed that the TACT program, particularly its police enforcement component, was successful in curbing aggressive interactions between cars and trucks during the program period.

Keywords: Police enforcement; Passenger cars; Trucks; Transportation safety; Aggressive Behavior

INTRODUCTION

More than 5,000 people died in large truck crashes in the United States in 2006. According to the NCHRP Report 500 Volume 13 (2004), truck crashes are more likely to result in fatality because of their size, weight, and stiffness. Thus, heavy trucks are overrepresented in fatal crashes. Compared with passenger cars, when a heavy truck is involved in a crash, it is about 2.6 times as likely to result in a fatality.

In NCHRP Report 500 Volume 1 (2003) "aggressive driving" is defined as operating a motor vehicle in a selfish, pushy, or impatient manner, often unsafely, that directly affects other drivers. In many cases, the behavior results from interaction between the driver and the driving environment. For this reason, resolving the problem does not only depend on enforcement but also on driver's education and engineering.

Similarly, Shinar et al. (2004) defines aggressive driving as any behavior that interferes with the movement of other drivers or pedestrians. Five measures of aggressive driving are discussed: (a) a short honk of the horn, (b) a long honk of the horn, (c) cutting in front of another vehicle in a passing lane maneuver, (d) cutting in front of another vehicle in a multi-lane passing maneuver, (e) passing one or more vehicles by driving on the shoulder and then cutting in. However, it is found that the most frequent behavior is by far cutting in front of another vehicle in a passing maneuver involving a lane shift.

Selective Traffic Enforcement Programs (sTEPs) have been used effectively for many years to change motorists' behavior (Geary et al. (2005)). Their concept is to concentrate resources for a limited time to noticeably and intensively enforce against a particular kind of traffic violation. These programs typically span a four-week period with the first week focusing on the pre-enforcement survey and median campaign, followed by two weeks of concentrated, intensive, and highly visible enforcement, and one (final) week involving the post-enforcement survey, completion of reporting requirements, and announcement to the media that the program has ended.

The Click It or Ticket (CIOT) model is a well known sTEP and is associated with an impressive increase in safety belt use across the nation in the past several years (Solomon et al. (2002)). Its purpose is not necessarily to issue safety belt tickets, but rather to convince motorists that non-usage will result in a ticket. North Carolina was the first State to implement Click It or Ticket. After a successful pilot program (Reinfurt, 2004) in three different North Carolina areas, the statewide program was launched in October 1993, and has been very effective (many other States have followed North Carolina's example over the last decade). Solomon et al. (2004) presents a historical perspective on the implementation and evaluation of Click It or Ticket programs. In 2001, Click It or Ticket was implemented across all eight states of the southeast. In 2002, ten states in various parts of the country implemented Click It or Ticket; four states implemented parts of the full Click It or Ticket program; and four states were used as comparison. Safety belt usage increases were the greatest in the full implementation states. Click It or Ticket was implemented nationally in 2003.

Clayton et al. (2009) used a multi-element design to compare the ‘‘Click It or Ticket’’ and ‘‘Please Buckle Up—I Care’’ programs. The study attempted to systematically compare the efficacy of the two programs for increasing safety belt usage by drivers exiting a large university parking lot. Results indicate that the Click It or Ticket program resulted in a 20 percent increase in safety belt use; whereas Please Buckle Up—I Care resulted in a 14 percent increase. This illustrated that drivers are more likely to comply with a campaign that results in a monetary fine (i.e., Click It or Ticket) than one that does not (i.e., Please Buckle Up—I Care). One problem identified with this type of campaign is that unless the authorities frequently and visibly penalize noncompliance, the procedure probably loses some of its effectiveness.

Chaudhary et al. (2004) used motorist survey data to examine the effect of Perceived Risk of being Ticketed (PRT) for a safety belt infraction on self-reported safety belt usage. It was indicated that individuals and groups of individuals who have higher PRT typically report higher safety belt usage. Law changes without enforcement were found to minimally impact safety belt law compliance.

Thomas et al. (2011) evaluated the 2009 CIOT program by comparing changes in safety belt usage during the daytime and nighttime, for males and females, and from the pre- and post-CIOT program surveys. It was found that the CIOT program (a) was effective at increasing the overall safety belt usage, (b) was associated with increased safety belt usage during both daytime and nighttime driving periods, and (c) had the greatest impact on males.

Chaudhary et al. (2005) conducted a study in Pennsylvania where it was found that front seat safety belt usage at night increased significantly from 50 percent prior to the media campaign of the sTEP, to 56 percent right after the campaign. Usage of safety belt during the daylight was also found to increase, to a lesser extent though (56 to 59 percent). A similar statewide nighttime safety belt usage observation survey was also conducted in Connecticut (Chaudhary et al., 2006). The study showed how day versus night differences were greater before as compared to after a safety belt usage enforcement program. Thus, the enforcement and media campaign appeared to have an impact on nighttime safety belt use. On the other hand, Vivoda et al. (2007) found that safety belt programs implemented only during the day do not influence nighttime safety belt usage.

Other recent sTEPs include Operation ABC (Always Buckle Up). Milano et al. (2004) described the impact of national safety belt enforcement programs in terms of changes in public awareness, perceptions, and opinions as they relate to Operation ABC. Overall, the six years of Operation ABC/Click It or Ticket programs –and the many observational and opinion surveys that have accompanied them– have provided a rich database of results. These results suggest that, when fully implemented, combined enforcement and media campaign efforts can be very effective in reducing safety belt non-usage. Key characteristics of such programs include optimal intensity, placement, and timing of media efforts and clarity of the media message. Paid media and the use of ‘‘hard’’ enforcement messaging appear to greatly enhance the impact potential of these campaigns.

Like other sTEP programs, the Connecticut’s ‘‘sTEP Wave’’ program incorporates paid and bonus (i.e., news coverage of program activities, and particular coverage of safety belt

checkpoints) media as well as highly publicized heightened enforcement. The program has helped to improve awareness of safety belt issues and laws and has aided in increasing the overall number of safety belt citations issued across the state (Geary et al., 2005). Generally, the post-enforcement observation yields a higher rate of safety belt usage as compared to the pre-enforcement observation. Safety belt usage then decreases somewhat after the end of the enforcement, but still remains higher than the original pre-enforcement observation rate. Although safety belt usage does decrease between enforcement phases, the overall safety belt usage progressively raises with subsequent enforcement waves.

Williams et al. (2004) highlighted the importance of police leadership, focused publicity about enforcement, and sustained rather than "single-shot" efforts. In fact, it was found that the improvements in drivers' behavior only have short-term results. The decay in occupant behavior can be offset by conducting frequent interventions, such as an annual CIOT intervention, which reinforces the importance of using safety belts.

In 2004, the Washington State applied NHTSA's High Visibility Enforcement program used in the Click It or Ticket safety belt campaign in an attempt to reduce unsafe driving behaviors around commercial motor vehicles. The program is called Ticketing Aggressive Cars and Trucks (TACT). It is a newly developed sTEP that uses education, enforcement, and media in an attempt to ameliorate aggressive and unsafe driving behavior around commercial vehicles. TACT enforcement focuses on violations committed by passenger vehicles around commercial vehicles and violations by commercial vehicles around other commercial vehicles, such as "cutting off trucks", speeding, reckless driving and tailgating commercial vehicles. Based on the success of the Washington State TACT program and other traffic enforcement programs such as Click It or Ticket, other States were encouraged to undertake TACT programs on roadways with injuries and fatalities resulting from crashes between cars and trucks. TACT programs have been and are currently implemented in several States. (Current TACT States: Washington, Kentucky, Georgia, North Carolina, Pennsylvania, Alabama, Texas, Nevada, Oregon, Indiana, Montana, and New Jersey, South Dakota, Maine, Connecticut, and Rhode Island.)

The evaluation of the TACT program conducted by Nerup et al. (2006) and presented by Thomas et al. (2008) included a quasi experimental/control design with measures before, during, and after the intervention periods. The same evaluation materials and methods were used at each of the test sites for each wave of data collection. The two experimental sites were chosen based on collision and traffic data. Two control sites were chosen based on similarity to the intervention sites, and geographic separation from the intervention sites (to prevent spillover effects from media and enforcement). The control sites did not receive any direct media or any enforcement interventions beyond regularly scheduled patrol. Overall, the evaluation results provided a consistent picture of the effectiveness of the TACT pilot project. Success was demonstrated at every step: messages were received and understood, self-reported driving behavior around large trucks improved, and observed driving behaviors confirmed the self-reported surveys.

Lee et al. (2010) presented how, in general, all safety campaigns related to aggressive driving have used enforcement interventions as the primary means of reducing aggressive driving behavior. Some campaigns have supplemented enforcement actions combined with media awareness about the issue, and only a few campaigns, such as within the TACT program, have

effectively used a combination of enforcement, media, and education on a large scale to deal with aggressive driving. It is clear that enforcement plays a crucial role in reducing aggressive driving; however, limited efforts have been made to enhance the awareness of aggressive driving behavior by providing proper education to the public.

This study presents the evaluation results of the TACT program implemented in Indiana, in order to investigate its effectiveness. The program specifics are first presented, followed by the approach for the evaluation task, the data collection and processing, the results of the statistical analysis, and the conclusions and evaluation of the program's effectiveness.

PROGRAM SPECIFICS

The Indianapolis area of Marion County was selected as the project area, where four major interstate corridors (I-65, I-69, I-70, and I-74) meet. The circular bypass, I-465, complements the interstate system to provide an alternative route around the Indianapolis central area. The I-465 bypass and the four interstate sections experience a high volume of truck traffic and frequent truck crashes. The total number of crashes on the I-465 bypass in the period 2004-2007 was 3,782, which converts to a high average crash density per mile. Interestingly, 72 percent of the truck crashes were determined by investigating police officers to have been the result of aggressive driving. The most common aggressive driving behaviors include improper lane usage, following too closely, driving at unsafe speeds or speeds too fast for weather conditions, and failure to yield the right of way. The TACT project focused on two interstate sections of I-465: the south section, where the Indiana State Police implemented the TACT enforcement, and the north section, which had no police enforcement (Figure 1).

Figure 1. Studied I-465 sections

Other possible control sites in the northwest corner of Indiana (City of Gary area) were also considered. Interstate users in that area include a significant percentage of Chicago area drivers. It is quite likely that the traffic characteristics and driver behaviors in the Indianapolis and Chicago areas are not comparable so this option was rejected. Obviously, there are no other metropolitan areas closer to Indianapolis to serve as a control area; therefore, the one presented in Figure 1 was the most appropriate for the purpose of the project. Two locations in the I-465 South (police enforcement site) and two in the I-465 North (control site) were selected for data collection, which are illustrated in Figure 3.

Figure 2. The four selected locations (Points A and B in the police enforcement zone, and Points 1 and 2 in the control site)

The time frame of the TACT project is shown in Figure 3, including the media campaign (TV, radio, message signs), the periods with Police TACT enforcement, and the periods with data collection.

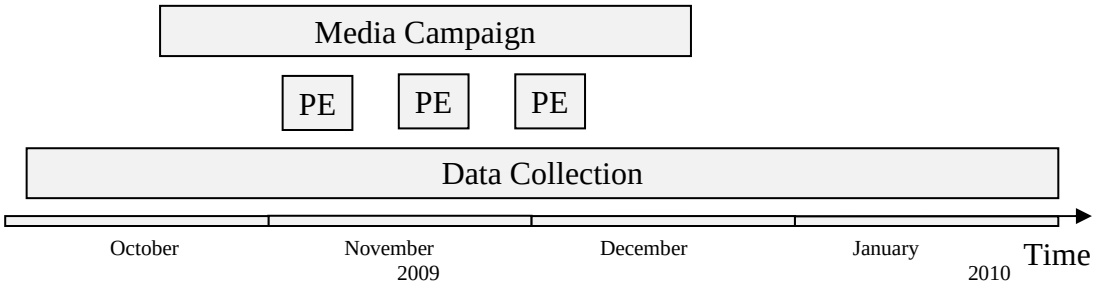

Figure 3. Project schedule (PE: police enforcement)

Indiana designed a high-visibility enforcement campaign that follows the TACT model recommended by FMCSA. The campaign had two elements: education and outreach, and enforcement.

The education and outreach element (initiated on October 19, 2009) communicated to the public an awareness of driving behaviors around commercial vehicles. Indiana utilized the local radio and television stations to air the public safety announcements. Billboard space for the messages was also contracted, and the billboards were placed in the campaign corridor.

The enforcement element, (initiated on November 2, 2009) consisted of saturated patrols in a designated corridor during the designated blitz period. The enforcement campaign spanned a five-week period of November 2 - December 4, 2009 with three weeks of enforcement (first, third, and fifth weeks) separated by two individual weeks without enforcement (second and fourth weeks). On the enforcement weekdays, between 8:00 am and 4:00 pm, six police officers patrolled the 18-mile stretch of the I-465 North section.

GENERAL APPROACH TO THE EVALUATION TASK

The impact of the project on drivers and safety can be confirmed by detecting the following results: (a) awareness of the campaign among drivers and increased perception of the risk induced by aggressive car-truck interactions; (b) reduction in the frequency of aggressive car-truck interactions; and (c) reduction in the number of crashes caused by aggressive car-truck interactions. Detecting the three impacts of the TACT project was the main objective of the evaluation effort and a crucial condition for appropriate interpretation of the results. For example, the lack of improvements in drivers' behaviors is explainable if awareness of the campaign and its goals was lacking among drivers. Obviously, a lack of safety improvement would be expected as well in this situation. On the other hand, the strongest safety impact would be expected if both an increase in risk awareness and desired behavioral improvements are detected. The extent to which the three campaign impacts were present among drivers depended on driver-related and project-related factors. Knowing these factors would help target the right group of drivers and improve the effectiveness of future projects. The data collection period includes prior, during, and after phases in relation to the media campaign and police enforcement

(Figure 2). Ticketed drivers were surveyed during the police enforcement phase. Traffic volume, travel time, and speed data were collected, processed, and analyzed to evaluate the project's effectiveness (i.e., surveillance cameras were utilized to collect video material and the drivers' behaviors were extracted). The details for these elements of the study are presented in the following sections.

Data Collection and Processing

The following actions were performed by the evaluation team to prepare for the data collection: (a) information was obtained from the media campaign about the communication campaign, the campaign messages, and other details needed for developing the drivers' survey tool; (b) a survey was prepared to document the answers given by the drivers interviewed by police officers; and (c) the Purdue Traffic Mobile Laboratory was utilized for the data (video images) collection.

Awareness and Perception

A survey technique was used to measure the awareness of the media campaign and police enforcement among auto and truck drivers. To keep the interview as short as possible, the questionnaire included only the questions necessary for the research objectives and pertained to the drivers, the media campaign, and the communication messages regarding safe driving. All drivers stopped and ticketed on the south section of I-465 were interviewed by the police officers. The survey was conducted during the police enforcement to detect trends in the awareness and attitudes that might be caused by the project. The questions were intended to help collect the following information: type of vehicle, local/in-state/out-of-state driver, awareness of the media campaign, ability to recall some of the campaign messages, awareness of the police enforcement, risk perception of driving in front, behind, or alongside a truck (car), attitude towards ticketing a car (truck) drivers who drive too close in front, behind, or alongside side a truck (car), risk perception of cutting in front of a truck (car), and attitude towards ticketing car (truck) drivers who cut in front of a truck (car).

Driving Behavior

Seven types of aggressive interactions between cars and trucks were considered for this study:

- Following too closely (tailgating): keeping less than 0.5 or 1 second-distance from the preceding vehicle.
- Driving too fast (speeding): driving 10 or 20 mph faster than the 55-mph speed limit.
- Cutting in, causing a following vehicle to slow down: when the "aggressive" vehicle attempts to change its traveling lane abruptly into the adjacent lane even though the gap between the vehicles in that lane is not sufficient (i.e., separation between the vehicles after cutting in is less than 80 feet or 4-passenger car lengths). When the separation between the two vehicles, after cutting in from the adjacent lane, is less than approximately 80 feet, the driving maneuver was considered aggressive.
- Changing multiple lanes: when a vehicle attempts to simultaneously change two or more lanes.

- Crossing a continuous line in the gore area: while merging from the ramp into the main stream, vehicles make a short-cut maneuver to merge into the mainstream traffic by driving over the white lines at the gore area.
- Driving in the blind spots of trucks: when any light vehicle (such as a passenger car, SUV, minivan, or pickup truck) is driving side-by-side or too closely to a trailer truck (not in passing maneuver). In such cases, light vehicles are driving in the blind spots of trailer trucks. While in the blind spots (No Zones), the trailer truck driver cannot clearly detect the presence of other vehicles in the vicinity of the trailer truck. The "No Zones" or blind spots of trailer trucks are presented in Figure 4.
- Changing lanes without using turn signal indicators.

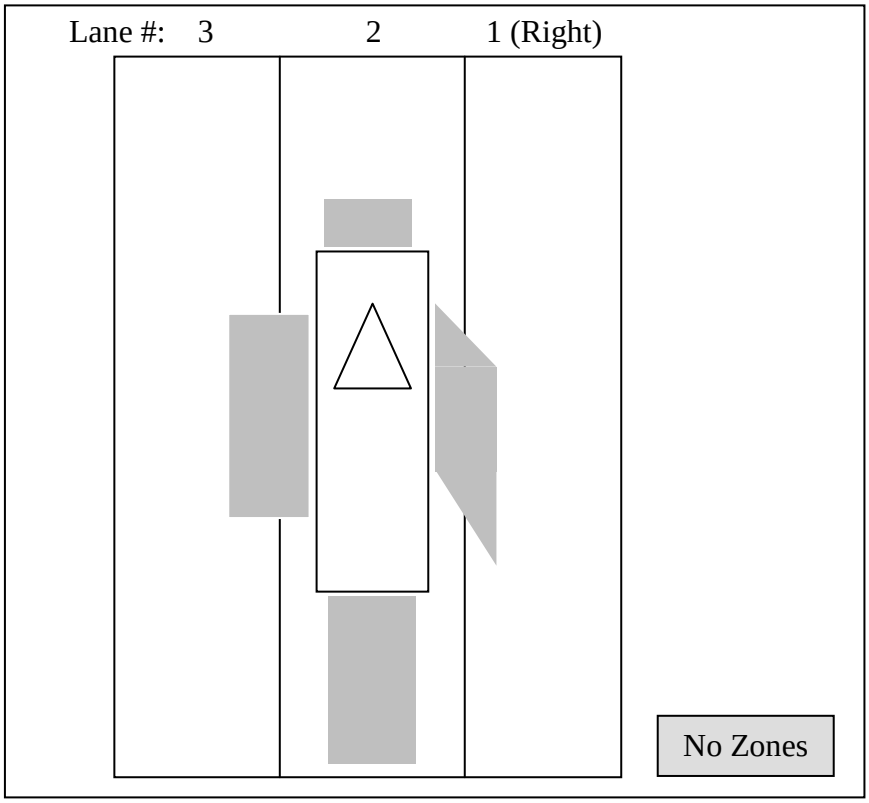

Figure 4. Driving in the blind spots ('No Zones') of trucks

A portable traffic mobile laboratory was utilized for the data collection. The van is equipped with two high quality pan/tilt/zoom color cameras mounted on a 42-foot telescoping mast (Figure 5). These cameras were used to collect high-definition video images for prolonged periods. The images were then processed to extract traffic, aggressive driver behaviors, weather, and pavement information. A total of 180 hours of video material was recorded and processed, producing more than 140,000 vehicles for analysis.

Figure 5. The Mobile Traffic Laboratory

Traffic Safety

Crash data were collected from the Indiana State Police and the Indiana Department of Transportation, and were assigned to the studied road network. Traffic safety improvement is the ultimate goal of the Indiana TACT Project and the single most important criterion of success.

Processing of the Data

The obtained data containing information about the campaign and crash risk awareness, driver behaviors, and traffic safety were stored and pre-processed. The preprocessing phase included the following operations: (a) data coding and reformatting; (b) checking data correctness (internal consistency, large errors, etc.); and (c) data conversion to final samples ready for statistical analysis. Once the data were converted to the final tabular format (statistical samples), the next step was data analysis. The input values reflecting awareness, behavior, and safety were in the form of proportions, rates, or frequencies, depending on the need and meaning of the input. All input values pertaining to the project area and period had assigned locations, dates, and time stamps to allow investigating the impacts across locations and over time.

Aggregation of the input values by site type (enforcement site, no-enforcement site, project site) and by period (before campaign, during campaign, after campaign, before enforcement, during enforcement, and after enforcement) allowed comparisons to detect the differences and to draw conclusions about the project impacts. Suitable tests of the statistical significance of the detected differences were performed to rule out the possibility that these differences were merely the effect of random fluctuations.

Comparison of relevant rates, percentages, and frequencies is appealing by its simplicity and straightforward interpretation of the results but it should be done with adequate control sites (similar to the treated sites and free of the studied impact), careful planning, and good quality of data. This was the approach adopted.

As explained earlier, the lack of a convenient control site compelled us to select the north I-465 section as a control site. This section is located in the media market area where the project communication campaign took place. A before-and-after analysis of the aggressive behavior frequencies was conducted along with estimating the effects of individual sites, volume, and weather to isolate the most important effects of the media campaign and the police enforcement. The media campaign started well before the police enforcement in order to be able to separate these two important impacts.

ANALYSIS OF AGGRESSIVE DRIVING BEHAVIOR

Table 1 summarizes the number of aggressive driving events recorded and then extracted from the video material. The most frequent aggressive behaviors included tailgating and speeding, followed by cutting in and changing lanes without turn signals. These four had a sufficient number of events for conducting statistical analysis. This section presents the analysis results with respect to these four aggressive driving behaviors.

Table 1. Summary of aggressive behavior data

Aggressive Driving Behavior	Counts
Number of Truck-Related Speeding (75mph) Events	715
Number of Non-Truck-Related Speeding (75mph) Events	7,625
Total Number of Speeding (75mph) Events	8,340
Number of Truck-Related Tailgating Events (Car Following Cases)	1,866
Number of Non-Truck-Related Tailgating Events (Car Following Cases)	17,593
Total Number of Tailgating Events (Car Following Cases)	19,459
Number of Truck-Related Cutting-In Events	145
Number of Non-Truck-Related Cutting-In Events	343
Total Number of Cutting-In Events	488
Number of Truck-Related Changing Lane Without Turning Signal Indicators Events	18
Number of Non-Truck-Related Changing Lane Without Turning Signal Indicators Events	222
Total Number of Changing Lane Without Turning Signal Indicators Events	240
Number of Truck-Related Multilane Changing Events	6
Number of Non-Truck-Related Multilane Changing Events	72
Total Number of Multilane Changing Events	78
Total Number of Driving at the Blind Spot of Trucks Events	249

Disaggregate binary probit models were developed to investigate the factors of the frequency of tailgating and speeding. An estimable model of binary outcomes is (Washington et al., 2011):

$$P_n(0) = P(\beta_0 X_{0n} - \beta_1 X_{1n} \geq \varepsilon_{1n} - \varepsilon_{0n}), \quad (1)$$

where $P_n(0)$the probability of outcome 0 occurring for observation n, with ε_{0n} and ε_{1n} being error terms normally distributed with mean = 0, variances σ^2_0 and σ^2_1, respectively, and covariance σ_{01}. Aggregate negative binomial models were also developed to investigate the factors of frequency of cutting in and changing lanes without turn signal indicators. Negative binomial regression

specifies the parameter λ_i (the expected number of aggressive driving behaviors) as a function of explanatory variables by typically using a log-linear function,

$$\lambda_i = EXP(\boldsymbol{\beta}\boldsymbol{X}_i + \varepsilon_i), \quad (2)$$

where $\boldsymbol{X}_i$ is a vector of explanatory variables, $\boldsymbol{\beta}$ is a vector of estimable parameters, and $EXP(\varepsilon_i)$ is a Gamma-distributed error term with mean 1 and variance α^2 (Washington et al., 2011). The negative binomial probability density function has the form:

$$P(n_i) = \left(\frac{1/\alpha}{(1/\alpha)+\lambda_i}\right)^{1/\alpha} \frac{\Gamma[(1/\alpha)+n_i]}{\Gamma(1/\alpha)n_i!}\left(\frac{\lambda_i}{(1/\alpha)+\lambda_i}\right)^{n_i} \quad (3)$$

where $\Gamma(.)$ is a gamma function.

Marginal effects were estimated (see Washington et al., 2011), and Tables 2 through 5 present the major factors of the frequency of aggressive behavior. After accounting for traffic volume, weather, and specifics of road locations where traffic was observed, police enforcement was found to be reducing the frequency of truck speeding (75 mph or faster) by 21% and truck tailgating by 2%, and non-truck speeding by 13% and non-truck tailgating by 8%. It was also found to reduce the frequency of "cutting in" and "changing lanes without turning signal indicators" events by 47% and 68%, respectively.

Table 2. Change in percent of car-following drivers who tailgate

Tailgating (one-second or shorter separation between vehicle fronts)	% Change	
Ramp nearby	13 %	increase
Second lane compared to first lane	3 %	increase
Third lane compared to first lane	19 %	increase
Fourth lane compared to first lane	10 %	reduction
Rain	7 %	reduction
Snow	21 %	reduction
Police enforcement effect on trucks	**2 %**	**reduction**
Police enforcement effect on non-trucks	**8 %**	**reduction**
Media campaign period	**0 %**	

The effect of the media campaign was not as strong as the effect of the police enforcement. It reduced the frequency of speeding by approximately 7% and did not seem to have any obvious impact on the other types of aggressive driving behavior. The frequency of tailgating and changing lanes without using a turn signal seemed to return to the original level, and the speeding increased while cutting in decreased. This "after" period included the holiday season and winter weather conditions so these results could be the effect of other factors not included in the analysis. These results indicate that the TACT enforcement strategy did indeed have an effect on curbing the driving behavior; however, this cannot be said about the media campaign and about the lasting effect of the program after it ended. One possible explanation of these results is a high percent of out-of-area drivers who were not exposed to the media campaign and were responding only to the current enforcement. Repetitive exposure to enforcement that could translate to a longer residual effect after the enforcement ends could not occur where the majority of motorists are "one-time" users.

Table 3. Change in percent of drivers moving at 75 mph or faster

Speeding (75 mph or higher)	% Change	
Ramp nearby	12 %	reduction
Second lane compared to first lane	46 %	increase
Third lane compared to first lane	167 %	increase
Fourth lane compared to first lane	440 %	increase
Initial section of the enforcement zone	53 %	increase
Increase of hourly volume by 1,000 veh/hr	69 %	reduction
Rain	53 %	reduction
Snow	80 %	reduction
Media campaign	7 %	reduction
Police enforcement effect on trucks	21 %	reduction
Police enforcement effect on non-trucks	13 %	reduction
After campaign period	65 %	increase

Table 4. Percent change in the frequency of "cutting in" events

Frequency of truck-related "cutting in" events (per location/direction/hour)	% Change	
High traffic volume (3,300 veh/hr or more)	271 %	increase
Police enforcement	**47 %**	**reduction**
Media campaign	**0 %**	
After media campaign	52 %	reduction

Table 5. Percent change in the frequency of "changing lanes without turn signal" events

Frequency of "changing lanes without using turn signal" events (per location/direction/hour)	% Change	
High traffic volume (3,300 veh/hr or more)	126 %	increase
Police enforcement	**68 %**	**reduction**
Media campaign	**0 %**	

Traffic volume is one of the other factors of aggressive driving behavior that should be mentioned. The results show that a 1,000 vehicles per hour increase in volume reduces the frequency of tailgating and speeding by approximately 22% and 69%, respectively; whereas, hourly volumes of 3,300 and 3,700 vehicles per hour increase the frequency of "cutting in" and "changing lanes without turn signal indicator" events by 271% and 126%, respectively. These results are not surprising. High traffic volume reduces the opportunity to drive fast; hence, high volume is logically associated with lower speeds but it reduces the available gaps between vehicles, which may increase the frequency of "cutting in" and "changing lanes without turning signal indicators" because drivers may change lanes abruptly to maneuver traffic.

The presence of a ramp in the traffic stream was also found to increase the frequency of tailgating by roughly 13%. Drivers change lanes and slow down around ramps, which in turn may cause a pseudo-tailgating effect (i.e., the preceding vehicle brakes abruptly, which forces the next vehicle to follow the preceding vehicle at a much closer distance).
The lane position (first, second, etc.) was found to play a significant role in the frequency of tailgating and speeding. For example, vehicles that moved in the second lane (the first left lane of the right outmost lane) and the third lane (the lane left of the second lane) had approximately 3% and 19% increase in their tailgating frequency, respectively; whereas, the vehicles moving to the left outmost lane (the fourth lane) had about a 10% reduction in their tailgating frequency. This result is expected because it shows that tailgating is less likely in the faster and typically less congested left lane compared to the other slower and more congested lanes. In a similar context, it is more likely for drivers to speed in the left lanes compared to the right lanes. For example, Table 3 shows that there was an approximate 46% increase in the frequency of speeding if the vehicle was moving in the second (as defined above) lane, a 167% increase in the frequency of speeding if the vehicle was moving in the third (as defined above) lane, and a 441% increase in the frequency of speeding if the vehicle was moving in the fourth (left outmost) lane.

Weather was also found to affect in an expected manner the frequency of tailgating and speeding. The results show that rain reduces the frequency of tailgating and speeding by approximately 6% and 53%, respectively; whereas, snow reduces their frequency by approximately 21% and 80%, respectively. Adverse weather conditions, such as rain and snow, keep drivers more alert and force them to maintain greater distances from the preceding vehicles and move at slower (and safer) speeds.

Finally, a number of location-specific variables were found to be related to the frequency of the four aggressive driving behavior types. Although most of these factors may be capturing unobserved characteristics (e.g., driver- or vehicle-specific information), from some of them important inferences may be drawn. For example, Table 3 shows that there is a roughly 53% higher frequency of speeding if the vehicle enters the police enforcement zone compared to those leaving the enforcement zone. This shows that vehicles moving in this zone are less probable to speed, most likely due to the TACT tactics (campaign and enforcement).

FINDINGS FROM THE SURVEY

A total of 1,047 surveys were collected by the police officers during the police enforcement phase of the project. A first finding was that respondents who were aware of the TACT project maintained more space before pulling back when they passed cars and semi trucks on interstates (20% and 33% of those who were aware of TACT leave more than eight car-lengths when they pull back in after passing cars and semi trucks, respectively, as opposed to 3.5% and 10.2%, respectively, for those who are not aware of TACT).

To further assess the effect that TACT may have on aggressive behavior characterized by the distance left by the drivers when they pass other vehicles, statistical models (ordered probit models; see Washington et al., 2011) were developed. Marginal effects were estimated, and Table 6 presents the percent change in the probability of leaving two, four, eight, or more than eight car lengths before pulling back when passing a car or a semi truck, respectively.

Table 6. Percent change in the probability of leaving 2, 4, 8, or more than 8 car lengths after passing a car or a semi truck

When you pass a **car** on an interstate highway, how many car lengths do you leave before pulling back in?	% Change in Probability of leaving: 2 car lengths	4 car lengths	8 car lengths	More than 8 car lengths
TACT Awareness	-26%	10%	10%	6%
Gender: Female	10%	-4%	-4%	-2%
Age: 16-25 years old	12%	-4%	-5%	-3%
Age: 50 years old or more	-10%	4%	4%	2%
Vehicle type: passenger car	13%	-5%	-5%	-3%
Vehicle type: semi truck	-24%	9%	9%	6%
Residence: Indiana	7%	-2.5%	-2.5%	-2%
When you pass a **semi truck** on an interstate highway, how many car lengths do you leave before pulling back in?	% Change in Probability of leaving: 2 car lengths	4 car lengths	8 car lengths	More than 8 car lengths
TACT Awareness	-21%	-6 %	12%	15%
Gender: Female	8%	2%	-4%	-6%
Age: 16-25 years old	6%	2%	-3%	-5%
Age: 50 years old or more	-5%	-2%	3%	4%
Vehicle type: passenger car	7%	2%	-4%	-5%
Vehicle type: semi truck	-14%	-4%	8%	10%

The results show that a number of factors are important, such as gender (females are less likely to leave more space), age (older drivers leave more space compared to younger drivers), vehicle type (semi truck drivers leave more space compared to passenger car drivers), and residence location of driver (drivers who reside in Indiana leave less space, as compared to drivers who live outside Indiana). Most of these findings are intuitive. Note, however, that drivers who reside in Indiana were the vast majority of the respondents (about 80%), whereas those who reside in Indianapolis were only 10% of the total respondents of the survey. This implies that the out-of-state travelers who were passing through the enforcement site may not have been informed of the TACT project. This was also verified by looking at the nearly zero association of the respondents who were aware of the TACT project and were not from Indiana, but were still reported to be keeping longer distances when passing other vehicles. This effect was also captured by the "Indiana" variable.

Interestingly, drivers who are aware of TACT are roughly 10% more likely to leave four or eight car lengths, and 6% more likely to leave more than eight car lengths when they pass a car; whereas, they are 12% more likely to leave eight car lengths, and 15% more likely to leave more than eight car lengths when they pass a semi truck. This is an important finding that indicates that TACT's media campaign and police enforcement tactics indeed affected driving behavior by making it less aggressive.

SUMMARY AND CONCLUSIONS

This paper presents the results of the statistical analysis of the TACT project in order to investigate its effectiveness. Traffic data and information regarding aggressive driving behavior for two sections of I-465 in Indianapolis were collected. The police enforcement site was located on the South section, and the North section was the control site. There were three phases: the pre-TACT phase, the phase when a media campaign was conducted and the police enforcement took place, and the after the campaign and enforcement phase. For the data collection, the Mobile Traffic Laboratory of Purdue University's Center for Road Safety was utilized. The data were extracted from video images and included traffic volumes, speeds, time headways, and several types of aggressive driving behavior, such as tailgating, speeding, cutting in front of other vehicles, changing lanes without the use of turning signal indicators, driving at the blind spots of trucks, changing multiple lanes, and driving over continues lines (e.g., over the gore markings). For statistical modeling, sufficient data were available for the first, second, third and fourth aggressive behaviors.

Furthermore, a total of 1,047 surveys were collected by the police officers during the police enforcement phase of the project. The survey data were analyzed to assess the effect that TACT may have had on aggressive behavior characterized by noting the distance left by the drivers when they passed other vehicles (the probability of leaving two, four, eight or more than eight car lengths before pulling into the next lane when passing a car or a semi truck).

The police enforcement was found to reduce the frequency of truck speeding and tailgating. It was also found to reduce the frequency of "cutting in" and "changing lanes without turning signal indicators" events. The media campaign was also found to slightly reduce the frequency of speeding. The "after" period, however, did not experience any clear and lasting effect of the campaign. These results clearly show that the TACT program had an effect on driving behavior, during the program period, by making driving less aggressive. In addition, it was found that vehicles moving in the police enforcement zone were less likely to speed. Also, vehicles exiting the police enforcement zone had lower frequencies of "cutting in" and "changing lane without turning signal indicator" events, as opposed to the vehicles entering the zone. These findings show the positive effect of police enforcement on reducing aggressive driving behavior.

The analysis of the survey data showed that drivers aware of TACT were more likely to leave a longer distance between their vehicles and the vehicles passed, which clearly indicates that the TACT program significantly affected the drivers' behavior by making it less aggressive. However, these results may suffer from selectivity bias as the respondents were only drivers who violated and were cited for some driving regulation.

The TACT program, particularly its police enforcement components, was successful in curbing aggressive interactions between cars and trucks during the program period. On the other hand, the effect of the media campaign was not as obvious as the effect of police enforcement during the TACT program period. Also, the residual effect of the program was difficult to detect. The most appealing explanation of the weak effect of the campaign and the residual effect of the program was the low percent of motorists using I-465 who lived in the program target area and could be exposed to the media campaign and the repetitive police enforcement.

ACKNOWLEDGEMENTS

The authors would like to thank Mouyid Bin Islam for his help with the data processing. We also thank Jose Thomaz for his help in the management of the collected data. Finally, we are grateful to Anoumou (Tino) Atisso, Brian Pigman, Chi Ni, Christina Lou Millhouse, Dayna J. Rauwerdink, Julia Giselle Hankins, and Mazhar Iqbal Arshad, who critically helped with the data extraction from the video images. Finally, special thanks should go to R.H. Marlin, Inc. Crane Rentals, for allowing us to use their property to collect video images from the adjacent roadways. The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policies of the FHWA and the Indiana DOT, nor do the contents constitute a standard, specification, or regulation.

REFERENCES

Chaudhary, N.K., Solomon, M.G., and Cosgrove, L.A. (2004). The Relationship between Perceived Risk of being Ticketed and Self-Reported Seat Belt use. *Journal of Safety Research*, 35(40), 383-390.

Chaudhary, N.K., Alonge, M., and Preusser, D.F. (2005). Evaluation of the Reading, PA Nighttime Safety Belt Enforcement Campaign: September 2004. *Journal of Safety Research*, 36(4), 321-326.

Chaudhary, N.K., and Preusser, D.F. (2006). Connecticut Nighttime Safety Belt use. *Journal of Safety Research*, 37(4), 353-358.

Clayton, M.C., and Helms, B.P. (2009). Increasing Seatbelt use on a College Campus: An Evaluation of Two Prompting Procedures. *Journal of Applied Behavior Analysis*, 42(1), 161-164.

Geary, L.L., Ledingham, K.A., and Maloney, S.C. (2005). Connecticut Statewide sTEP Wave Evaluation. *Journal of Safety Research*, 36(4), 333-340.

Milano, M., McInturff, B., and Nichols, J.L. (2004). The Effect of Earned and Paid Media Strategies in High Visibility Enforcement Campaigns. *Journal of Safety Research*, 35(2), 203-214.

Lee, C., Saxena, M., Lin, P., Gonzalez-Velez, E., and Rouse, J.W. (2010). Aggressive Driving and Safety Campaigns: Lessons Learned from Better Driver Campaign in Florida. *Transportation Research Record*, 2182, 79-87.

NCHRP (2003). Report 500. Volume 1: A Guide for Addressing Aggressive-Driving Collisions.

NCHRP (2004). Report 500. Volume 13: A Guide for Reducing Collisions Involving Heavy Trucks.

Nerup, P., Salzberg, P., VanDyk, J., Porter, L., Blomberg, R., Thomas, F.D., and Cosgrove, L. (2006). Ticketing Aggressive Cars and Trucks in Washington State. High visibility Enforcement Applied to Share the Road Safely. Technical Report for the National Highway Traffic Safety Administration, DTNH22-05-D-3505, 25099, Washington, DC.

National Highway Traffic Safety Administration - NHTSA (2007). Guidelines for Developing a High-Visibility Enforcement Campaign to Reduce Unsafe Driving Behaviors among Drivers of Passenger and Commercial Motor Vehicles. Technical Guidelines for the National Highway Traffic Safety Administration, DOT HS 810 851, Washington, DC.

Reinfurt, D.W. (2004). Documenting the Sustainability of a Mature Click it Or Ticket Program: The North Carolina Experience. *Journal of Safety Research*, 35(2), 181-188.

Shinar, D., and Compton, R. (2004). Aggressive driving: an observational study of driver, vehicle, and situational variables. *Accident Analysis and Prevention*, 36, 429-437.

Solomon, M.G., Ulmer, R.G., and Preusser, D.F. (2002). Evaluation of click it or ticket model programs. Technical Report for the National Highway Traffic Safety Administration, DOT HS 809 498, Washington, DC.

Solomon, M.G., Compton, R.P., and Preusser, D.F. (2004). Taking the Click it Or Ticket Model Nationwide. *Journal of Safety Research*, 35(2), 197-201.

Sprinthall, R.C. (2003). *Basic Statistical Analysis.* Seventh Edition, Pearson Education Group.

Thomas, F.D., Blomberg, R.D., Peck, R.C., Cosgrove, L.A., and Salzberg, P.M. (2008). Evaluation of a High Visibility Enforcement Project Focused on Passenger Vehicles Interacting with Commercial Vehicles. *Journal of Safety Research*, 39(5), 459-468.

Thomas, A.M., Cook, L.J., and Olson, L.M. (2011). Evaluation of the Click it Or Ticket Intervention in Utah. *Accident Analysis & Prevention*, 43(1), 272-275.

Vivoda, J.M., Eby, D.W., Louis, R.M.St., and Kostyniuk, L.P. (2007). A Direct Observation Study of Nighttime Safety Belt use in Indiana. *Journal of Safety Research*, 38(4), 423-429.

Washington, S.P., Karlaftis, M.G., Mannering, F.L. (2011). *Statistical and econometric methods for transportation data analysis*. Chapman and Hall/CRC, Boca Raton, FL, Second edition.

Williams, A.F., and Wells, J.K. (2004). The Role of Enforcement Programs in Increasing Seat Belt use. *Journal of Safety Research*, 35(2), 175-180.