Paper No. 10-3360

Dilemma Zone Driver Behavior as a Function of Vehicle Type

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Word Count = 7,200 (5,200 words + 8 tables/figures * 250)
Revised submission for the 2010 TRB Annual Meeting CD-ROM, November 15, 2009

ABSTRACT

A comprehensive investigation of the influence of vehicle type on various aspects of dilemma zone driver behavior, including brake response time, deceleration rate, and red-light-running occurrence, was performed. A field observational study was performed at six urban or suburban signalized intersections in Wisconsin. Driver behavior data were obtained for 1,275 vehicles that were between 2.0 and 6.5 seconds upstream of the intersection at the onset of the yellow interval. Each vehicular observation was placed into one of five vehicle type categories, which included: motorcycle, car, light truck (pickups, SUVs, vans, minivans), single unit truck (all single unit heavy trucks, delivery trucks, RVs, buses), and tractor trailer (all multi-unit heavy trucks). Appropriate statistical analyses were performed, including both ANOVA and logistic regression. Vehicle type was found to have a statistically significant effect on both deceleration rate and red light running occurrence but did not have an effect on brake response time. Deceleration rates were highest for cars and light trucks, while single unit trucks showed significantly lower deceleration rates. Deceleration rates for tractor trailers were similar to those of single unit trucks. Tractor trailers were 3.6 times more likely to commit red light running compared to passenger vehicles. Single unit trucks were 2.5 times more likely to commit red light running compared to passenger vehicles. The rates of red light running for cars and light trucks were not substantially difference from each other. The effects of other factors, including time of day and whether the subject vehicle was part of a platoon of vehicles, were also investigated. Time of day (i.e. peak versus off-peak) had a statistically significant effect on both deceleration rate and occurrence of red light running. Deceleration rates were significantly higher during off-peak times. Red light running was 1.3 times more likely to occur during peak-periods compared to off-peak periods. Vehicular platooning was found to have no significant effect on deceleration rates, brake response times, or red light running occurrence.

INTRODUCTION

When a traffic signal changes from a green indication to a yellow indication, approaching drivers often face the dilemma of whether to stop or proceed through the intersection. The term "dilemma zone" or, more appropriately, "indecision zone" is often used to describe this occurrence (*1*). A detailed literature review by Bonneson et al found that the dilemma zone typically exists between 2.5 and 5.5 seconds upstream of the intersection at the start of the yellow interval (*2*), which represents the threshold between which 10 percent and 90 percent of drivers stop in response to the yellow (*3*). Throughout this paper, the term dilemma zone will be used to represent the indecision zone situation as it is the more familiar term.

Previous research over the last several decades has investigated various characteristics of driver behavior in the dilemma zone (*1,3,4,5,6,7,8,9,10,11,12,13)*, including brake response times, deceleration rates, the probability of stopping versus going-through, and red light running. However, the published literature shows relatively little investigation into to the differences in dilemma zone driver behavior as a function of the type of vehicle. The only relevant analyses that were found in the literature were limited to comparison of passenger vehicles versus heavy trucks. Zegeer and Deen found that heavy trucks committed red light running events at more than twice the rate of passenger vehicles (*3*). A similar result was reported by Bonneson et al who found heavy trucks to be more than twice as likely to commit red light running compared to passenger vehicles (*13*). Schultz performed an extensive literature review on non-emergency deceleration rates for passenger vehicles versus heavy trucks (*14*). Non-emergency deceleration rates for passenger vehicles fell within a range of 7 feet per second squared and 12 feet per second squared. Truck deceleration rates were found to be slightly lower than passenger cars, particularly for trucks not equipped with antilock brakes, which showed deceleration rates for non-emergency stopping between 5 feet per second squared and 9 feet per second squared. Trucks with antilock brakes decelerated between 10 and 11.6 feet per second squared – similar to the middle range of values observed for passenger vehicles.

Previous work by Gates et al provided a comprehensive investigation of dilemma zone driver behavior, including differences between passenger vehicles and heavy vehicles (i.e., buses, recreational vehicles, single unit trucks, and semi-trailers) (*12*). Heavy vehicles were found to be less likely to stop when presented with a yellow indication and were more likely to commit a red light running event. Heavy vehicles in the dilemma zone were also found to use a lower deceleration rate when stopping and a shorter brake response time. While the Gates et al work provided a comprehensive analysis of dilemma zone driver behavior, due to a limited sample size for heavy vehicles, it did not provide a complete analysis of the effects of vehicle type, beyond that of passenger vehicles versus heavy vehicles. Recent expansion of the data set used by Gates et al allowed for a comprehensive investigation of vehicle type to be performed, the results of which are described herein.

GOAL AND OBJECTIVES

The primary goal of this study was to provide a comprehensive investigation of the influence of vehicle type on various aspects of dilemma zone driver behavior. The specific behavioral characteristics for dilemma zone drivers that were of interest included:

- Brake response time;
- Deceleration rate; and
- Occurrence of red light running events (RLR).

Therefore, the study objectives were to determine the differences in brake response time and deceleration rate, and to predict the likelihood of a red-light-running event as a function of vehicle type. The effects of other factors, including time of day and whether the subject vehicle was part of a platoon of vehicles, were also investigated.

METHODOLOGY

Field Study

A field study was performed at six signalized intersection approaches in greater Madison, Wisconsin. The characteristics of each study site are included in Table 1. Data were collected using a video camera mounted on a 20 ft tall steel pole that was temporarily attached to a roadside sign post that was between 400 and 800 feet upstream of the intersection. The camera was aimed towards the intersection so that the rear of vehicles could be viewed while approaching the intersection on the subject approach. During installation it was also ensured that the camera obtained a clear view of the entire intersection including the traffic signal indication. Data were only collected during dry conditions and daylight hours to prevent damage or vandalism to the video camera. Full details of the field study procedures are described in a recent publication by Gates et al (*12*).

TABLE 1 Site Characteristics

Characteristics	Johnson at Park	Verona at Raymond	Verona at McKee	John Nolen at Lakeside	Fish Hatchery at Caddis	East Washington at Baldwin
Subject Approach	Eastbound	North-bound	North-bound	South-bound	South-bound	Westbound
Speed Limit (mph)	25	40	50	45	40	35
Approach Grade (%)	0.0	-0.3	1.1	-0.7	1.9	-0.7
Cycle Length (s)	110 s (peak) 80 s (off-peak)	Variable	Variable	Variable	Variable	80
Yellow Duration (s)	3.5	4.5	5.0	4.0	4.0	3.5
All-Red Time (s)	3.0	1.75	2.0	1.5	1.0	1.0
Intersection Width (ft)	90	90	125	80	90	70
Signal Actuation	Pretimed	Fully Actuated	Fully Actuated	Fully Actuated	Fully Actuated	Pretimed
Signal Coordination[a]	C	U	U	U	U	C
Area Type	Urban	Suburban	Suburban	Suburban	Suburban	Urban

[a] C = Coordinated; U = Uncoordinated

Approximately 43 hours of video were obtained during data collection activities. The researchers reviewed the video data and recorded several attributes related to the behavior of all dilemma zone vehicles that were either the last vehicle to go-through or the first vehicle to stop in each lane for each signal cycle. A vehicle was considered in the dilemma zone if the front of the vehicle was between 2.0 and 6.5 seconds upstream of the intersection at the start of the yellow, determined based on the subject vehicle's approach speed and distance from the intersection. This time range represented a dilemma zone that was slightly larger than that cited in a detailed literature review by Bonneson et al (*2*), which was deemed necessary to capture dilemma zone behavior for all vehicle types. Red light running vehicles that were greater than 6.5 seconds upstream at the start of the yellow were also included in the sample. It should be noted that only one red light running event that was greater than 6.5 seconds away from the stop bar was observed. The following information was obtained from the video for each subject vehicle included in the sample:

- Time to traverse the initial 50 feet (for speed computation);
- Position and time at the onset of yellow;
- Position and time after the onset of yellow when the brake light became illuminated (stopping vehicles only);
- Time required for the vehicle to stop after the brake lights became illuminated;
- Time elapsed from the onset of yellow until entry to the intersection (go-through vehicles only);
- Action of the vehicle:
  - Stopped;
  - Went through, but entered the intersection prior to the end of the yellow;
  - Went through, but entered the intersection after the end of the yellow (i.e., red light running);
- Time of day:
  - Peak (7 – 9 AM or 4 – 6 PM);
  - Off-peak (all other observation times);
- Platooning:
  - Platooned (headway and/or tailway less than or equal to 2 seconds);
  - Not platooned (both headway and tailway greater than 2 seconds);
- Vehicle type:
  - Motorcycle;
  - Passenger car;
  - Sport utility vehicle [SUV];
  - Pick up;
  - Minivan;
  - Van;
  - Bus;
  - Recreational vehicle [RV];
  - Single unit truck;
  - Tractor trailer.

Vehicular observations were excluded from the analysis for any of the following reasons:

- Turned right or left at the intersection;
- Braked prior to the onset of yellow; or
- Presence of a queue on the subject approach.

For purposes of this study, red light running events were defined as cases where the front of the vehicle did not reach the stop bar by the onset of the red indication.

Data Reduction and Coding

The raw time and positioning information obtained for each subject vehicle was used to compute approach speeds, estimated travel time to the stop bar at the onset of yellow, brake response times, and deceleration rates for each vehicle. Approach speeds (ft/s) were calculated using the vehicle's time to traverse the initial 50 feet on the intersection approach. The estimated travel time to the stop bar at the onset of yellow was calculated by dividing the subject vehicle's distance from the stop bar at the onset of yellow by its approach speed. Brake response times were computed as the difference between the time at start of yellow and the time when the brake lights became illuminated. The occurrence of driver "coasting" (i.e., removing foot from accelerator and not immediately applying the brake) could not be quantified based on the data collection methods. The average deceleration rate was computed for each vehicle based on the approach speed and braking time. Braking time was computed as the difference between the time that the brake lights became illuminated and the time that vehicle had stopped. The following formula was used to compute the average deceleration rate:

$$decel\ rate\ (ft/s^2) = \frac{approach\ speed}{braking\ time} \quad (1)$$

Vehicle type was initially classified into several specific categories for each type of vehicle. However, small sample sizes for several of the heavy-vehicle categories coupled with the impracticality of discerning between certain types of vehicles, such as some SUVs, minivans, and station wagons led the researchers to consolidate the vehicle type variable into five categories for analysis, which included:

- Motorcycle;
- Car;
- Light Truck (pickups, SUVs, vans, minivans);
- Single Unit Truck (all single unit heavy trucks, delivery trucks, RVs, buses); and
- Tractor Trailer (all multi-unit heavy trucks).

Data Classifications and Distributions

The data set included records for 1,275 dilemma zone vehicles. A crosstabulation of the vehicular observations separated by action and vehicle type is shown in Table 2.

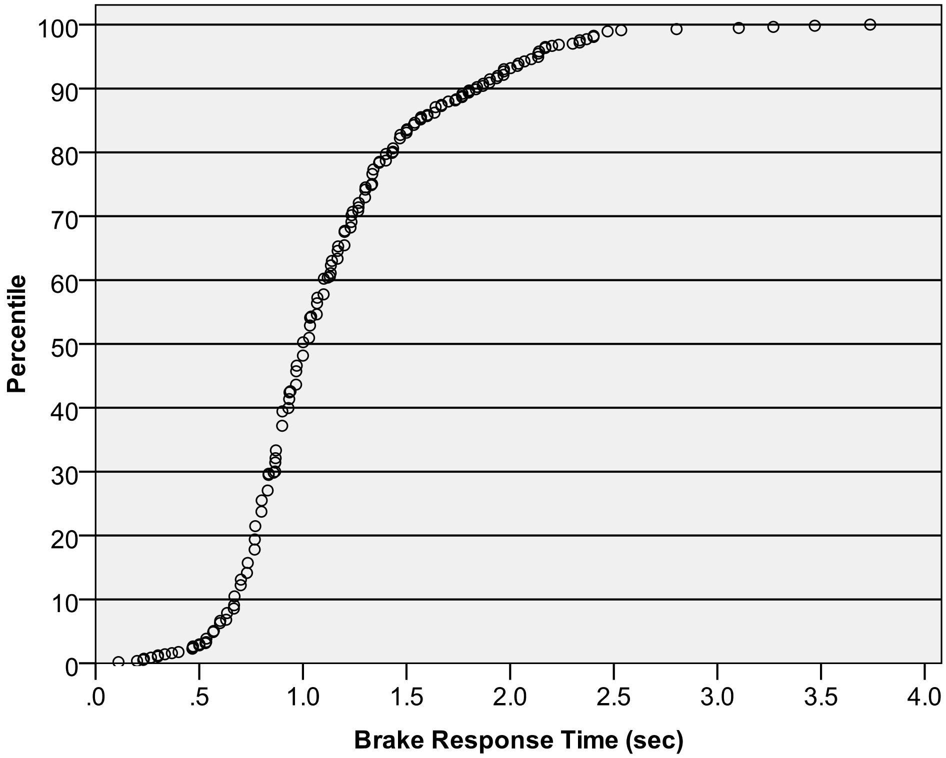
TABLE 2 Vehicular Action by Vehicle Type

	Action			Total	
Vehicle Type	Stopped	Went Thru - Entered Prior to Red	Went Thru - Entered After Red (RLR)	Count	Percent
Car	332	298	44	674	52.9%
Light Truck	236	234	21	491	38.5%
Single Unit Truck	25	30	9	64	5.0%
Tractor Trailer	8	24	8	40	3.1%
Motorcycle	1	5	0	6	0.5%
Total Count	602	591	82	1,275	
Total Percent	47.2%	46.4%	6.4%		100.0%

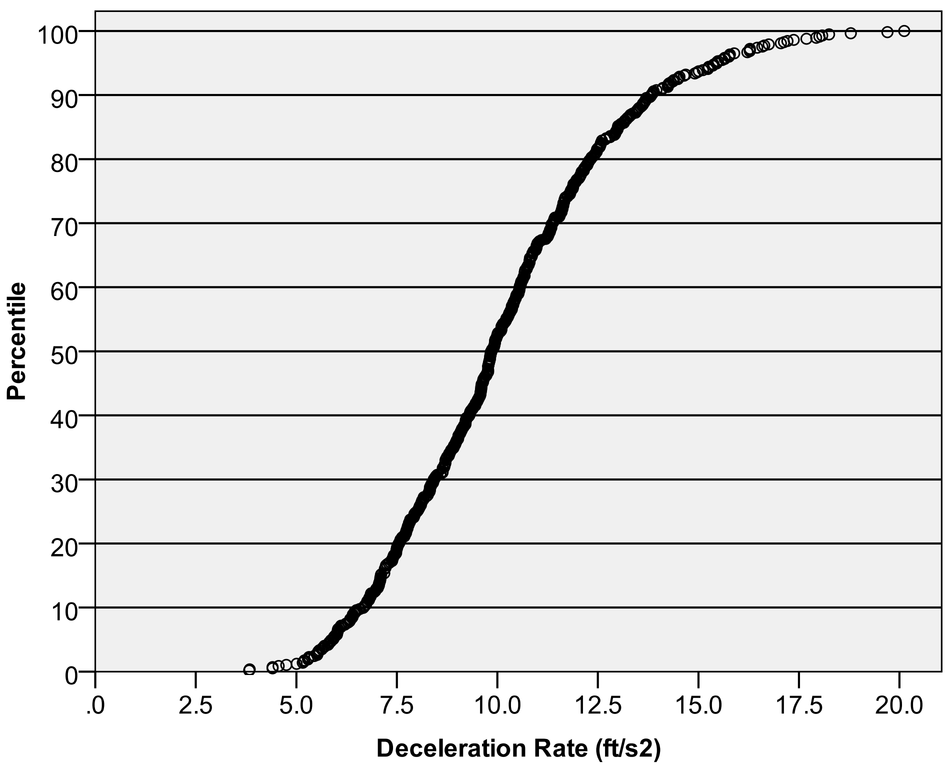
Table 2 shows that 52.9 percent of the observed dilemma zone vehicles were passenger cars, while 38.5 percent of the observations were categorized as light trucks. Single unit trucks and tractor trailers made up 5.0 percent and 3.1 percent of the observations, respectively, while motorcycles comprised only 0.5 percent of the observations. For comparison purposes, recent data for vehicle miles traveled (vmt) on urban non-Interstates was obtained from the Federal Highway Administration (FHWA) website. The FHWA data shows that cars accounted for 57.8 percent of the vmt, light trucks: 37.3 percent, single unit trucks/buses: 2.5 percent, tractor trailers: 2.0 percent, and motorcycles: 0.4 percent (*15*). Thus, compared to the FHWA proportions, cars were slightly underrepresented in the data set, while heavy vehicles were slightly overrepresented. Stopping vehicles and vehicles entering the intersection prior to the start of red accounted for 47.2 and 46.4 percent of the observations, respectively, while red light running vehicles accounted for the remaining 6.4 percent of the observations. Red light running occurred at a rate of approximately 1.9 events per hour, which was lower than the 4.9 events per hour observed by Bonneson et al at 10 Texas intersections (*13*).

For 29 of the 602 first-to-stop vehicles, brake response times and deceleration rates could not be discerned from the video tapes due to obstruction by other vehicles, reflections, or other visibility issues. Furthermore, because only one stopping motorcycle was observed, motorcycle was removed as a vehicle type category in both the brake response or deceleration rate analysis. Thus, deceleration rates and brake response times for 572 first-to-stop vehicles were included in the analysis. Figure 1 displays the cumulative distributions of a) brake response times and b) deceleration rates for the aggregated data.

The brake response times ranged from 0.11 to 3.74 seconds, with a mean and standard deviation of 1.13 and 0.48 seconds, respectively. The 15^{th}, 50^{th}, and 85^{th} percentile brake response times were 0.73, 1.00, and 1.57 seconds, respectively. Deceleration rates ranged from 3.83 to 20.12 seconds, respectively, with a mean and standard deviation of 10.13 and 2.86 seconds, respectively. The 15^{th}, 50^{th}, and 85^{th} percentile deceleration rates were 7.10, 9.87, and 13.01 seconds, respectively. The mean values and cumulative distributions for the aggregated brake response time and deceleration rate data were similar to those reported in previous research (*5,6,7*). Furthermore, the median brake response time (1.00 s) and deceleration rate (9.87 ft/s^2) were in agreement with the respective values recommended by ITE for timing of the yellow interval based on elimination of the dilemma zone (*16*).



a.) Brake response time



b.) Deceleration rate

FIGURE 1 Cumulative distributions for stopping characteristics (aggregated data)

Analytical Procedures

Three primary analyses were performed using the appropriate statistical procedures. The dependent variables for these analyses included the following (statistical procedure shown in parenthesis):

- Brake response time for first-to-stop vehicles (univariate analysis of variance with covariates [ANOVA]);
- Deceleration rate for first-to-stop vehicles (ANOVA); and
- Likelihood of a red light running event (logistic regression).

Brake Response Time and Deceleration Rate

For the analyses of brake response times and deceleration rates, the independent variables included:

- Continuous variables (Covariates):
    - Approach speed (mph);
    - Estimated travel time to the stop bar at the start of yellow (s);
    - Brake response times (s) [deceleration rate analysis only];
    - Deceleration rates (ft/s^2) [brake response time analysis only];
- Categorical variables:
    - Vehicle type (motorcycle, car, light truck, single unit truck, tractor trailer);
    - Time of day (peak, off peak);
    - Platoon (platoon, non-platoon).

The ANOVA analyses were performed in SPSS version 17 using the General Linear Model command (*17*). Full-factorial analyses were performed, which included the main-factor effects, in addition to two-way and three-way interactions of the main effects.

Red Light Running Likelihood

Stepwise binary logistic regression was used to determine the likelihood of red light running events. Logistic regression is a technique used to predict the probability of an outcome based on values of a set of predictor variables (continuous or categorical) and is similar to linear regression except that the response variable is categorical rather than numeric. For the analysis of red light running events the independent variables entered into stepwise model included:

- Continuous variables:
    - Approach speed (mph);
    - Estimated travel time to the stop bar at the start of yellow (s);
- Categorical variables:
    - Vehicle type (motorcycle, car, light truck, single unit truck, tractor trailer);
    - Time of day (peak, off peak);
    - Platoon (platoon, non-platoon).

The logistic regression analysis was performed in SPSS version 17 using the Binary Logistic Regression command (*17*). The confidence level for a predictor to be removed from the backward stepwise model was 0.10 (0.05 for re-entry into the model).

RESULTS

Brake Response Times

The brake response time data were analyzed using the analysis of variance statistical technique to determine the effect of the independent variables and interactions of the independent variables on brake response times. Although they were included in the ANOVA model, two-way and three-way interactions were not found to be statistically significant, and thus have been excluded from further discussion. The summary results of the statistical analysis along with the relevant descriptive statistics are shown in Table 3.

TABLE 3 Brake Response Time Descriptive Statistics and Results of Statistical Analysis

					Percentiles (s)			ANOVA	
Factor	**Level**	**Count**	**Mean (s)**	**St. Dev. (s)**	**15th**	**50th**	**85th**	**F-statistic**	**p-value**
Vehicle Type	Car	315	1.17	0.50	0.77	1.03	1.64	1.729	0.160
	Light Truck	226	1.08	0.46	0.70	0.97	1.47		
	Single Unit Truck	23	1.17	0.50	0.59	1.10	1.65		
	Tractor Trailer	8	1.18	0.61	0.57	1.02	2.13		
Time of Day	Peak	228	1.17	0.51	0.77	1.07	1.61	1.697	0.193
	Off-Peak	344	1.11	0.47	0.72	1.00	1.54		
Platoon	Platooned	185	1.14	0.47	0.77	1.03	1.60	0.918	0.338
	Not Platooned	387	1.13	0.49	0.73	1.00	1.57		
Speed		Not Applicable						412.4	0.000*
Travel Time to Stop Bar		Not Applicable						528.6	0.000*
Deceleration Rate		Not Applicable						424.6	0.000*
Full Model**	**All Data**	**572**	**1.13**	**0.48**	**0.73**	**1.00**	**1.57**	**41.527**	**0.000***

* Indicates that the factor was statistically significant at a 95 percent confidence level.
** R^2 = 0.528. Two-way and three-way factor interactions were included in the analysis, but were excluded from the table, as they were not statistically significant.

The full factorial ANOVA model including all interactions (not shown in Table 3) was statistically significant (at 95-percent confidence) and showed an adequate R^2 value (0.528), indicating that the variability in brake response time is partially explained by the factors included the model. Three of the six main independent variables entered into the stepwise model were found to significantly affect brake response, although none of the categorical variables, including vehicle type, were found to have a significant effect. Each of the covariates, approach speed, travel time to the stop bar, and deceleration rate, were found to have similar effects on deceleration rate in terms of magnitude, as indicated by the F-statistic. Further investigation of the effects of the covariates indicated that brake response time decreased as approach speed increased (i.e., faster drivers reacted more quickly), increased as travel time from the stop bar increased (i.e., drivers reacted more slowly when farther from the intersection), and increased as the deceleration rate increased (i.e., drivers reacted more slowly if a greater deceleration rate was subsequently used).

Deceleration Rates

The deceleration rate data were also analyzed using the analysis of variance statistical technique to determine the effect of the independent variables and interactions of the independent variables on deceleration rates. Although they were included in the ANOVA model, two-way and three-way interactions were not found to be statistically significant, and thus have been excluded from further discussion. The summary results of the statistical analysis along with the relevant descriptive statistics are shown in Table 4.

TABLE 4 Deceleration Rate Descriptive Statistics and Results of Statistical Analysis

Factor	Level	Count	Mean (ft/s^2)	St. Dev. (ft/s^2)	Percentiles (ft/s^2) 15th	50th	85th	ANOVA F-statistic	p-value
Vehicle Type	Car	315	10.09	2.95	7.00	9.78	13.12	3.163	0.024*
	Light Truck	226	10.42	2.72	7.46	10.33	13.29		
	Single Unit Truck	23	8.18	2.12	5.91	7.73	10.95		
	Tractor Trailer	8	8.59	1.95	6.37	8.54	11.30		
Time of Day	Peak	228	9.87	3.03	6.46	9.65	13.20	5.104	0.024*
	Off-Peak	344	10.30	2.72	7.49	10.01	12.96		
Platoon	Platooned	185	9.86	2.86	6.86	9.68	12.58	2.246	0.135
	Not Platooned	387	10.25	2.85	7.23	10.00	13.31		
Speed			Not Applicable					1207.9	0.000*
Travel Time to Stop Bar			Not Applicable					1419.5	0.000*
Brake Response Time			Not Applicable					424.6	0.000*
Full Model**	**All Data**	**572**	**10.13**	**2.86**	**7.10**	**9.87**	**13.01**	**162.8**	**0.000***

* Indicates that the factor was statistically significant at a 95 percent confidence level.
** R^2 = 0.815. Two-way and three-way factor interactions were included in the analysis, but were excluded from the table, as they were not statistically significant.

The full factorial ANOVA model including all interactions (not shown in Table 4) was statistically significant (at 95-percent confidence) and showed a relatively high R^2 value (0.815), indicating that most of the variability in deceleration rate is explained by the factors included the model. Five of the six main independent variables entered into the stepwise model were found to significantly affect deceleration rate. Whether or not a vehicle was platooned was the only factor that was not statistically significant. Of the statistically significant variables, approach speed and travel time to the stop bar were found to have the strongest effect on deceleration rate, as indicated by the F-statistic. Brake response time was also found to have a significant effect on deceleration rate, although this effect was not as strong as speed and travel time. Further investigation of the effects of the covariates indicated that deceleration rate increased as approach speed increased (i.e., faster drivers used greater deceleration), decreased as travel time from the stop bar increased (i.e., drivers used lower deceleration when farther from the intersection), and increased as the brake response time increased (i.e., slower-reacting drivers subsequently used greater deceleration rates). The correlations of dilemma zone deceleration rates with travel time, approach speed, and brake response time were similar to those found by Chang et al (*5*).

Effect of Vehicle Type

Vehicle type was found to have a statistically significant effect on deceleration rate, although the magnitude of the effect was much smaller than those observed for speed, travel time, and brake response time. The cumulative distribution of deceleration rates by vehicle type is shown in

Figure 2. The mean deceleration rates for each vehicle type along with the 95 percent confidence interval for the means are shown in Figure 3.

Mean deceleration rates were highest for the car and light truck categories, although light truck deceleration rates were slightly, but not statistically significantly, higher than those for cars. The mean deceleration rate for single unit trucks was significantly lower than that for both cars and light trucks. The mean deceleration rate for tractor trailers was similar to that of single unit trucks and considerably lower than that for cars and light trucks, but was not statistically different from any of the other vehicle types, due in large part to the small sample size.

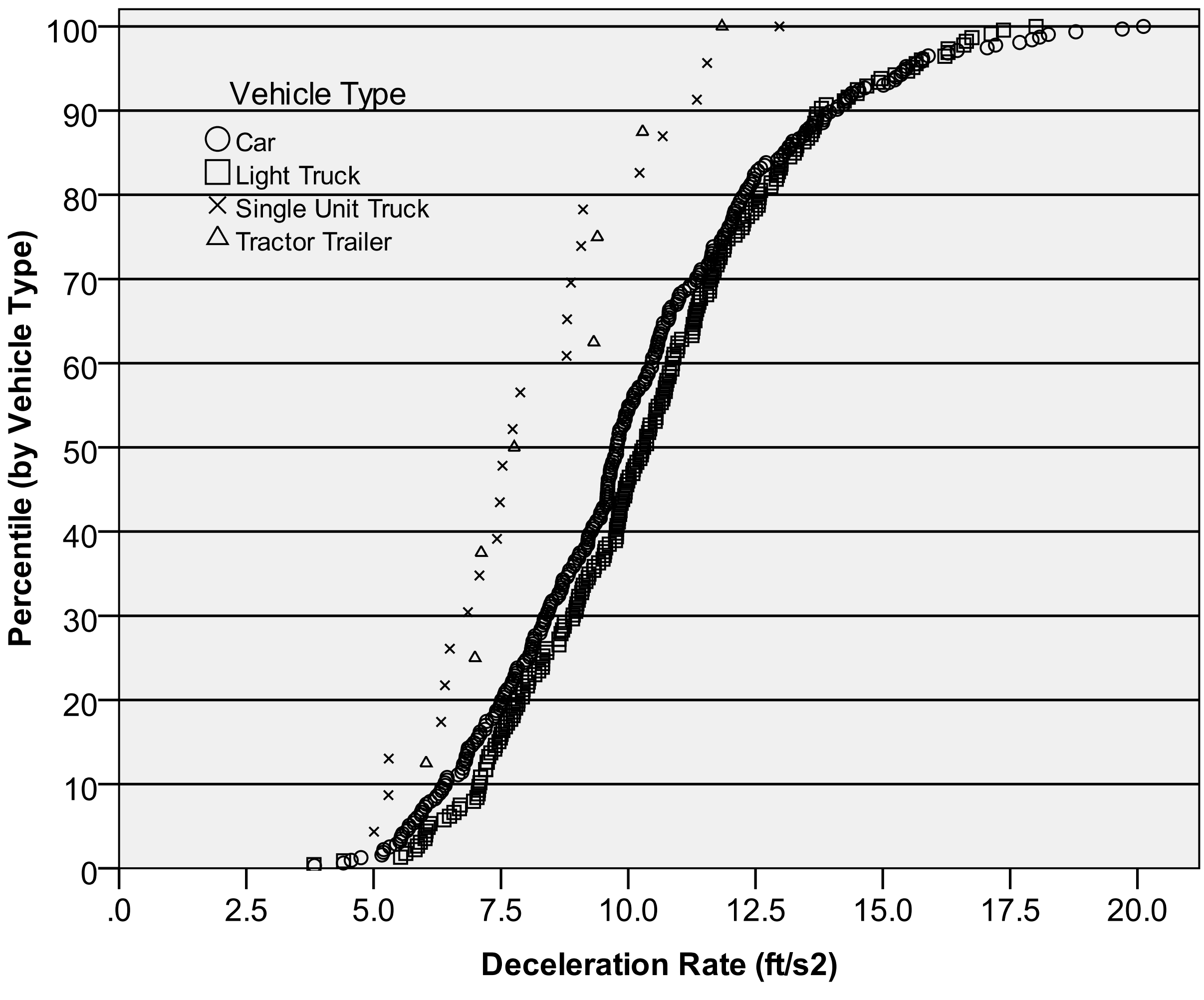


FIGURE 2 Cumulative distribution for deceleration rate by vehicle type.

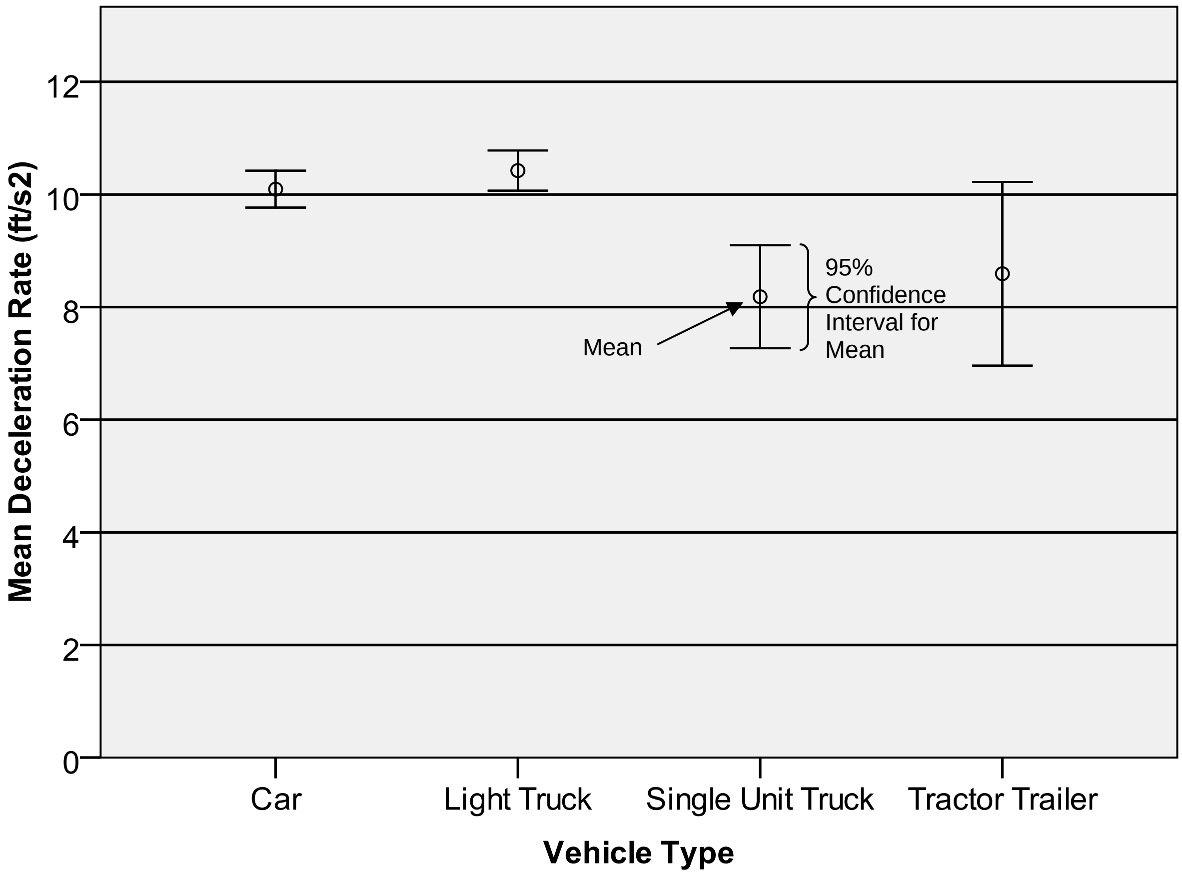


FIGURE 3 Mean and 95 percent confidence interval for deceleration rate by vehicle type.

Effect of Time of Day

Time of day was found to have a statistically significant effect on deceleration rate, although the magnitude of the effect was much smaller than those observed for speed, travel time, and brake response time. The mean deceleration rates for peak versus off-peak times along with the 95 percent confidence interval for the means are shown in Figure 4.

Mean deceleration rates were significantly higher during off-peak times. This was likely a result of dilemma zone drivers being less inclined to stop during peak times, particularly if a relatively high deceleration rate was necessary to stop.

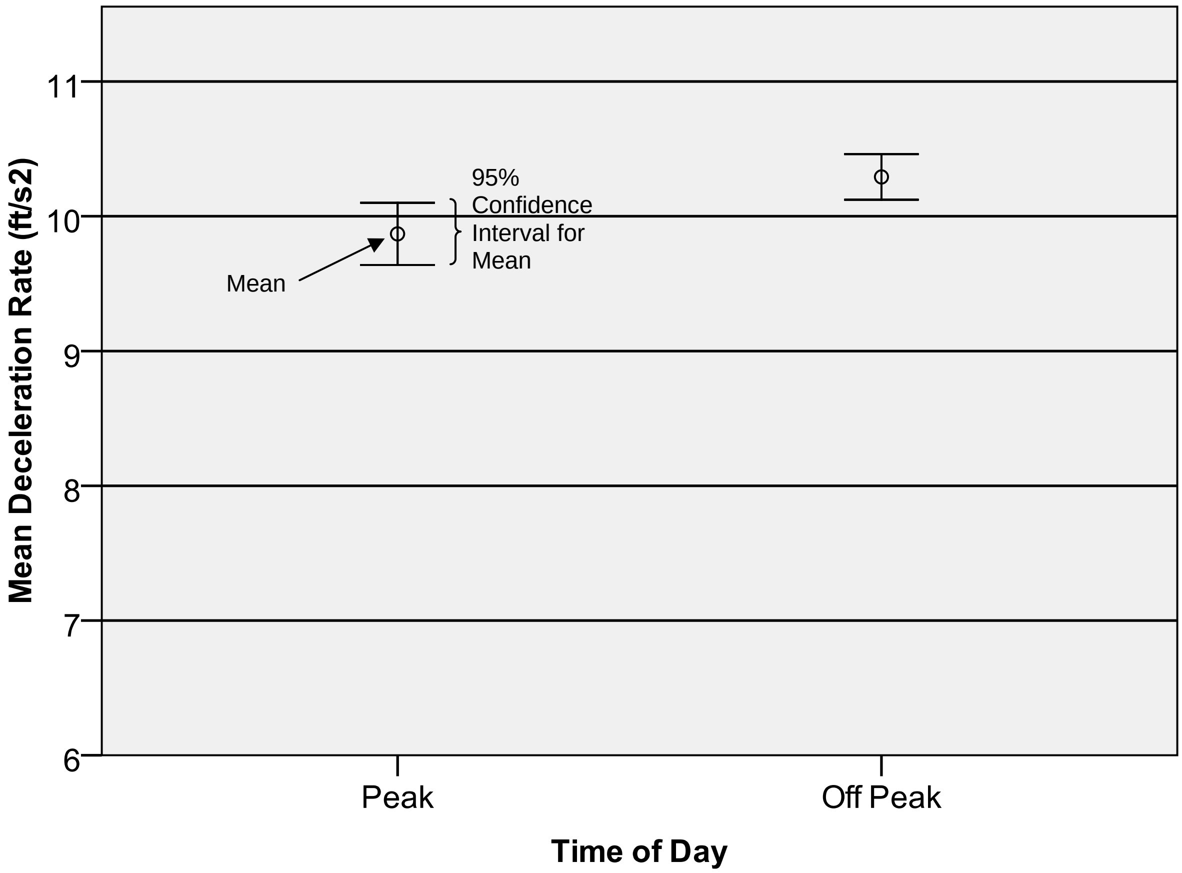


FIGURE 4 Mean and 95 percent confidence interval for deceleration rate by time of day.

Red Light Running

Of the 1,275 vehicles in the data set, 82 red light running events were observed, accounting for 6.4 percent of the vehicles. The logistic regression analysis showed that red light running events were difficult to predict based on the potential predictor variables used here, largely because red light-running events often occur due to the attitude or inattention level of the individual driver. Nevertheless, the following variables were found to significantly affect red light running occurrence:

- Travel time to the stop bar at the start of yellow;
- Approach speed;
- Vehicle type; and
- Time of day.

The direction of the parameter estimates from the logistic regression analysis indicated that the following conditions contributed to a higher likelihood of red light running:

- Greater travel time to the stop bar at the start of yellow;
- Higher approach speed;
- If the subject vehicle was a heavy vehicle, particularly a tractor trailer; and
- If the event occurred during the peak period.

As expected, the travel time to the intersection at the start of yellow had the strongest effect on red light running occurrence. The median estimated travel time to the intersection at the start of yellow for the red-light-runners was 4.45 seconds, compared to 3.68 seconds for all other vehicles. Also as expected, faster drivers were more likely to commit a red light running event. The mean approach speed for red light running vehicles was 45.81 mph compared to 42.28 mph for all other vehicles. The time of day was also significant in that drivers were more likely to commit red light running during peak times compared to off-peak times. Red light running accounted for 7.6 percent of the peak-period observations and 5.7 percent of the off-peak observations.

Heavy vehicles, particularly tractor trailers, were overrepresented in red light running observations. Red light running was committed by 20.0 percent of tractor trailers and 14.1 percent of single unit trucks (16.3 percent of all heavy vehicles combined), while only 6.5 percent of cars and 4.3 percent of light trucks committed red light running (5.6 percent of all passenger vehicles combined). In terms of relative rates of occurrence, tractor trailers were 3.6 times more likely and single unit trucks were 2.5 times more likely to commit red light running compared to all passenger vehicles combined. The red light running rate of occurrence for heavy vehicles was 2.9 times that of passenger vehicles, which is consistent with research by Bonneson et al that found heavy vehicles to be 2.3 times more likely to commit red light running (*13*).

CONCLUSIONS

Vehicle type was found to have a statistically significant effect on both deceleration rate and red light running occurrence but did not have an effect on brake response time. Deceleration rates were highest for cars and light trucks, while single unit trucks showed significantly lower deceleration rates. Deceleration rates for tractor trailers were similar to those of single unit trucks. Heavy vehicles, particularly tractor trailers, were overrepresented in red light running observations. Tractor trailers were 3.6 times more likely to commit red light running compared to passenger vehicles. Single unit trucks were 2.5 times more likely to commit red light running compared to passenger vehicles. The rates of red light running for cars and light trucks were not substantially difference from each other. The differences in stopping behavior between passenger vehicles and heavy vehicles were expected as heavy vehicle operators are less likely to stop due to several reasons, including: 1) heavy vehicles cannot stop as rapidly as passenger vehicles, 2) heavy vehicle operators typically have higher delay-related costs, and 3) heavy vehicle operators may avoid using high deceleration rates during non-emergencies to prevent shifting of cargo.

The time of day (i.e. peak versus off-peak) had a statistically significant effect on both deceleration rate and occurrence of red light running. Deceleration rates were significantly higher during off-peak times. Red light running was 1.3 times more likely to occur during peak-periods compared to off-peak periods. Both of these results were expected as drivers are less inclined to stop during peak periods due to: 1) greater time pressure, 2) greater levels of delay when stopped at signalized intersections, 3) greater uncertainty of the actions of trailing drivers, and/or 4) a perceived reduction in the threat of being cited for committing red-light-running. Brake response times were not significantly affected by time of day. Vehicular platooning was found to have no significant effect on deceleration rates, brake response times, or red light running occurrence.

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