U.S. Department
of Transportation
National Highway
Traffic Safety
Administration

www.nhtsa.gov

DOT HS 811 506 October 2011

Effect of Daytime Running Lights On Left Turning Drivers' Gap Acceptance

DISCLAIMER

This publication is distributed by the U.S. Department of Transportation, National Highway Traffic Safety Administration, in the interest of information exchange. The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Department of Transportation or the National Highway Traffic Safety Administration. The United States Government assumes no liability for its contents or use thereof. If trade names, manufacturers' names, or specific products are mentioned, it is because they are considered essential to the object of the publication and should not be construed as an endorsement. The United States Government does not endorse products or manufacturers.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 811 506		

4. Title and Subtitle
Effect of Daytime Running Lights on Left Turning Drivers' Gap Acceptance

5. Report Date
October 2011

6. Performing Organization Code

7. Author(s)
James W. Jenness, Richard W. Huey, Shawn McCloskey, and Jeremy Walrath

8. Performing Organization Report No.

9. Performing Organization Name and Address
Westat
1600 Research Blvd.
Rockville, MD 20850-3129

10. Work Unit No. (TRAIS)n code

11. Contract of Grant No.
DTNH22-05-D-01002

12. Sponsoring Agency Name and Address
National Highway Traffic Safety Administration
1200 New Jersey Avenue SE.
Washington, DC 20590

13. Type of Report and Period Covered
Task 3 Final Report

14. Sponsoring Agency Code

15. Supplementary Notes
NHTSA Task Order Manager: Stephanie Binder.

16. Abstract

An observational field study was conducted by video recording traffic in clear weather during afternoon rush hours at two intersections. The purpose of the study was to determine whether drivers turning left from the main road onto the minor road across the path of approaching traffic were influenced in their gap acceptance decisions by daytime running lights (DRL) on approaching vehicles. Video recordings were analyzed to extract information about the size of 6711 temporal gaps available to turning drivers, whether the approaching vehicle had DRL or not, and several other factors. Clearance times between the turning vehicle exiting the intersection and the approaching vehicle entering the intersection were also determined from the video recordings. "Potential conflicts" between turning vehicles and approaching vehicles were defined based on short clearance times and decreases in the approaching vehicle's speed. To determine the effect of DRL on gap acceptance at each site, the probability of gap acceptance was modeled (for 5125 available gaps less than seven seconds) with a logistic regression procedure that included effects of available gap size, DRL status of the approaching vehicle, approaching vehicle speed, approaching vehicle size, turning vehicle size, whether the available gap was the first gap encountered by the turning driver, and whether there were any vehicles queued behind the turning vehicle. Similar analyses were conducted for each site with available gaps less than four seconds. For all gaps taken, a separate model predicted potential conflicts based on effects of DRL, available gap size, and all other factors mentioned above. The results indicated that DRL on approaching vehicles did not significantly decrease the probability of gap acceptance suggesting that DRL may not encourage turning drivers to be more cautious. Despite the finding from one site that turning drivers were more likely to accept 3- to 4-second gaps in front of approaching vehicles with DRL as compared to approaching vehicles without DRL, there was no evidence from this study to suggest that this effect would influence crash rates for left-turn-across-path scenarios. DRL status of the approaching vehicle was not a reliable predictor of potential vehicle conflicts at either study site. Overall, the results do not provide evidence to support the use of daytime running lights as a countermeasure for fair weather daytime crashes involving right-of-way violations.

17. Key Words	18. Distribution Statement
DRL, daytime running lights, conspicuity, headlamps, lighting, driver behavior	Document is available to the public from the National Technical Information Service www.ntis.gov

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No of Pages	22. Price
Unclassified	Unclassified	38	

Form DOT F1700.7 (8-72) **Reproduction of completed page authorized**

Executive Summary

The annual number of motorcycle rider fatalities in the United States increased from 2294 in 1998 to 5290 in 2008 (National Highway Traffic Safety Administration, 2010). Many multi-vehicle motorcycle crashes involve right-of-way violations where another vehicle turns in front of, or crosses the path of an on-coming motorcycle. Improving the frontal conspicuity of motorcycles with auxiliary forward lighting during the daytime may have the potential to reduce these types of crashes, but the effects of daytime running lights (DRL) on drivers' gap acceptance are not well understood. The study reported here is one of several studies conducted for a NHTSA-sponsored research program on motorcycle conspicuity and DRL. The purpose of the overall project is to understand how daytime conspicuity of motorcycles may be affected by both motorcycle lighting and DRL on other vehicles. Findings from each completed study are described in separate reports.

This study does not specifically address lighting on motorcycles; it was designed to determine whether the presence of DRL on approaching vehicles is associated with gap acceptance for left-turning drivers. The study focused on all approaching vehicles rather than only approaching motorcycles so that a large enough sample size could be obtained to assess other factors besides DRL such as approaching vehicle speed and approaching vehicle size. If daytime use of vehicle lighting is shown to be associated with a reduced probability that turning drivers will accept small gaps in the approaching traffic stream (while statistically controlling for other factors), then the use of additional daytime lighting on motorcycles may be promising technology to pursue as a countermeasure.

Researchers videotaped more than 3,000 drivers turning left in front of approaching vehicles at two intersections. One intersection was on MD-355 in Boyds, MD and the other intersection was on MD-198 in Burtonsville, MD. At both of these intersections, traffic on the state highway was not required to stop, but traffic on the minor road was controlled by a stop sign. Left-turning drivers at both sites turned from the state highway across a lane of opposing traffic onto a minor road.

Four video cameras were used to record views of left-turning drivers and approaching traffic during afternoon rush hours on days with fair weather. Video recordings were analyzed to extract information about movements of left-turning vehicles and approaching vehicles traveling in the adjacent opposing lanes. DRL status of approaching vehicles and the duration of available gaps in the approaching traffic stream were determined from the videos. Left-turning drivers' gap acceptance was analyzed based on the DRL status of the approaching vehicle, while statistically controlling for available gap size and several other factors.

Clearance times between the turning vehicle exiting the intersection and the approaching vehicle entering the intersection were also determined from the video recordings. "Potential conflicts" between turning vehicles and approaching vehicles were defined based on instances where clearance times were less than one second. Potential conflicts also included instances where the clearance time was less than two seconds and the approaching vehicle decreased its speed (by more than five mph) as it travelled through the study site.

To determine the effect of DRL on gap acceptance at each site, the probability of gap acceptance was modeled (for available gaps less than seven seconds) with a logistic regression procedure that included effects of available gap size, DRL status of the approaching vehicle, approaching vehicle speed, approaching vehicle size, turning vehicle size, whether the available gap was the first gap encountered by the turning driver, and whether there were any vehicles queued behind the turning vehicle. Similar analyses were conducted on a subset of the data where available gaps were less than four seconds. Another set of logistic regression analyses was conducted to model potential conflicts based on effects of DRL, available gap size, and all of the other factors mentioned above.

Turning drivers' acceptance of available gaps up to seven seconds long did not depend significantly on DRL status of approaching vehicles at either site. Gap acceptance at both sites was significantly more likely for longer available gaps, for the first gap encountered, and for higher speeds of the approaching vehicle. Gap acceptance at both sites was significantly less likely when the turning vehicle had another vehicle queued behind it. Gap acceptance did not depend significantly on the size of the turning vehicle. However, the two sites differed for the effect of approaching vehicle size. At the Boyds site, gap acceptance was significantly less likely when the approaching vehicle was large, but there was no significant effect of approaching vehicle size at the Burtonsville site.

Other differences between two study sites emerged when gap acceptance was examined for short available gaps (less than four seconds long). At both sites gap acceptance for short gaps was significantly related to gap size, first gap encountered, and queue as described above. However, gap acceptance for short available gaps differed between the two sites with respect to the effects of DRL, and approaching vehicle speed. At the Boyds site, gap acceptance for available gaps less than four seconds was significantly more likely when the approaching vehicle had DRL and when the approaching vehicle's speed was higher. These two effects were not statistically significant predictors of short gap acceptance at the Burtonsville site.

For both study sites there was no statistically significant difference in mean clearance times (between turning vehicles and approaching vehicles) based on the DRL status of the approaching vehicle. This result may suggest that turning drivers do not feel any more urgency to clear the intersection when a vehicle with DRL is approaching as compared to a vehicle without DRL.

Results from both study sites were consistent in indicating that neither DRL status of the approaching vehicle nor approaching vehicle size was a reliable predictor of potential vehicle conflicts as defined by short clearance times and decreases in the approaching vehicle's speed. The analyses indicate that potential conflicts at both sites were significantly less likely for:

- turns taken within larger available gaps
- turns taken within the first available gap encountered

Overall, the results of this study provided only limited evidence that DRL on passenger vehicles influenced gap acceptance by left-turning drivers. For available gaps in the approaching traffic stream less than four seconds, DRL on the approaching vehicle was associated with a higher rate of gap acceptance for vehicles turning in front of the approaching vehicle at one study site, but not at the other site. DRL status of the approaching vehicle was not a reliable predictor of potential vehicle conflicts at either site.

These results do not provide evidence to recommend DRL as a countermeasure for reducing daytime left-turn-across-path crashes. However, the results do not suggest that DRL increases crash risk for this scenario.

Contents

List of Tables

List of Figures

1. Introduction

1.1 Motorcycle Conspicuity Project overview

National Highway Safety Administration (NHTSA) issued a Task Order to Westat to investigate daytime frontal conspicuity of motorcycles as it relates to frontal lighting treatments on motorcycles and as it relates to the use of daytime running lights (DRL) within the passenger vehicle fleet. The annual number of motorcycle rider fatalities in the United States has more than doubled from 2294 in 1998 to 5290 in 2008 (National Highway Traffic Safety Administration, 2010). Over the same period, the total number of traffic fatalities has remained relatively stable. Many multi-vehicle motorcycle crashes involve right-of-way violations where another vehicle turning in front of, or crossing the path of an on-coming motorcycle (Longthorne, Varghese, & Shankar, 2007). Improving the frontal conspicuity of motorcycles may reduce the occurrence of these types of crashes. There is some evidence that DRL use on passenger vehicles is associated with lower crash rates (Elvik, Christensen, & Olsen, 2003, Krajicek & Schears, 2010), and daytime use of illuminated lamps on motorcycles has been shown to increase their conspicuity (for a review see Wulf, Handcock, & Rahimi,1989). On the other hand, widespread use of DRL on passenger vehicles may reduce the safety effectiveness of daytime headlamp use by motorcyclists. As drivers become accustomed to searching for two headlamps (i.e., another passenger vehicle), they may inadvertently "overlook" motorcycles with only one headlamp lit. Research is needed to address these questions.

The overall goals of the project were to:

- Examine if the frontal conspicuity of motorcycles can be improved to reduce their chances of being struck by other motorists who may not have seen them or may not have accurately judged their approaching speed.
- Determine the impact of passenger fleet daytime running lights (DRL) on motorcycle crashes by analyzing crash data from a country that has mandated fleet use of DRL.
- Compare the response (e.g. gap size, turning speed) of motorists turning left in front of approaching passenger vehicles with DRL to those without DRL.
- Evaluate which, if any motorcycle conspicuity treatments might be most likely to improve motorcycle safety (e.g. by increasing the gaps afforded to approaching motorcycles by turning vehicles).

This report describes the work performed on Task 3 (Compare the response of motorists to approaching vehicles with DRL and without DRL). Findings of other project tasks are described in separate reports.

1.2 Study objective

The objective of Task 3 was to compare the response of drivers to approaching passenger vehicles with daytime running lights to those without daytime running lights. More specifically, the study was designed to determine whether drivers turning left in front of oncoming traffic under daylight conditions are more or less likely to accept smaller, more dangerous gaps if the approaching vehicles have illuminated lamps (including daytime running lights). The study focused on all approaching vehicles rather than only approaching motorcycles so that a large enough sample size may be obtained to assess several other factors besides DRL such as approaching vehicle speed and approaching vehicle size. This study is meant to provide additional insights into the work on motorcycle conspicuity that was performed under a previous NHTSA project (Pierowicz, Gawron, Wilson, & Bisantz, 2011).

1.3 Background

A previous NHTSA-sponsored project was done to study the effects of motorcycle lighting treatments on motorists' speed-spacing judgments of approaching motorcycles (Pierowicz, Gawron, Wilson, & Bisantz, 2011). One phase of that project was an observational study of drivers making left turns at a site in Canada (with a high rate of DRL use in the passenger vehicle fleet) and at a similar site in the U.S. (with a low rate of DRL use in the passenger vehicle fleet). Video data were collected for vehicles that turned left in front of an oncoming experimental motorcycle traveling at a constant speed of 30 mph. The video data were later reduced to determine "gap" measurements which were defined as the *distance* between the approaching vehicle and the left-turning vehicle at the moment when the left-turning vehicle had initiated the turn and was oriented at an angle of approximately 45 degrees to the roadway. Similar left turn "gap" measurements were obtained for vehicles turning left in front of non-motorcycle traffic (SUVs, sedans, and mini-vans). Approximately 170 of these events were recorded at each test site.

Note that in the previous study only those gaps *accepted* by turning drivers were measured. The study did not consider the temporal gaps between successive vehicles in the traffic stream that were rejected by each left-turning motorist. It is possible that any observed differences between data collected at the U.S. site and the Canadian site may be due to the relative availability of short versus long gaps in the traffic stream rather than DRL usage. Perhaps shorter gaps are more likely to be accepted when only shorter gaps are available. Due to these and other concerns about the comparability of the U.S. and Canadian data, the results of the observational study were inconclusive. Whether gap acceptance for drivers in the United States is influenced by DRL on approaching passenger vehicles remains an open question to be addressed by the current study.

In the previous study, data were analyzed by comparing mean (distance-based) gaps accepted for motorists turning in front of motorcycles with various lighting treatments and passenger vehicles. However, the average size of accepted gaps (whether time- or distance-based) is not necessarily closely related to the critical safety problem of right-of-way violations that occur when passenger vehicle drivers do not notice approaching vehicles (i.e. motorcycles) or when they underestimate the approaching vehicle's speed. The rate of small temporal gaps accepted may be a more meaningful safety metric for these types of crashes. The present analysis considered the probability of left-turning drivers accepting temporal gaps of various sizes (especially short gaps) for approaching vehicles with and without DRL.

Factors Related to Left Turn Gap Acceptance

A complete predictive model of left turn gap acceptance may include several factors in addition to the presence of daytime running lights on an approaching vehicle. For example, the probability of a left-turning driver accepting any given gap presented may depend upon:

- Size of the available temporal gap in the traffic stream (longer gaps more likely to be accepted)
- Gap size distribution presented to driver (if the only gaps available are primarily small ones, driver is more likely to accept a small gap)
- Site factors (distance across the conflict zone, weather and roadway conditions)
- Characteristics of turning vehicles (e.g. capability to accelerate quickly)
- Characteristics of approaching vehicle (size, speed, acceleration, conspicuity related factors such as DRL, whether approaching vehicle is alone or at the head of a platoon)
- Characteristics of turning driver (age, gender, personality factors, and impairments due to alcohol, drugs, fatigue, or distractions)
- Situational motivations - Among the many situational motivations that may influence the driver's decision to accept a given gap there may be social factors (e.g. social pressure from passengers, social pressure from other drivers queued up behind the turning vehicle), trip purpose and schedule, and the total elapsed time waiting to turn (drivers may become impatient over time and may be more likely to accept smaller gaps).

The present study was designed to focus on the effect of DRL on gap acceptance while statistically controlling for a subset of other possibly relevant factors, including the size of the available temporal gap, and characteristics of approaching vehicles and turning vehicles.

2. Method

2.1 Study design

To determine whether left turning drivers' gap acceptance decisions are influenced by approaching vehicles' daytime running lights, researchers videotaped a large sample drivers turning left in front of approaching vehicles at two intersections in Montgomery County, Maryland. Video data were recorded during the afternoon on days with fair weather. Under these conditions, few vehicles were expected to have their headlamps on, but many were expected to have some form of DRL illuminated. Video recordings were analyzed to extract information about movements of left-turning vehicles and approaching vehicles traveling in the adjacent opposing lanes. DRL status of approaching vehicles and the duration of available gaps in the approaching traffic stream were determined from the videos. Left-turning drivers' gap acceptance was analyzed based on the DRL status of the approaching vehicle, while statistically controlling for available gap size and several other factors.

2.2 Study sites

Field site selection

Vehicles making left turns and approaching traffic in opposing lanes were recorded at two non-signalized intersections. Non-signalized intersections were chosen so that left-turning drivers would be exposed to a large variety of gap sizes between approaching vehicles and so that turning drivers' gap acceptance decisions would not be influenced by traffic signal phases. The study sites and data collection times were selected on roadways and times (late afternoon, weekdays) when traffic volumes were sufficiently high that left-turning drivers often were forced to wait for gaps in the traffic stream before making their turns. Site selection also depended on the availability of adequate locations to place cameras in inconspicuous locations and appropriate vantage points, and on the safety of researchers and road users. Late afternoon hours with high traffic volumes were chosen over high volume early morning hours because fewer vehicles had their headlamps on in the afternoon.

Study site locations and roadway configuration

The first study site was located in Burtonsville, Maryland the intersection of MD-198 and Peach Orchard Road (Figure 1). At this site, Route 198 carries most of the traffic straight through the intersection with Peach Orchard Road. There is flashing yellow light at the intersection for traffic on MD-198 and a flashing red light for traffic on Peach Orchard Road. Stop signs are also used on the minor road (Peach Orchard). Left-turning vehicles were observed approaching the intersection on MD-198 from the West and turning left (South) onto Peach Orchard Road. Approaching traffic traveling East on MD-198 provided a variety of gaps for left-turning drivers to accept or reject. Video cameras were placed in the southwest quadrant of the intersection.

Figure 1. Burtonsville Study Site at the Intersection of MD-198 and Peach Orchard Road

The second study site was located in Boyds, Maryland at the intersection of MD-355 and West Old Baltimore Road (Figure 2). At this site, Route 355 carries most of the traffic straight through the intersection with West Old Baltimore Road. Traffic on the minor road (West Old Baltimore Road) is controlled with a stop sign. Traffic on MD-355 does not face any stop sign or traffic signal at this intersection. During the data collection periods, relatively few vehicles entered or exited MD-355 from Greenridge Drive, Greenbrook Drive, and Brink Road. Video cameras were located to the south of the intersection. Left-turning vehicles approached the intersection from the Southeast and turned left (West) onto West Old Baltimore Road. Southeast-bound traffic on MD-355 provided a variety of gaps for left-turning drivers to accept or reject.

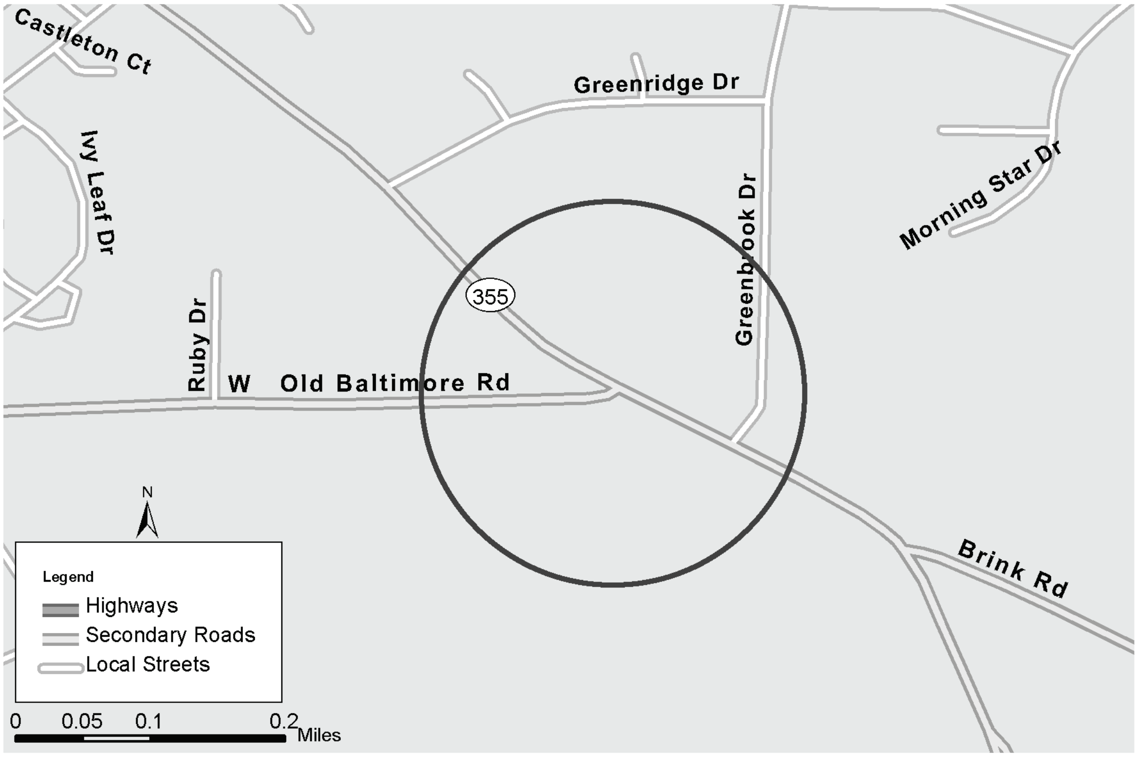

Figure 2. Boyds Study Site at the Intersection of MD-355 and West Old Baltimore Road

Figure 3 shows a view of the Burtonsville intersection as seen from the position of a driver preparing to turn left from MD-198 onto Peach Orchard Road. Figure 4 shows a view of the Boyds intersection as seen from the position of a driver preparing to turn left from MD-355 onto West Old Baltimore Road. Note that at each site there is a single through-lane in each direction for traffic on the main road. At the Burtonsville site, there is also a left turn lane. Through traffic is free to travel past a left-turning vehicle that is stopped in the turn lane, but left turning vehicles sometimes form a queue. The intersection at the Boyds site does not have any turn lane so traffic tends to queue up behind stopped vehicles waiting to turn left onto West Old Baltimore Road.

Figure 3. Left-Turning Driver's View at the Burtonsville Site Looking West on MD-198

Figure 4. Left-Turning Driver's View at the Boyds Site Looking Northwest on MD-355

Apparatus

Four video cameras connected to a video multiplexer and video recorder were used to collect and synchronize video data. The cameras captured views of both approaching traffic and left-turning vehicles. The general configuration of the four cameras with respect to the intersection is shown in Figure 5. A similar camera configuration was used at both study sites. Turning vehicles (Vt) approached from the right side of the diagram, made a left turn onto the roadway pictured at the bottom of the diagram. The opposing approaching vehicles (Va) which provided temporal gaps for the turning vehicles' maneuvers, are shown approaching from the left side of the diagram. Once an approaching vehicle passed the intersection (Vr) it was captured by camera C2. Various reference points were defined within the video views. These are shown as points A, B, C, for approaching vehicles and points 1, 2, 3 for turning vehicles. Figure 6 shows a single frame from each of the video cameras used at the Burtonsville site.

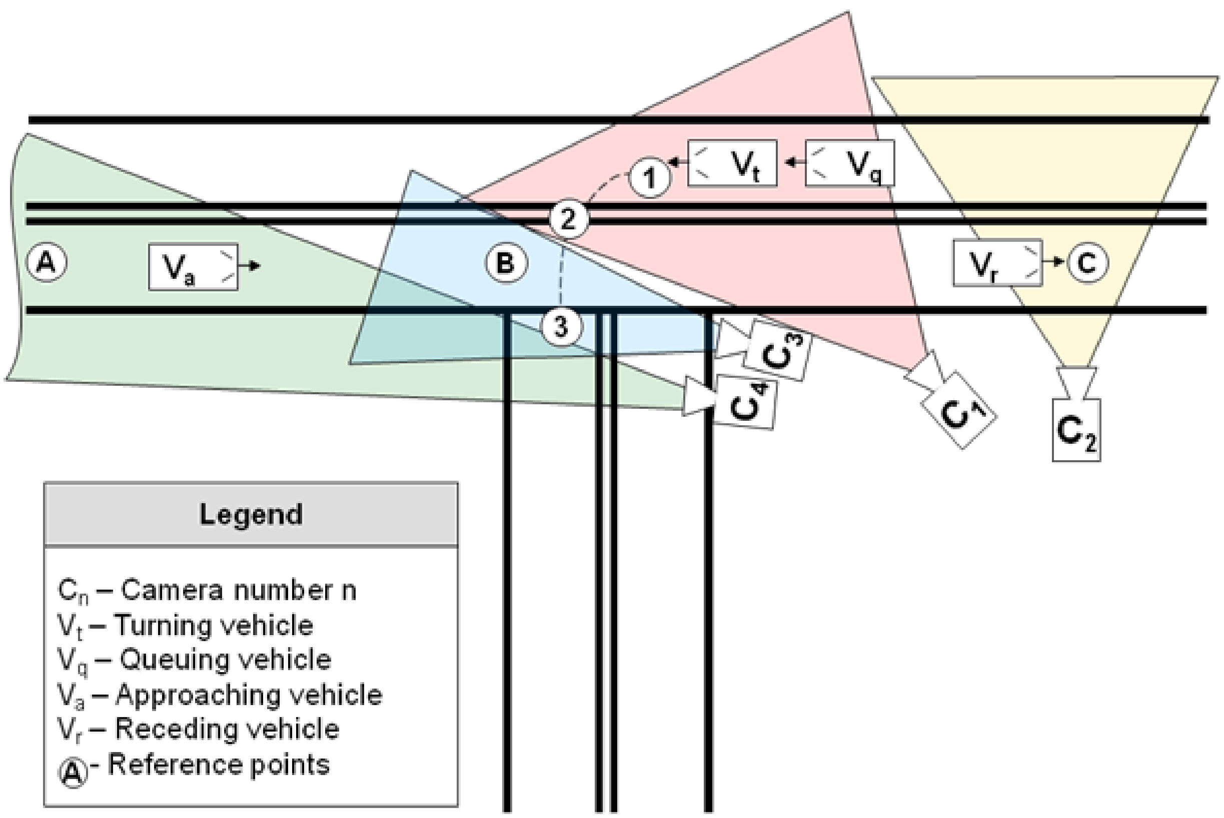

Figure 5. Simplified Plan View of an Intersection Showing Approximate Camera Coverage Zones and Reference Points

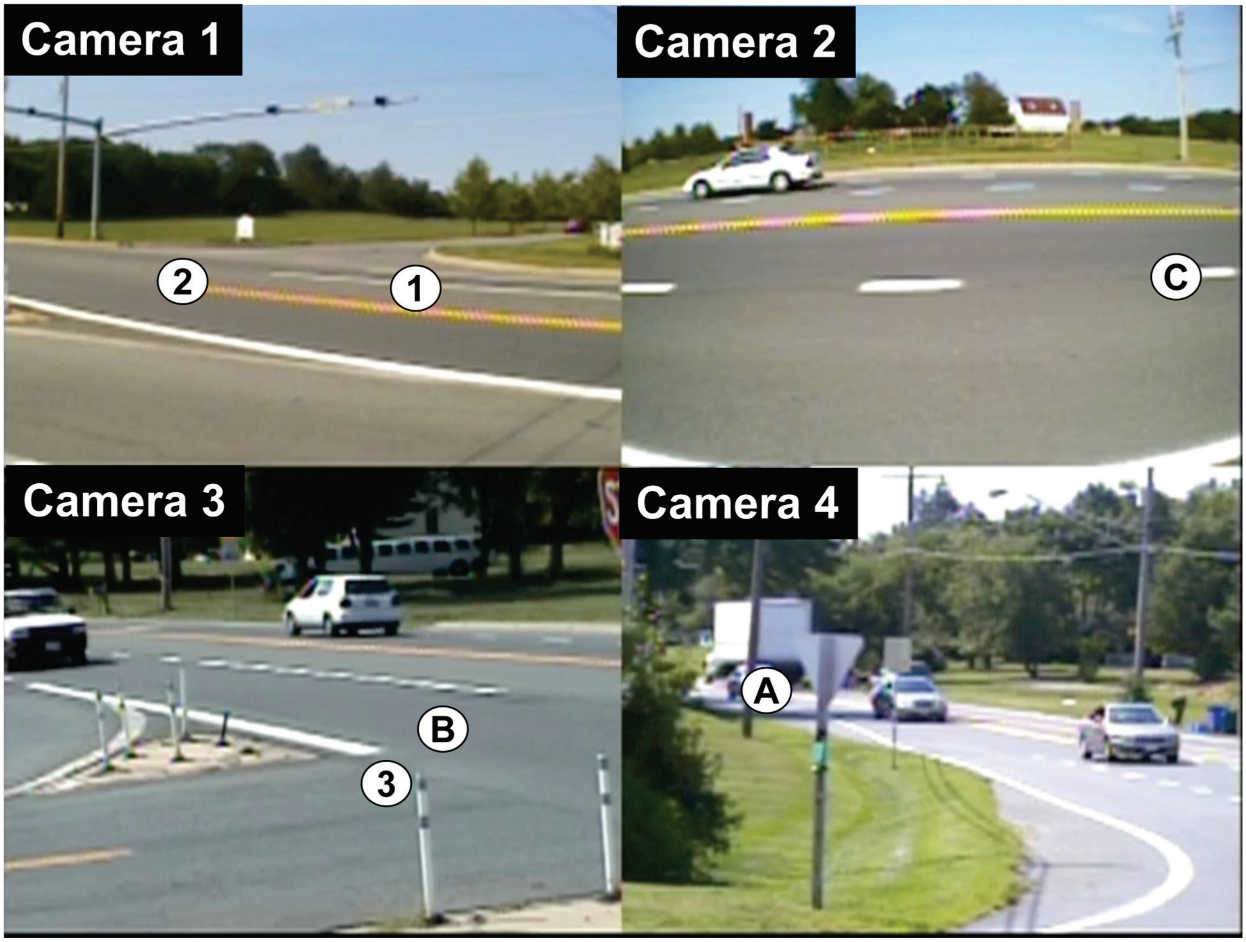

Figure 6. Quad-Split Video Views of the Burtonsville study site (MD-198)

In Figure 6, cameras C1 and C3 recorded the movements of turning vehicles as they prepared to turn (1), entered the intersection (2), and exited the intersection (3). The presence of any vehicles queued behind the turning vehicle was noted in the Camera C1 view. Cameras C4, C3, and C2 were used to record images of vehicles approaching from the left as they passed landmarks at locations A, B, and C.

2.5 Procedure

Video Data Collection

Video data were recorded in clear weather during the summer of 2009 on weekdays between 3:30 p.m. and 6:30 p.m. (EDT). Data were collected on six afternoons between August 11th and August18th at the Burtonsville site and on six afternoons between August 26th and September 3rd at the Boyds site. During these data collection periods, sunset occurred at approximately 8:05 p.m. at the Burtonsville site and 7:42 p.m. at the Boyds site.

The exact camera locations were determined ahead of time and the data collection system was pilot tested prior to collecting data for the study. In both locations, video cameras C1, C3, and C4 were mounted together on a single board that was temporarily attached to a utility pole. Camera C2 was temporarily mounted to a signpost. These cameras were positioned in the same locations each day and carefully aimed with the aid of a small monitor and hard copy reference prints of single video frames taken from pilot tests. Distance measurements between various landmarks seen in the video views were obtained to allow for distance and speed calculations to be made from vehicle movements observed in the video images.

2.6 Data reduction

Video data were reduced by research staff using Interact (Mangold) video coding software. Videos were reviewed several times at various speeds including stepping through important segments frame-by-frame in order to define the moments when vehicles were positioned at the various reference points (A, B, C, 1, 2, 3). First, video segments that captured turning vehicles were identified and coded then variables for relevant approaching vehicles were coded.

The following variables were recorded for left-turning vehicles:

- Turning vehicle type: Six types were defined: motorcycle, car, pickup, SUV, van or minivan, or heavy truck.
- Time at points 1, 2, 3: Exact times that the turning vehicle reached reference point 1 (vehicle reached a "wait to turn" point on the roadway), point 2 (vehicle committed to turn and was oriented at approximately a 45 degree angle to forward roadway), and point 3 (rear end of vehicle cleared intersection).
- Available temporal gaps: Gaps in the approaching traffic stream through which the turning vehicle could have turned. Two types of available gaps were defined. These were "first available gaps" and "other available gaps." The first available gap was defined by the moment that a turning vehicle reached point 1 until an approaching vehicle arrived at point B. Other available gaps were defined as the elapsed time between an approaching vehicle reaching point B and the next approaching vehicle reaching point B. It was important to distinguish between first available gaps and other available gaps because the turning vehicle was much more likely to be rolling forward during a first available gap event.
- Gap taken or not taken: For each available gap, a turning vehicle either turned, or did not turn.
- Queue: The presence or absence of another vehicle queued up behind the turning vehicle was noted for each available gap.

The following variables were recorded for approaching vehicles:

- Approaching vehicle type: Six types were defined: motorcycle, car, pickup, SUV, van or minivan, or heavy truck.
- Time at points A, B, C: Exact times that approaching vehicle reached reference point A (front of vehicle reached a defined reference point upstream from intersection, point B (front of vehicle entered intersection), and point C (front of vehicle reached a defined landmark past intersection).
- Presence of DRL: Due to the modest video quality and reflections of sunlight from lamp housings, researchers were sometimes not able to distinguish between low/high beam headlamps, white DRL, and amber DRL with or without other lights. Therefore, only the presence or absence of illuminated lamps was coded as "DRL" or "None."
- Approaching vehicle speed: Point to point average speed was calculated based on elapsed times and known distances from point A to point B and from point B to point C.

- Change in approaching vehicle speed: Approaching vehicle's BC speed minus AB speed. This measure gives an indication of whether the approaching vehicle decelerated or accelerated as it approached and travelled through the intersection.

Finally, a variable was created to describe the temporal proximity between the turning vehicle and the approaching vehicle. Clearance time was computed by subtracting the time that the rear end of a turning vehicle cleared the intersection (point 3 in Figures 3 and 4) from the time that the front end of the approaching vehicle entered the intersection (point B in Figures 3 and 4).

Certain vehicles were excluded from the samples at both sites.

- No data were coded for approaching vehicles when there was no turning vehicle present.
- No data were coded for turning vehicles that reached the intersection and turned when no approaching vehicles were present.
- Approaching vehicles within tightly spaced platoons were not coded (except for the lead vehicle) because it would be impossible for a turning vehicle to fit in between the very small gaps. The final vehicle in a tightly spaced platoon defined the beginning of an available gap (as defined above).

No individual drivers were identified in this study, in fact, the quality of the video collected was not sufficient to personally identify any driver and no attempt was made to classify drivers based on age, gender, or any other personal characteristics.

All data files were checked for errors and were corrected as necessary. Preparation of the data sets and statistical analyses were carried out with SAS software. An alpha level of .05 was used to determine the statistical significance of the results described below.

3. Results

3.1 Samples of turning vehicles and approaching vehicles

Data reduction yielded 3311 observations of a turning vehicle presented with a gap by an approaching vehicle at the Boyds site and 3400 such observations at the Burtonsville site. Table 1 shows the number of turning vehicles by vehicle type in the Boyds sample, and Table 2 shows the number of turning vehicles by vehicle type in the Burtonsville sample. Table 3 and Table 4 show the number of approaching vehicles at each site by vehicle type. Note that although turning vehicles in each sample were unique, approaching vehicles were occasionally included in these counts more than once when they were relevant for more than one turning vehicle. For example, sometimes a turning vehicle followed another turning vehicle across the intersection in front of the same approaching vehicle. In this case, the temporal gap available to the second turning vehicle was shorter than for the first turning vehicle, but characteristics of the approaching vehicle (vehicle size, speed) were the same for the two observations.

Table 1. Turning Vehicles (Boyds Site)

Vehicle Type	Frequency	Percent
Motorcycle	18	1.06
Car	886	52.27
Pickup	169	9.97
SUV	386	22.77
Van or Minivan	215	12.68
Bus	3	0.18
Heavy Truck	18	1.06
Total	1695	100.00

Table 2. Turning Vehicles (Burtonsville Site)

Vehicle Type	Frequency	Percent
Motorcycle	5	0.38
Car	720	54.59
Pickup	104	7.88
SUV	322	24.41
Van or Minivan	157	11.90
Bus	1	0.08
Heavy Truck	10	0.76
Total	1319	100.00

Table 3. Approaching Vehicles (Boyds Site)

Vehicle Type	Frequency	Percent
Motorcycle	23	0.69
Car	1646	49.71
Pickup	248	7.49
SUV	849	25.64
Van or Minivan	461	13.92
Bus	23	0.69
Heavy Truck	61	1.84
Total	3311	100.00

Table 4. Approaching Vehicles (Burtonsville Site)

Vehicle Type	Frequency	Percent
Motorcycle	7	0.21
Car	1826	53.71
Pickup	402	11.82
SUV	657	19.32
Van or Minivan	331	9.74
Bus	8	0.24
Heavy Truck	169	4.97
Total	3400	100.00

Due to the relatively small number of motorcycles, buses, and heavy trucks observed, vehicle types were combined for subsequent analyses and recoded as a binary variable that described vehicle size (small or large). Motorcycles and cars were classified as small and all other vehicles types were classified as large.

In the Boyds sample, 40.2 percent of approaching vehicles had illuminated lamps (coded as DRL) and in the Burtonsville sample 37.3 percent of approaching vehicles had illuminated lamps. Table 5 shows the total number of vehicles with DRL by vehicle type for the two study sites combined.

Table 5. Approaching Vehicles with DRL by Vehicle Type (Both Sites)

Vehicle Type	Frequency (Both Sites)	Frequency with DRL	Percent with DRL
Motorcycle	30	28	93.33
Car	3472	1367	39.37
Pickup	650	240	36.92
SUV	1506	581	38.58
Van or Minivan	792	270	34.09
Bus	31	30	96.77
Heavy Truck	230	83	36.09
Total	6711	2599	38.73

3.2 Available gaps and accepted gaps

The number of temporal gaps in the approaching traffic stream that were available to 1695 left-turning vehicles at the Boyds site and 1319 left-turning vehicles at the Burtonsville site are shown in Table 6 by gap size.

Table 6. Gaps Available to Left-Turning Vehicles in the Boyds and Burtonsville Samples

Available Gap Size (seconds)	Boyds Site	Burtonsville Site
< 1.0	138	177
1.0 to 1.99	686	1013
2.0 to 2.99	543	584
3.0 to 3.99	338	323
4.0 to 4.99	250	293
5.0 to 5.99	234	202
6.0 to 6.99	199	145
7.0 to 7.99	193	125
8.0 to 8.99	160	96
9.0 to 9.99	113	72
≥ 10.0	457	370
Total	3311	3400

Figure 7 shows the percentage of available gaps at the Boyds site in which a left turn maneuver was performed (gap taken). The percentage of gaps taken by a turning driver is shown for available gaps occurring in front of approaching vehicles with DRL (white bars) or no illuminated lamps (black bars). For most of the time bins shown, the percentage of available gaps taken was similar for DRL and No Lights conditions. Only two of the time bins shown in Figure 7 had a statistically significant difference between DRL and No Lights in the percentage of available gaps taken. The significant differences occurred for available gap sizes between five and six seconds ($\chi^2 = 4.52$, $p = .033$) and for gap sizes between three and four seconds ($\chi^2 = 7.75$, $p = .005$). Available gaps between five and six seconds were more frequently taken when the approaching vehicle had no lamps illuminated and available gaps between three and four seconds were more frequently taken when the approaching vehicle had DRL. These differences were not observed at the Burtonsville site where none of the gap time bins had a significant difference between DRL and No Lights conditions (Figure 8).

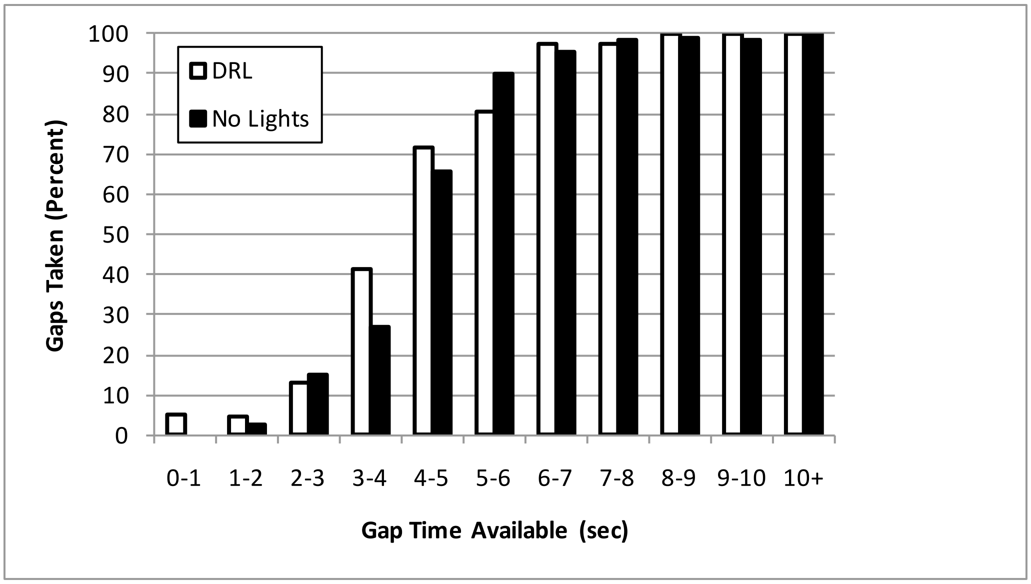

Figure 7. Percentage of Available Gaps Taken by DRL Status of Approaching Vehicle (Boyds Site)

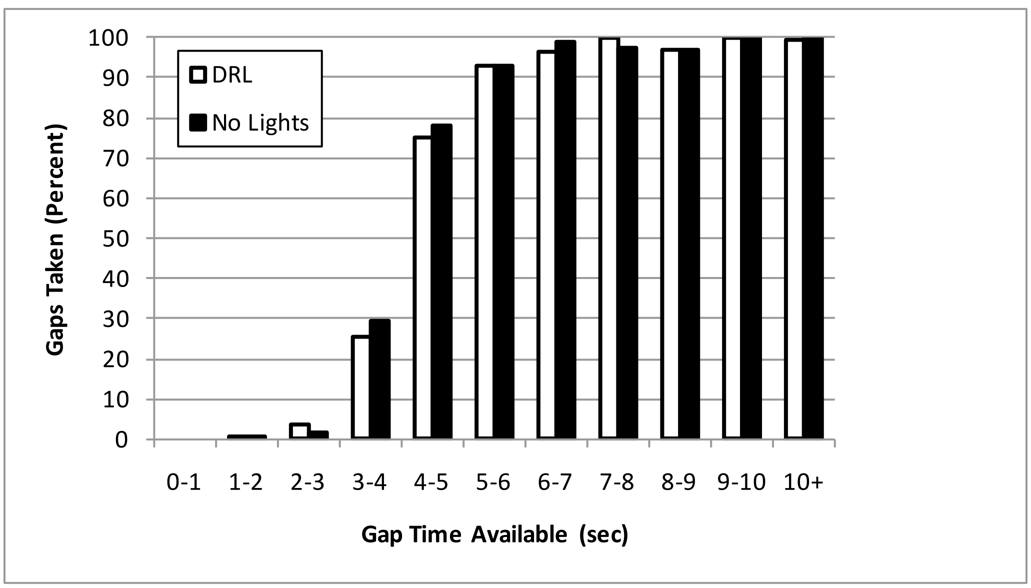

Figure 8. Percentage of Available Gaps Taken by DRL Status of Approaching Vehicle (Burtonsville Site)

In order to test the effect of approaching vehicles' DRL on gap acceptance by turning drivers, the probability of accepting a gap was modeled using logistic regression implemented with the SAS GENMOD procedure. This approach allowed researchers to control for several other factors besides DRL that may influence gap acceptance. For this analysis, only data where the available gap was less than seven seconds were included because gaps greater than seven seconds were accepted at a high rate (95 to 100 percent) and turning maneuvers through larger gaps were unlikely to lead to vehicle conflicts. The statistical model specified a binomial underlying distribution for the outcome variable and a logit link function. The binary outcome variable (gap accepted versus gap not accepted) was parameterized so that the model predicted the probability of accepting a gap based on several factors including:

- Available gap size (seconds)
- Whether the available gap was the first gap encountered
- Factors related to the approaching vehicle including speed, vehicle size, and DRL status
- Factors related to the turning vehicle including vehicle size and presence of a queue behind the turning vehicle

Driver-related factors such as age, gender, motivation (trip purpose), risk taking propensity, etc. which may have influenced gap acceptance were not measured in this study.

Many of the observed turning drivers were presented with several available gaps before they initiated a left turn maneuver. To account for data clustered by each turning driver, a repeated measures (subject) adjustment was included when fitting the model. The model used GEE (Generalized Estimating Equations) for final parameter estimation.

Data for this analysis were 2388 observations of available gaps including 778 gaps taken (32.6 percent). Table 7 shows the parameter estimates (and empirical standard error estimates) for predicting gap acceptance based on the effects of DRL on the approaching vehicle as well as gap size, first gap encountered (versus other gaps), approaching vehicle speed, approaching vehicle size, turning vehicle size, and queue. The DRL effect was not statistically significant. However, effects of gap size, first gap encountered, approaching vehicle speed, queue, approaching vehicle size were statistically significant. The positive coefficient for gap size indicates that gap acceptance was more likely for larger gaps. Positive coefficients for the effect of first gap and approaching vehicle speed indicate that gap acceptance was more likely for first gaps encountered (as compared to later gaps) and that gap acceptance was more likely for greater approaching vehicle speeds. The negative coefficient for the effects of queue indicates that having another vehicle behind the turning vehicle was associated with a lower probability that a gap was accepted. The negative coefficient for approaching vehicle size indicates that vehicles were less likely to turn in front of large approaching vehicles as compared to small approaching vehicles.

This analysis was repeated with a subset of the data that included 1705 observations where the available gap was less than four seconds. Of these short gaps, 215 (12.6 percent) were taken by the turning driver. The parameter estimates are shown in Table 8 for a model predicting gaps taken from available gap data less than four seconds. These estimates are similar to the estimates shown in Table 7 with statistically significant positive coefficients for available gap size, first gap encountered, approaching vehicle speed, and negative coefficients for queue and approaching vehicle size, although the effect of approaching vehicle size did not reach statistical significance. The effect of DRL, which was not statistically significant when available gaps less than seven seconds were considered, was statistically significant for predicting whether gaps less than four seconds were taken. The positive coefficient for the DRL effect indicates that when short gaps (less than four seconds) were available, drivers at the Boyds site were more likely to turn if the approaching vehicle had DRL rather than no illuminated lamps.

Table 7. Parameter Estimates for Modeling the Probability of Gap Acceptance for Available Gaps Less than Seven Seconds (Boyds Site)

Effect	Estimate	SE	Z	*p*
Intercept	-6.446	0.617	-10.95	<.0001
Available gap size (seconds)	1.674	0.084	20.02	<.0001
First gap encountered	1.805	0.196	9.19	<.0001
Approaching vehicle speed (mph)	0.053	0.013	4.07	<.0001
Queue (behind turning vehicle)	-3.701	0.247	-15.01	<.0001
DRL (versus no lights)	0.297	0.176	1.68	0.092
Approaching vehicle size (large)	-0.366	0.172	-2.13	0.032
Turning vehicle size (large)	0.026	0.175	0.15	0.883

Table 8. Parameter Estimates for Modeling the Probability of Gap Acceptance for Available Gaps Less than Four Seconds (Boyds Site)

Effect	Estimate	SE	Z	*p*
Intercept	-8.877	1.327	-6.69	<.0001
Available gap size (seconds)	1.702	0.143	11.89	<.0001
First gap encountered	2.837	0.328	8.65	<.0001
Approaching vehicle speed (mph)	0.113	0.030	3.73	0.0002
Queue (behind turning vehicle)	-4.256	0.431	-9.89	<.0001
DRL (versus no lights)	0.632	0.224	2.82	0.005
Approaching vehicle size (large)	-0.388	0.216	-1.79	0.073
Turning vehicle size (large)	0.032	0.224	0.14	0.886

Data from the Burtonsville site were analyzed in the same way. Table 9 shows the parameter estimates (and empirical standard error estimates) for predicting gap acceptance among 2737 available gaps less than seven seconds. 662 of those gaps (24.2 percent) were taken by turning drivers.

The effects of DRL, approaching vehicle size, and turning vehicle size were not statistically significant for predicting gap acceptance. However, effects of gap size, first gap encountered, approaching vehicle speed, and queue were statistically significant. The positive coefficient for gap size indicates that gap acceptance was more likely for larger gaps. Positive coefficients for the effect of first gap and approaching vehicle speed indicate that gap acceptance was more likely for first gaps encountered (as compared to later gaps) and that gap acceptance was more likely for higher approaching vehicle speeds. The negative coefficient for the effect of queue indicates that having another vehicle queued behind the turning vehicle was associated with a lower probability that an available gap was accepted.

The analysis of Burtonsville data was repeated with a subset of the data that included only 2097 observations where the available gap was less than four seconds. Of these short gaps, 106 (5.1 percent) were taken by the turning driver. The parameter estimates are shown in Table 10 for a model predicting gaps taken among available gaps less than four seconds. As was the case for the analysis of gaps less than seven seconds, the effects of DRL, approaching vehicle size, and turning vehicle size were not statistically significant for predicting gap acceptance for gaps less than four seconds. Unlike the results for gaps less than seven seconds, the effect of approaching vehicle speed was not statistically significant for predicting gaps taken less than four seconds.

Only effects of gap size, first gap encountered, and queue were statistically significant predictors of gap acceptance among short available gaps at the Burtonsville site. The positive coefficients for gap size and first gap indicate that gap acceptance was more likely for larger gaps and more likely for first gaps encountered. The negative coefficient for the effects of queue indicates that gap acceptance was less likely when another vehicle was queued behind the turning vehicle.

Table 9. Parameter Estimates for Modeling the Probability of Gap Acceptance for Available Gaps Less than Seven Seconds (Burtonsville Site)

Effect	Estimate	SE	Z	*p*
Intercept	-10.888	1.219	-8.93	<.0001
Available gap size (seconds)	2.382	0.130	18.32	<.0001
First gap encountered	0.887	0.183	4.86	<.0001
Approaching vehicle speed (mph)	0.051	0.024	2.11	<.0001
Queue (behind turning vehicle)	-3.447	0.500	-6.88	<.0001
DRL	-0.104	0.190	-0.55	0.583
Approaching vehicle size (large)	0.141	0.180	0.78	0.436
Turning vehicle size (large)	0.042	0.186	0.23	0.820

Table 10. Parameter Estimates for Modeling the Probability of Gap Acceptance for Available Gaps Less than Four Seconds (Burtonsville Site)

Effect	Estimate	SE	Z	*p*
Intercept	-10.785	1.618	-6.67	<.0001
Available gap size (seconds)	3.047	0.272	11.22	<.0001
First gap encountered	1.339	0.252	5.32	<.0001
Approaching vehicle speed (mph)	0.009	0.030	0.31	0.753
Queue (behind turning vehicle)	-3.614	1.079	-3.35	0.0008
DRL (versus no lights)	-0.037	0.276	-0.13	0.893
Approaching vehicle size (large)	-0.195	0.263	-0.74	0.459
Turning vehicle size (large)	0.045	0.259	0.17	0.862

3.3 Clearance times

Clearance time was computed by subtracting the time that the rear end of a turning vehicle cleared the intersection (point 3 in Figure 5 and Figure 6) from the time that the front end of the approaching vehicle entered the intersection (point B in Figure 5 and Figure 6). For all observed left turns that occurred within available gaps of seven seconds or less, 328 clearance times computed for cases where the approaching vehicle had DRL at the Boyds site and 450 clearance times were computed for cases where the approaching vehicle did not have DRL. The Burtonsville site yielded 232 clearance time observations with DRL and 429 clearance time observations without DRL. Cumulative distributions for clearance times for approaching vehicles with and without DRL are shown in Figure 9 for the Boyds site and in Figure 10 for the Burtonsville site.

At the Boyds site, mean clearance times for approaching vehicles with DRL (M = 1.92, SD = 1.28) and approaching vehicles without DRL (M = 1.91, SD = 1.30) did not differ significantly $t(776) = 0.09$, $p = .93$, two-tailed. Also, at the Burtonsville site, mean clearance times for approaching vehicles with DRL (M = 1.93, SD = 1.08) and approaching vehicles without DRL (M = 1.92, SD = .98) did not differ significantly $t(659) = 0.09$, $p = .93$, two-tailed. Note that the slightly smaller standard deviation of clearance times for approaching vehicles without DRL (as compared to clearance times for vehicles with DRL) is reflected in Figure 10 by the slightly steeper slope of the "No lights" distribution as compared to the "DRL" distribution.

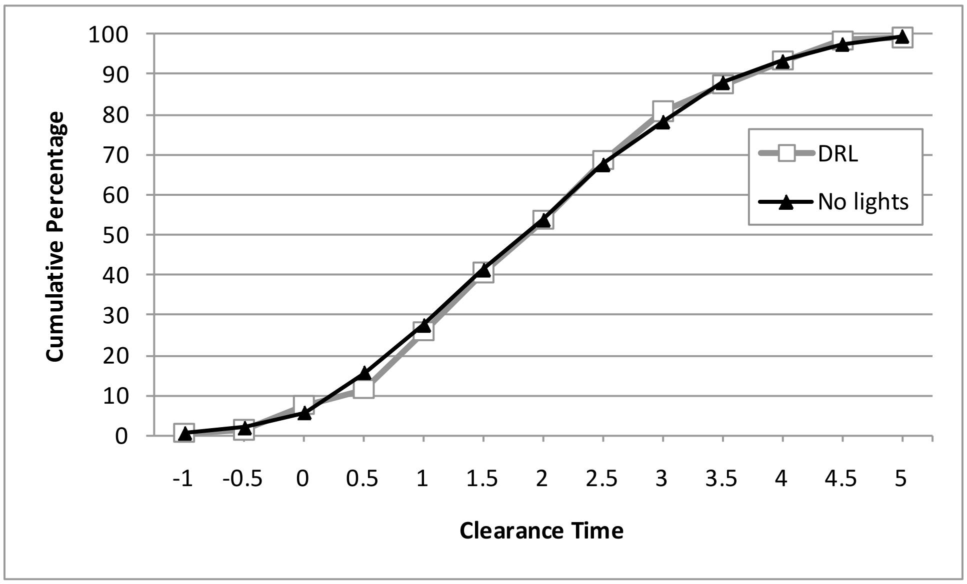

Figure 9. Cumulative Distributions of Clearance Times for Vehicles Turning in Front of Approaching Vehicles with DRL or No Lights (Boyds Site)

Figure 10. Cumulative Distributions of Clearance Times for Vehicles Turning in Front of Approaching Vehicles with DRL or No Lights (Burtonsville Site)

3.4 Potential vehicle conflicts

Short clearance times indicate that the approaching vehicle and the turning vehicle passed through the intersection in close temporal proximity of each other. From a safety perspective, short clearance times are indicative of possible vehicle conflicts (i.e. where it may have been necessary for one or both vehicles to perform some evasive action to avoid a collision.) Clearance times may have been affected by changes in the speed of the approaching vehicle as well as the timing of the turning vehicle's maneuver. For example, if a vehicle turned too close in front of an approaching vehicle, the approaching driver may have decelerated in order to avoid a collision, or to avoid passing uncomfortably close to the turning vehicle. A surrogate measure for vehicle conflicts was used in this study. "Potential conflicts" were defined based on clearance time and changes in the approaching vehicle's speed.

Figure 11 shows the clearance times for turning vehicles and the corresponding changes in the approaching vehicles' speed at the Boyds site. Data for cases where the approaching vehicle was equipped with DRL are shown by the small filled circles and cases where the approaching vehicle had no lamps illuminated are shown by the cross symbols. Negative clearance times indicate that the rear bumper of the turning vehicle did not clear the conflict zone until after the front bumper of the approaching vehicle had entered the conflict zone, but negative clearance times do not indicate that the vehicles collided, in fact, no collisions were observed. Any clearance times less than one second were defined as potential conflicts. Also, clearance times up to two seconds were also defined as potential conflicts if the approaching vehicle decreased its speed by more than 5 mph. The step-shaped boundary in Figure 11 separates observations defined as potential conflicts from those defined as non-conflicts. This definition was based on the researchers' judgment, but is somewhat arbitrary. The purpose of defining potential conflicts was to determine whether DRL (or no DRL) on approaching vehicles was associated with a higher probability of a vehicle conflicts between the approaching vehicle and the turning vehicle. Figure 12 shows the same potential conflict boundary applied to the Burtonsville data.

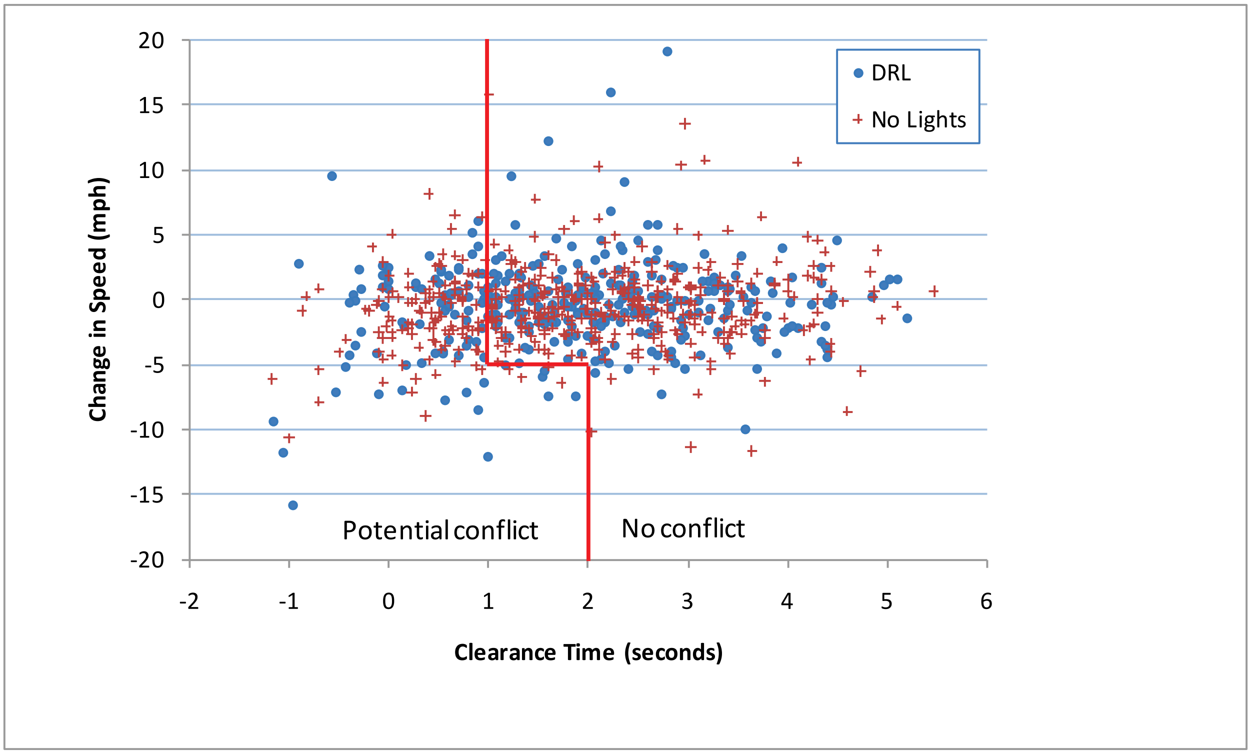

Figure 11. Potential Conflicts and Non-Conflicts for 778 Left-Turning Vehicles Based on Clearance Time and Changes in the Approaching Vehicle's Speed (Boyds Site)

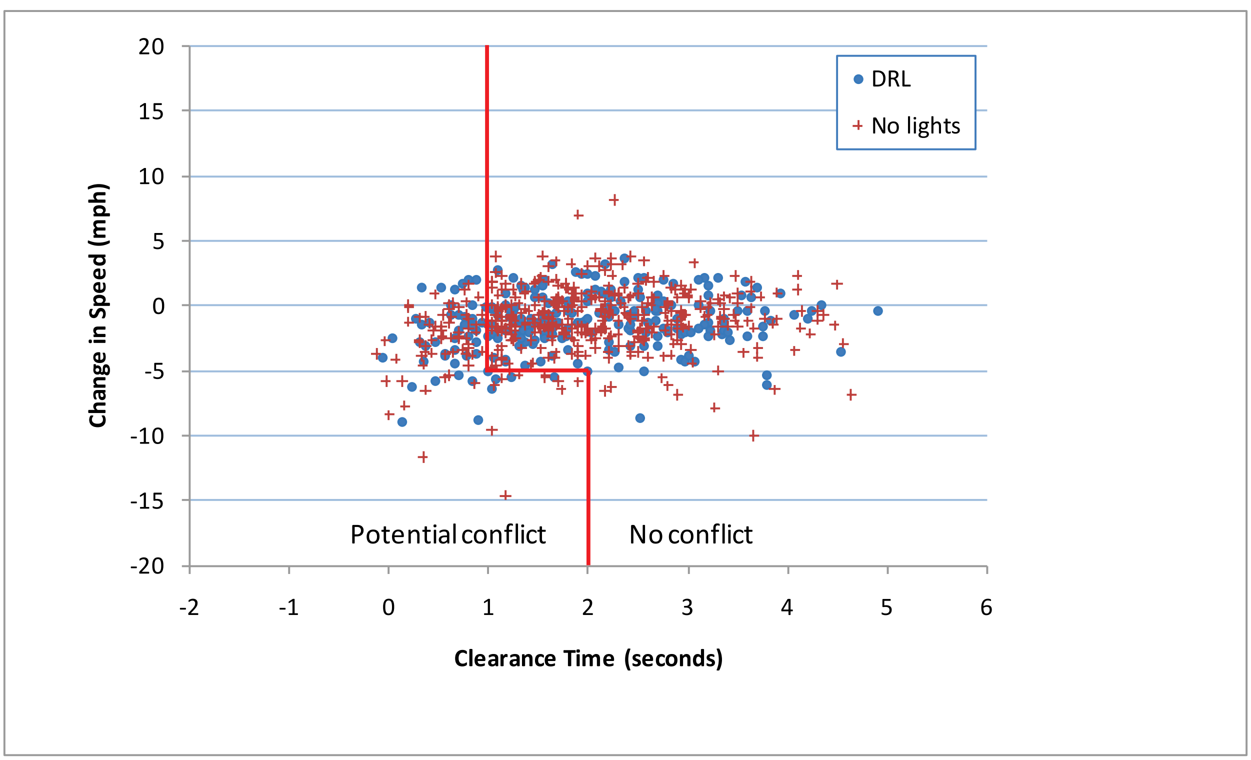

Figure 12. Potential Conflicts and Non-Conflicts for 661 Left-Turning Vehicles Based on Clearance Time and Changes in the Approaching Vehicle's Speed (Burtonsville Site)

Separate logistic regression analyses were conducted with the Boyds data and the Burtonsville data to determine whether DRL on the approaching vehicle and other factors reliably predict whether an observed left turn event resulted in a potential conflict as defined above (e.g. Figure 9). Table 11 shows the parameter estimates for predicting the probability that an observed left turn event at the Boyds site was a potential conflict. The model included effects for the available gap size, whether the gap taken was the first gap encountered (versus a later gap), approaching vehicle speed, whether a queue was present behind turning vehicle, DRL (or not) on the approaching vehicle, approaching vehicle size, and turning vehicle size. The effect of DRL was not statistically significant. The effects of approaching vehicle speed and approaching vehicle size also were not statistically significant.

Effects of available gap size, first gap encountered, queue, and turning vehicle size were all statistically significant predictors of potential conflicts. These results indicate that potential vehicle conflict events were:

- Less likely for left turns taken within larger available gaps
- Less likely for turns taken within the first available gap encountered
- More likely when there was a queue behind the turning vehicle
- More likely if the turning vehicle was large

Table 11. Parameter Estimates for Modeling the Probability that an Accepted Gap Resulted in a Potential Vehicle Conflict (Boyds Site)

Effect	Estimate	SE	$\chi 2$	*p*
Intercept	7.162	1.084	43.66	<.0001
Available gap size (seconds)	-1.781	0.133	178.27	<.0001
First gap encountered	-2.050	0.305	45.21	<.0001
Approaching vehicle speed (mph)	-0.024	0.021	1.27	0.259
Queue (behind turning vehicle)	1.093	0.360	9.23	0.002
DRL (versus no lights)	-0.175	0.229	0.58	0.446
Approaching vehicle size (large)	-0.370	0.228	2.63	0.104
Turning vehicle size (large)	0.630	0.229	7.60	0.005

Data from the Burtonsville site were analyzed in the same way. Table 12 shows the parameter estimates for predicting potential conflicts at the Burtonsville site based on DRL status of the approaching vehicle and several other factors. DRL, presence of a queue behind the turning vehicle, approaching vehicle size, and turning vehicle size were not statistically significant predictors of potential conflicts at this site.

Available gap size, first gap encountered, and approaching vehicle speed were statistically significant predictors of potential conflicts. These results indicate that potential vehicle conflicts were:

- Less likely for turns taken within larger available gaps
- Less likely for turns taken within the first available gap encountered
- More likely when the approaching vehicle speed was higher

Table 12. Parameter Estimates for Modeling the Probability that an Accepted Gap Resulted in a Potential Vehicle Conflict (Burtonsville Site)

Effect	Estimate	SE	$\chi 2$	*p*
Intercept	3.801	1.788	4.52	<.0001
Available gap size (seconds)	-2.379	0.225	111.97	<.0001
First gap encountered	-2.091	0.310	45.47	<.0001
Approaching vehicle speed (mph)	0.092	0.035	6.83	0.009
Queue (behind turning vehicle)	-3.596	3.069	1.37	0.241
DRL	0.257	0.275	0.87	0.350
Approaching vehicle size (large)	-0.035	0.265	0.02	0.894
Turning vehicle size (large)	0.065	0.265	0.06	0.806

4. Discussion

4.1 Summary and interpretation of results

A key traffic safety question is whether DRL on approaching vehicles may reduce the incidence of right-of-way violations from vehicles turning across their path. This question was addressed indirectly in this study by videotaping left-turning vehicles and opposing traffic at two different intersections and extracting information about vehicle movements and vehicle characteristics. Because crashes and near crashes are rare, this study was designed to determine whether DRL and other factors were related to:

- gap acceptance (controlling for available gap size)
- gap acceptance for short available gaps (less than four seconds)
- mean clearance times between the turning vehicle and the approaching vehicle
- potential conflicts between the turning vehicle and the approaching vehicle

Turning drivers' acceptance of available gaps up to seven seconds long did not depend significantly on DRL status of approaching vehicles at either site. Gap acceptance at both sites was significantly more likely for longer available gaps, for the first gap encountered, and for higher speeds of the approaching vehicle. It is obvious that safety conscious drivers should be more motivated to turn when a longer gap is available as opposed to a shorter gap. The higher likelihood of gap acceptance for the first gap encountered is probably due to two main factors. The first available gap usually occurred when the turning vehicle was in motion, which may have allowed the turning driver to accept slightly smaller gaps than they would have found acceptable if they had to initiate their turn maneuver from a dead stop. Also, before the turning vehicle reached the point where the turn maneuver was initiated, the turning driver may have modulated his or her approach speed so as to time the arrival at the intersection with an available gap large enough to turn through.

That greater gap acceptance was associated with greater approaching vehicle speed may indicate that drivers of the turning vehicles were somewhat influenced in their gap acceptance decisions by the distance of the approaching vehicle in addition to the size of the temporal gap available (and other factors). The results suggest that gap acceptance was more likely for a given size temporal gap when the approaching vehicle was further away (but traveling faster) rather than closer (and traveling slower).

Gap acceptance at both sites was significantly less likely when the turning vehicle had another vehicle queued behind it. A social pressure hypothesis would predict the opposite result; that drivers would feel more motivation (i.e. social pressure) to accept gaps when there was another vehicle queued up behind them. No alternative explanation is suggested here to explain the observed effect of queue, however, it should be noted that the statistically significant effect of queue on gap acceptance does not necessarily reflect a causal relation (in either direction) between these variables.

Data from the two sites were similar in that gap acceptance did not depend significantly on the size of the turning vehicle. However, the two sites differed for the effect of approaching vehicle size. At the Boyds site, gap acceptance was significantly less likely when the approaching vehicle was large, but there was no significant effect of approaching vehicle size at the Burtonsville site.

Other differences between two study sites emerged (including the effects of DRL and approaching vehicle speed) when gap acceptance was examined for a subset of the data with available gaps less than four seconds long. As for the full set of data with available gaps less than seven seconds, gap acceptance for the subset of short available gaps was significantly related to gap size. At both sites gap acceptance was more likely for longer gaps (up to four seconds). Gap acceptance was also more likely at both sites when the available gap was the first gap encountered by the turning driver and was significantly less likely when there was a queue behind the turning vehicle.

Gap acceptance for short available gaps differed between the two sites with respect to the effects of DRL, and approaching vehicle speed. At the Boyds site, gap acceptance for available gaps less than four seconds was significantly more likely when the approaching vehicle had DRL and when the approaching vehicle's speed was higher. These two effects were not statistically significant predictors of short gap acceptance at the Burtonsville site. The difference in results between sites is discussed below.

For both study sites there was no statistically significant difference in mean clearance times (between turning vehicles and approaching vehicles) based on the DRL status of the approaching vehicle. This result may suggest that turning drivers do not feel any more urgency to clear the intersection when a vehicle with DRL is approaching as compared to a vehicle without DRL.

Results from both study sites were consistent in indicating that neither DRL status of the approaching vehicle nor approaching vehicle size was a reliable predictor of potential vehicle conflicts as defined by short clearance times and decreases in the approaching vehicle's speed. The analyses indicate that potential conflicts at both sites were significantly less likely for:

- turns taken within larger available gaps
- turns taken within the first available gap encountered

Other factors differed between sites in their significance for predicting potential conflicts. At the Boyds site potential vehicle conflicts were significantly more likely:

- when there was a queue behind the turning vehicle
- when the turning vehicle was large

Potential vehicle conflicts at the Burtonsville site were significantly more likely:

- when the approaching vehicle speed was higher

In summary, the only significant effect of approaching vehicles' DRL on the behavior of turning drivers was for predicting gap acceptance for available gaps less than four seconds at the Boyds site, but not at the Burtonsville site. At the Boyds site, available gaps between 3 and 4 seconds were more likely to be taken by the turning driver when the approaching vehicle had DRL. Perhaps seeing DRL on the approaching vehicle served to reduce the turning driver's uncertainty about the approaching vehicle's location and speed, and increased the driver's confidence that a safe turn maneuver could be executed within the available gap.

It is possible that differences in the visual environments encountered by the turning drivers at the two study sites may account for the differences in the effect of DRL on short gap acceptance. Video coding staff found it somewhat easier to determine DRL status from reviewing videos collected at the Boyds site as compared to the Burtonsville site which suggests that DRL also may have had greater perceptual salience for turning drivers at the Boyds site. The position of the sun relative to the approaching vehicles' alignment was similar at the two sites. (At the Boyds site, approaching vehicles were aligned toward the southeast, and at the Burtonsville site, approaching vehicles were aligned toward east southeast.) However, turning drivers at the Boyds site viewed approaching vehicles against a relatively dark background of trees and dense vegetation close to the left side of the roadway, while turning drivers at the Burtonsville site viewed approaching vehicles against a lighter, more open background. Also, the roadway (MD-355) at the Boyds site was partially shaded from direct sunshine during the measurement period while the roadway at the Burtonsville site (MD-198) was not shaded.

Despite the tendency for turning drivers at the Boyds site to be more likely to accept 3- to 4-second gaps in front of approaching vehicles with DRL as compared to approaching vehicles without DRL, there was no evidence from this study to suggest that this effect would influence crash rates for left-turn across path scenarios. In this study, DRL status of the approaching vehicle was not a reliable predictor of potential vehicle conflicts at either site.

4.2 Study limitations

Several limitations to the present study were noted.

- Only a single common crash scenario was addressed by this study: Daytime left turn across path crashes (which may be related to conspicuity of the approaching vehicle). It is possible that DRL has significant benefits for reducing crash rates for other types of crashes not considered by the present protocol.
- In addition to DRL on the approaching vehicle, several other potential predictors of gap acceptance were considered in this study. However, limitations on video quality prevented analysis of any driver variables such as approximate age and gender. Future research may consider whether drivers in specific age/gender groups respond differently to vehicles with DRL.
- Quality of the video data was not sufficient to unambiguously and efficiently classify approaching vehicles by the type of lamps that were illuminated. It is likely some varieties of daytime running lights may be more or less conspicuous than other varieties that may differ in their physical characteristics (e.g. amber versus white lamp color, LED lamps versus conventional lamps, DRL versus normal low beam headlamps, reduced intensity high beam, multiple sets of lamps, classification of lamps by size, shape, intensity, beam pattern, etc.)
- Lighting conditions and time-of-day effects were not systematically varied in the present study. It is possible that drivers may react differently to seeing DRL on approaching vehicles when the sun is at a lower angle (i.e. closer to the horizon) or when the visual scene provides approaching vehicles with strong back lighting or strong front lighting. Also, in the present study the visual environment at the two sites was rather simple without much visual clutter. It is possible that DRL may be particularly effective at

helping turning drivers locate and keep track of approaching vehicles within more complex visual environments.

5. Conclusions

Overall, the results of this study provided only limited evidence that DRL on passenger vehicles influenced gap acceptance by left-turning drivers. For available gaps in the approaching traffic stream less than four seconds, DRL on the approaching vehicle was associated with a higher rate of gap acceptance for vehicles turning in front of the approaching vehicle at one study site, but not at the other site. DRL status of the approaching vehicle was not a reliable predictor of potential vehicle conflicts at either site.

Although some previous studies (which analyzed crash data) have indicated that DRL may be effective at reducing crash rates, the results of the present observational study do not provide evidence to recommend DRL as a countermeasure for reducing daytime left-turn-across-path crashes. However, the present results also do not indicate that DRL increases crash risk for this scenario.

References

Elvik, R., Christensen. P., and Olsen, S. F. (2003) *Daytime running lights. A systematic review of effects on road safety*. Report 688. Institute of Transport Economics. Oslo.

Krajicek, M. and Schears, R. (2010). Daytime running lights in the USA: What is the impact on vehicle crashes in Minnesota? *International Journal of Emergency Medicine, 3*: 39-43.

Longthorne, A., Varghese, C., and Shankar, U. (2007). Fatal two-vehicle motorcycle crashes. Report No. DOT HS 810 834. Washington DC: National Highway Traffic Safety Administration.

National Highway Traffic Safety Administration, (2010). Fatal Analysis Reporting System Encyclopedia. Retrieved April 16, 2010 from www-fars.nhtsa.dot.gov/Main/index.aspx. Washington, DC.: National Highway Traffic Safety Administration.

Pierowicz, J., Gawron, V., Wilson, G. and Bisantz, A. (2011). The effects of motor vehicle fleet daytime running lights on motorcycle conspicuity. Final Report under contract DTNH22-00-D-07007, T.O. 0019, Washington, DC.: National Highway Traffic Safety Administration.

Wulf, G. Handcock, P. A., and Rahimi, M. (1989). Motorcycle conspicuity: An evaluation and synthesis of influential factors. *Journal of Safety Research, 20*: 153-176.

DOT HS 811 504
October 2011

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

NHTSA
www.nhtsa.gov