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Technical Report

A Preliminary Assessment of the Crash-Reducing Effectiveness of Passenger Car Daytime Running Lamps (DRLs)

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Executive Summary

The effectiveness of daytime running lamps, DRLs, for passenger cars, are examined using three different crash types, two vehicle different direction fatal crashes, two vehicle non-fatal crashes, and single vehicle fatal pedestrian crashes. Two statistical techniques, the odds ratio and simple odds techniques are used to analyze the data.

RESULTS:

No difference was found in the risk of two-vehicle opposite-direction fatal crashes comparing vehicles with DRLs versus vehicles without DRLs. Data from the 1995-1997 Fatality Analysis Reporting System were used . Two statistical approaches to explore fatality risk were examined and neither approach showed a statistically significant difference between the two groups of vehicles (DRL versus non-DRL).

A difference associated with DRLs was found when the risk of non-fatal two-vehicle crashes during daytime hours was explored. Data from four states (Florida, Maryland, Missouri, and Pennsylvania) and two statistical approaches were used. DRLs are associated with a statistically-significant 7 percent reduction in the risk of these non-fatal crashes. This difference was found using the simple-odds technique, which is described below and in the report.

A lower risk of involvement in fatal pedestrian crashes for DRL-equipped vehicles was also found. DRLs are associated with 28 percent fewer pedestrian fatalities. This difference was found using the simple-odds technique, and it is statistically significant.

METHODOLOGY:

A case-control method was chosen as the approach for this study, since only specific make-models for each year were equipped with DRLs. The number of crashes for a set of vehicles equipped with DRLs is compared to either a group of similar vehicles without DRLs produced in earlier years or a fleet of vehicles without DRLs produced by a different manufacturer, namely Ford, built in the same years. Both comparison groups of vehicles are analyzed by time of day and crash type.

Two independent statistical techniques, the odds ratio and the simple odds, are used to analyze the data. Both techniques attempt to control for factors, other than the presence or absence of DRLs, that could be associated with crash occurrence. Individual estimates are combined using the methods described in Fleiss (1981) to obtain stable statistically significant results.

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Background

Many traffic crashes are the result of the failure of a driver to notice another vehicle. Visual contrast is an essential characteristic which enables a driver to detect vehicles. The purpose of daytime running lamps (DRLs) is to increase the visual contrast of DRL-equipped vehicles. Seven countries require the use of DRLs during all daytime periods: Canada, Denmark, Finland, Hungary, Iceland, Norway, and Sweden. Results of DRL studies from these countries consistently, however not conclusively, show that DRLs reduce the number of two-vehicle crashes during daylight, dusk, and dawn. This study, for the first time, examines the effectiveness of first-generation DRLs, using U.S. national data for passenger cars.

DRLs come in a variety of configurations. DRLs may be upper beam headlamps at reduced intensity, low-beam headlamps at full or reduced power, and in some vehicles, turn signals are used. Four manufacturers began equipping selected 1995 model year vehicles, for sale within the U.S., with DRLs. General Motors Corporation produces DRL-equipped vehicles with higher intensity DRLs than those used in Scandinavian countries. In the U.S. the availability of DRL-equipped vehicles has increased with each model year since 1995. Since the cost of DRLs is low, small reductions in the number of crashes would likely be considered cost effective. A chronological summary of results from previous studies of the effectiveness of DRLs follows.

Crash reductions associated with DRLs, of as much as 38 percent, were reported as early as 1964, in Allen and Clark's[1] survey of 181 U.S. companies that used DRLs. Among the surveyed companies were the Greyhound Bus Company and Chicago's Checker Cab Company, which reported total crash reductions of 11 and 7.2 percent, respectively. Three years later, the New York Port Authority (NYPA) conducted a study on DRLs by equipping 200 vehicles with modified parking and tail lights which were turned on by the engine ignition. In one year, NYPA reported a decrease in the crash rate of 18 percent for the modified vehicles.

Finland's legislation of 1972 required the use of low-beam headlights in rural areas during the winter. The rural multiple-vehicle daytime crash rate decreased by 27 percent as a result.[2]

In 1975, Clayton and Mackay[3], at Indiana University, found that almost half of all crashes were caused by drivers failing to process information properly. The most prevalent information processing errors were faulty visual perception, recognition errors and comprehension errors. In addition, it was shown that traffic crashes were due more to inattention and distraction than to poor vision. The crash reduction potential of DRLs lies in their ability to attract attention, especially in the peripheral visual field, thereby enhancing detectability.

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[1] Allen, M.J. and Clark, J.R. Automobile Running Lights - A Research Report. American Journal of Optometry and Archives of American Academy of Optometry 41(5).293-315, 1964.

[2] Andersson, K., Kilsson, G., and Salusjärvi, S. The Effect On Traffic Accidents on the Recommended use of Vehicle Running Lights in the Daytime in Finland. Report No 102. Swedish road and Traffic Research Institute (VTI), 1976.

[3] Claton, A.B. and Mackay, G.M. Aetiology of Traffic Accidents. Health Bulletin, 31(4), 277-280, 1972.

A study conducted by Transport Canada[4] in 1975-1976 examined the crash experience with part of the Canadian defense vehicle fleet equipped with automatic headlights, a version of DRLs. The results published by Attwood in 1981 showed a 20 percent crash decrease in the specially equipped vehicles compared to the comparison group of unmodified vehicles.

Swedish legislation required the use of DRLs throughout the year starting in October 1977. An 11 percent reduction in daytime crashes was observed. Two-vehicle head-on crashes were reduced by 10 percent, angle crashes were reduced 9 percent, crashes involving a bicycle or moped were reduced by 21 percent, and crashes involving a pedestrian were down by 17 percent.[5] These results were questioned by Theeuwes and Riemersma in 1995[6], as the proportion of multi-party crashes were not reduced as a proportion of all crashes.

Hills, in 1980[7], and more recently Sekuler and Blake[8] found that increasing the visual contrast of a vehicle increases the ability of other drivers to detect and monitor the vehicle. Low contrast between a vehicle and its background can be quite common during daylight hours. Contrast is reduced by color, rain, clouds and low levels of light which occur at dawn and dusk.

Stein reported in 1985[9] the results of a study by the Insurance Institute for Highway Safety (IIHS), which equipped over 2,000 passenger cars, light trucks and vans with DRLs. Relevant multi-vehicle crashes were 7 percent lower for the DRL-equipped vehicles than the comparison (unmodified) vehicles.

Norway required the installation of DRLs by vehicle manufacturers in January of 1985 and the use of low beam head lights was required on all vehicles in Norway not equipped with DRLs in April of 1988. Elvik reported[10] that a 15 percent reduction in all summertime multi-vehicle daylight crashes was achieved.

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[4]Attwood, D.A. The Potential of Daytime Running Lights as a Vehicle Collision Countermeasure. SAE Technical Paper 810190. Society of Automotive Engineers, 1981.

[5]Andersson, K. Nilsson, G. The Effects on Accidents of Compulsory use of Running Lights During Daylight in Sweden. Report No. 208A, Swedish Road and Traffic Research Institute (VRI),1981.

[6]Theeuwes, J. and Riemersma, J. Daytime Running Lights as a Vehicle Collision Countermeasure: The Swedish Evidence Reconsidered. Accident. Anal. Prevention. 27:633-642, 1995.

[7]Hills, B.L. Vision, Visibility and Perception in Driving. Perception, 9, 183-216, 1980.

[8]Sekuler, R. and Blake, R. Perception, (Second Edition) Toronto: McGraw-Hill, 1990.

[9]Stein, H. Fleet Experience with Daytime Running Lights in the United States. SAE Technical Paper 851239. Warrendale, PA, Society of Automotive Engineers, 1985.

[10]Elvik, R. The Effects of Accidents of Compulsory Use of Daytime Running Lights for Cars in Norway. Accident Analysis and Prevention, 25(4) 383-398, 1993.

Canada required that all new passenger cars, trucks, multi-purpose vehicles, and buses manufactured for sale in Canada be equipped with DRLs after December 1, 1989. In September 1993 Arora, et. al.[11] conducted an extensive analysis on the effectiveness of DRLs for Transport Canada. They estimate that relevant crashes were reduced by 11.3 percent, which was statistically significant at $p<0.05$.

In October of 1990, Denmark required universal use of DRLs. No overall effect was reported. However, a statistically significant 37 percent decrease in crashes involving a left turn was identified by Hansen in 1993[12].

Hungary has required the use of DRLs on rural roads since March 1993. Hollo studied the crash experience of DRL-equipped vehicles and presented the findings at a conference in the Czech Republic in 1995[13]. Several changes in traffic regulations and enforcement, which includes the reduction of the speed limit, stricter seat belt laws, increases in police patrols, significantly higher fines and a campaign to increase public awareness of traffic-related issues were considered confounding factors, thereby making it difficult to estimate the effect of DRLs. Nonetheless, Hollo estimates that DRLs reduced the number of rural daytime "frontal and cross traffic" crashes by 7 to 8 percent. Hallo further claims that during "good visibility" crashes are reduced 11 to 14 percent.

IIHS' Highway Loss Data Institute (HLDI) in 1997[14] released findings from a study of the personal injury claims for vehicles that added DRLs as a standard feature in 1995 and 1996, compared to the claim frequencies for the same makes and models prior to adding DRL. The number of relative claims was found to have increased slightly after DRLs were introduced. However, HLDI's study was not able to identify a consistent pattern of increases among vehicles. HLDI's study hypothesized that this finding was not surprising, as "...claims for striking vehicles, single-vehicle crashes, and nighttime crashes could not be identified..." and therefore, excluded from the study. Striking vehicle, single-vehicle, and nighttime crashes would not likely be impacted by the presence of DRLs.

Tofflemire and Whitehead[15] re-analyzed the Canadian DRL law in 1997 using a "quasi-experimental comparative posttest design" and found that opposite direction and angle crashes were reduced by 5.3 percent, which was statistically significant at $p<0.05$. The study concluded that the DRL law had a greater effect on opposite direction crashes (15 percent reduction) than angle crashes (2.5 percent

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[11]Arora, H. Collard, D. Robbins, G. Welbourne, E.R. White, J.G. Effectiveness of Daytime Running Lights in Canada, Report No. TP1298 (E), Transport Canada 1994.

[12]Hansen, L.K. Daytime Running Lights in Denmark - Evaluation of the Safety Effect. Translated exact.

[13]Hollo, P. Changes of the DRL-Regulations and their Effects on Traffic Safety in Hungary. Paper presented at the conference: Strategic Highway Safety Program and Traffic Safety, the Czech Republic, September 20-22, 1995. Preprint for sessions on September 21, 1995.

[14]Highway Loss Data Institute Bulletin Volume 15, Number 1, December 1997.

[15]Tofflemire, T. C., Whitehead, P.C. An Evaluation of the Impact of Daytime Running Lights on Traffic Safety in Canada, Journal of Safety Research, Volume 28, Number 4, 1997.

reduction).

Each province in Canada was individually analyzed. Only Nova Scotia and New Brunswick experienced a statistically significant ($p<0.05$) reduction in crashes.

While the 1993 and 1997 Canadian studies described above are among the few studies reporting statistically significant results, in most other studies the data sets are small, which can result in nonsignificant statistical results, even when an effect might exist.

Table 1 summarizes findings from studies of the effectiveness of DRLs in several counties, including the U.S. The individual studies are identified by year, investigator(s), the type of study, i.e., did the study analyze the effects of DRLs on a specific fleet of vehicles, or the result of a change in the law, applicable country, and the estimated effects of DRLs.

Several factors could influence the effectiveness of DRLs, e.g., geography and the climate, the mix of rural and urban crashes, traffic conditions, and manner of collision. The approach, of this study, attempts to limit the influence of such exogenous variables by using comparison groups where the effects should be similar. This study examines the effectiveness of DRLs in the U.S. for vehicles of model years 1995 and later. Two sources of data maintained by the National Highway Safety Traffic Administration (NHTSA) are used to study DRL effectiveness: the Fatality Analysis Reporting System (FARS) and data from Florida, Maryland, Missouri and Pennsylvania in NHTSA's State Data System (SDS).

Table 1
Summary of Findings on DRL Effectiveness*

Year Investigator(s)	Study Type	Country	Estimated Effects
1964 Allen and Clark[1]	Fleet	U.S.	7.2 % to 38 % crash reduction
1972 Anderson et al[2]	Law	Finland	27 % reduction rural multi-vehicle
1975 Attwood[4]	Fleet	Canada	20 % some defense vehicles
1977 Anderson et al[5]	Law	Sweden	9 % to 21 % crash type dependent
1985 Stein[9]	Fleet	U.S.	7 % reduction selected vehicles
1988 Elvik[10]	Law	Norway	15% reduction summer multi-vehicle
1993 Arora et al[11]	Law	Canada	11.3 % reduction 2 vehicle different direction
1993 Hansen[12]	Law	Denmark	up to 37% reduction - crash type dependent
1995 Hollo[13]	Law	Hungary	7 % to 14 % reduction frontal cross traffic
1997 Tofflemire et al[15]	Law	Canada	5.3 % reduction opposite direction/angle crashes

* See Bibliography for detailed information on published studies.

Data and Methodology

Previous studies of DRL effectiveness often have used a before vs. after approach. This approach is appropriate, for example, when a law goes into effect at a given point in time and one wishes to determine the effect of that law on traffic crashes. A case-control method was chosen as the approach for this study, since only specific make-models for each year were equipped with DRLs. A case-control method attempts to control for factors, other than the presence or absence of DRLs, that could be associated with crash occurrence. In this study, the number of crashes for a set of vehicles equipped with DRLs is compared to a group of similar vehicles without DRLs produced in earlier years, as well as, a fleet of vehicles without DRLs produced by a different manufacturer, Ford, built in the same years. Both comparison groups of vehicles are analyzed by time of day and crash type.

Data from FARS[16] for calendar years 1995 - 1997 were used to examine DRL effectiveness for fatal two-vehicle different direction crashes and for single vehicle pedestrian crashes. Crash data from the State Data System (SDS) for calendar years 1995 - 1996, from Florida, Maryland, Missouri, and

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[16] Fatal crash data are from NHTSA's *Fatality Analysis Reporting System (FARS)*. FARS contains data on a census of fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico. A crash must involve a motor vehicle traveling on a public roadway and must result in the death of an occupant of a vehicle or a nonmotorist within 30 days of the crash to be included in FARS.

Pennsylvania[17] were used to evaluate DRL effectiveness for all two-vehicle crashes.

The analysis focused on the possible effect of DRLs in reducing crashes during daylight or twilight hours, as opposed to nighttime hours, when traditional lighting would be in use by all drivers. Therefore, the target time period is daytime, including dawn and dusk and the comparison time period is night.

Target crashes and comparison crashes are defined by the crash configuration. Ideally, the only difference between daytime target crashes and daytime comparison crashes is that the set of daytime target crashes consists of crashes that could be affected by DRLs, while the set of daytime comparison crashes consists of crashes that would not be affected by DRLs. For example a target crash is one where DRLs can be seen by the driver of the other crash involved vehicle. An example of a comparison crash is a crash involving a single vehicle, where the visibility of DRLs is not relevant.

Neither the FARS nor the SDS data bases have a variable that partitions the data exactly into target and comparison crashes. The SAS® code used to partition FARS two-vehicle different direction crashes and single- vehicle crashes appears in the appendix. Both data sets have variables which permit one to approximate the desired partition. Therefore, it is possible that the partition of target crashes and comparison crashes may not be perfect. For example, the geometry of an angle crash might prevent a driver from seeing the DRLs of the other vehicle. If angle crashes, that cannot be affected by DRLs, are included in the set of target crashes, the estimated effect of DRLs, using FARS data, will be underestimated. At night, one assumes neither the target crashes nor the comparison crashes should be affected by DRLs. This assumption, like all assumptions can be challenged. For example, a driver of a DRL-equipped vehicle does not turn on his head/tail lights at night, which causes a crash. Again this unlikely set of events is within the realm of possibility; however, the available data do not permit one to identify or analyze such crashes. Two-vehicle crashes in FARS were further distinguished, for the purposes of this study, by focusing on those involving crashes in which the two vehicles were traveling in different directions.

The FARS target crashes include head-on, sideswipe opposite direction and angle crashes. The variables to identify crashes of vehicles traveling in different directions are not included in the SDS, therefore the SDS data contain both different direction and same direction crashes. For both FARS and SDS data, the set of single-vehicle crashes is used as a set of comparison crashes. When using FARS data, an additional set of comparison crashes can be used, namely two-vehicle crashes where both vehicles are traveling in the same direction, which includes rear-end crashes and sideswipe same direction crashes. Table 2 summarizes target and comparison crashes for both FARS and SDS.

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[17] Data from Florida, Maryland, Missouri, and Pennsylvania are maintained in NHTSA's *State Data System (SDS)*. The SDS is a collection of police-reported crash data files for 17 states maintained by NHTSA. States participating in the SDS forward their crash files to NHTSA, which are converted into a common file structure using the Statistical Analysis System (SAS®). Two criteria were used to select the four states. First the data, for the given time period, had to be available to NHTSA for analysis. Secondly the state data had to contain the Vehicle Identification Number, VIN, variable used to identify the presence or absence of DRLs. Florida, Maryland, Missouri and Pennsylvania were states that met both these requirements.

The comparison groups of crashes, ideally, would represent those crashes which would not be affected by the presence or absence of DRLs. In the case of nighttime crashes, it has been pointed out that the use of DRLs may cause head lamps to burn out more frequently contributing to an increase in nighttime crashes. However, only early Volkswagen and Volvo vehicles use full intensity lower beam headlamps for DRLs. In addition all vehicles equipped with DRLs are relatively new, model year 1995 and later, so the potential problem of burned out head lamps should be minimal. The set of "other two-vehicle crashes" requires the assumption that a following vehicle's DRLs are not visible in the rear view mirror or that the detection of the DRLs would not reduce the risk of a crash. This assumption may not be met if a vehicle turns in front of another vehicle’s lane of travel and is rear-ended. Hauer (1995) pointed out that single-vehicle crashes may also be affected by DRLs. Namely, two-vehicles on a collision course may detect each other earlier due to DRLs. In such a situation, a multi-vehicle crash may be avoided and a single-vehicle crash may result. Thus, all three comparison groups, nighttime crashes, other two-vehicle crashes, and single-vehicle crashes may not be statistically independent of DRLs, a required theoretical assumption for the analysis performed here. However, from a practical point of view, these groups are as statistically independent from the target, as is reasonably possible. That is, in general, a two-vehicle opposite direction crash does not cause nor does it prevent a single vehicle crash. Likewise a single vehicle crash does not cause nor does it prevent a two-vehicle crash.

As noted above, the SDS uses all two-vehicle crashes as its set of target crashes. This set of target crashes contains rear-end, side impacts and sideswipe same direction crashes, which are not expected to be affected by DRLs. As such, these crashes ideally should not be included in the set of target crashes. The result of these unwanted target crashes is to reduce the estimated effectiveness of DRLs. Although imperfect, the SDS does provide useful estimates of the effect of DRLs. Table 2 summarizes the target and comparison crashes used in this effort.

Crashes of three or more vehicles were eliminated from the analysis. The crash geometry can become quite complex and vague for crashes of three or more vehicles and the number of such crashes is small. It is easy to misclassify such a crash as a target or a comparison crash, and there are times when such a crash is both. Therefore, to reduce the possibility of contamination of the analysis, all crashes involving three or more vehicles have been eliminated.

Table 2
Crash Types and Data System

Crash Type	FARS	SDS
TARGET CRASHES	Two-vehicle Different Direction Crashes	All Two-vehicle Crashes
COMPARISON CRASHES	(1) Single-Vehicle Crashes or (2) Two-vehicle Same Direction Crashes	Single-Vehicle Crashes

Another possible source of contamination, albeit a small one, is crashes involving parked vehicles. To insure a vehicle involved in the crash was not parked, the requirement that a driver was present or that the driver had left the scene was imposed. Due to limitations of the state data, this requirement could only be imposed when using the FARS data set.

The target group of vehicles with daytime running lamps was identified by make, model, and model year. Vehicles of the same make and model, manufactured in earlier years, were selected for the first set of comparison vehicles. However, one must realize that within a given make and model, small changes occur, for example, in engine size or body style, the effects of which, could be confounded with the DRL results.

In the event that FARS or the SDS do not adequately separate the make and model, that make model was not included in the analysis to assure that only vehicles equipped with DRLs are included in the target group of vehicles. The target and the first set of comparison vehicles are listed in Table 3.

For every make and model, the first set of comparison model vehicles is always a year or two older than the corresponding DRL-equipped model vehicles. An argument can be made that differences between the target vehicles and the first set of comparison vehicles are due to the difference in age rather than the presence or absence of DRLs. To address this concern, a second group of Ford-manufactured comparison vehicles, without DRLs, was chosen with the same production dates. The Ford-manufactured vehicles consist of Ford, Mercury, and Lincoln passenger cars from model years 1995 to 1998. Although the choice of Ford-manufactured vehicles was arbitary, the inclusion of and additional set of comparison vehicles makes the analysis more robust. The list of Ford manufactured comparison vehicles appears in Table 4.

Table 3
DRL-Equipped Vehicles and Comparison Vehicles

Vehicle Make and Model	DRL-Equipped Model Year(s)	Comparison Model Year(s)
Buick Century	1998	1996
Buick LeSabre	1998	1996
Buick Park Avenue	1998	1996
Buick Rivera	1998	1996
Cadillac DeVille	1996-1998	1994-1995
Cadillac Eldorado	1996-1998	1994-1995
Cadillac Seville	1996-1998	1994-1995
Chevrolet Camaro	1998	1996
Chevrolet Cavalier	1996-1998	1994-1995
Chevrolet Corsica/Beretta*	1996-1998	1993-1994
Chevrolet Lumina	1998	1996
Chevrolet Geo Metro	1995-1998	1992-1994
Chevrolet Geo Prizm	1995-1998	1994-1995
Chevrolet Malibu	1998	1996
Chevrolet Monte Carlo	1998	1996
Oldsmobile Achieva	1996-1998	1994-1995
Oldsmobile Aurora	1996-1998	1994-1995
Oldsmobile Cutlass	1998	1996
Oldsmobile Eighty Eight	1996-1998	1994-1995
Oldsmobile Ninety Eight	1996-1998	1994-1995
Pontiac Bonneville	1996-1998	1994-1995

*All 1995 Chevrolet Corsicas/Berettas were not DRL-equipped and therefore are not included in either the DRL group or comparison group.

Table 3 - Continued
DRL-Equipped Vehicles and Comparison Vehicles

Vehicle Make	DRL-Equipped Model Year(s)	Comparison Model Year(s)
Pontiac Grand Am	1996-1998	1994-1995
Pontiac Grand Prix	1998	1996
Pontiac Sunfire	1996-1998	1994-1995
Saturn Sedan/Wagon	1996-1998	1994-1995
Saturn Coupe	1998	1996
Saab**	1995-1998	1992-1994
Volkswagen Golf III	1995	1994
Volkswagen GTI	1995	1994
Volkswagen Jetta III	1995	1994
Volvo (All Models)	1995-1998	1992-1994

** Saab model year 1995 convertibles are not included.

The analytic approach used to estimate the effectiveness of daytime running lamps uses two measures of effectiveness, the odds ratio and simple odds. Separate estimates were made using data from FARS and SDS. Both measures were calculated for each combination of target group and comparison group and the results are combined to obtain a weighed effectiveness of DRLs using both data systems. The first measure of effectiveness, the odds ratio, ? , is defined as:

? = (TD/CD)/(TN/CN),

where:

TD is the number of vehicles in Targeted crashes during Daylight.

CD is the number of vehicles in Comparison crashes during Daylight.

TN is the number of vehicles in Targeted crashes at Night.

CN is the number of vehicles in Comparison crashes at Night.

Table 4
Ford Comparison Vehicles

Vehicle Make/Model	Comparison Model Years
Ford Contour	1995-1998
Ford Crown Victoria	1995-1998
Ford Escort	1995-1998
Ford Mustang	1995-1998
Ford Taurus*	1995-1998
Lincoln Continental	1995-1998
Lincoln Mark VII/VIII	1995-1998
Lincoln Town Car	1995-1998
Mercury Cougar	1995-1998
Mercury Marquis	1995-1998
Mercury Mystique	1995-1998
Mercury Sable	1995-1998
Mercury Tracer	1995-1998

* Approximately 30,000 Taurus vehicles were equipped with DRL for OEM fleet purchase from 1995 to 1998. This is 2 percent of the Taurus 1995 to 1998 population.

The odds ratio is calculated for vehicles equipped with daytime running lamps $?_{DRL}$ and for a comparison group of similar vehicles $?_{CMP}$. Dividing $?_{DRL}$ by $?_{CMP}$ provides an estimate of DRL effectiveness and eliminates or reduces the consequence of any factors not included in the analysis that affect both odds. The estimated effectiveness of the daytime running lamps is defined by:

$$E_1 = 1-(?_{DRL}/?_{CMP})$$

The square of the standard error, se^2, is estimated to be sum of the reciprocals of the eight observations (e.g., TD_1 CD_1 TN_1 CN_1 ...). The weight, used to combine their results for the analyses, is defined as $? = 1/se^2$.

The second measure of effectiveness is the simple odds O and is the number of target crashes divided by "all other" crashes and is defined as:

$$O = TD/(CD+TN+CN)$$

Since the number of night crashes is small, small changes in night crashes, TN and CN, can have a large effect on the estimated effectiveness, E_1. Theeuwes and Riemersma proposed the simple odds in 1985 to measure the effectiveness of DRLs in response to this concern. The simple odds is calculated for vehicles equipped with daytime running lamps O_{DRL} and for a comparison group of similar vehicles O_{CMP}. Dividing O_{DRL} by O_{CMP} provides a second estimate of DRL effectiveness and eliminates or reduces the consequence of any factors not included in the analysis that effect both simple odds. The estimated effectiveness of the daytime running lamps, using this measure, is defined as:

$$E_2 = 1\text{-}(O_{DRL}/O_{CMP})$$

The square of the standard error, se^2, is estimated to be sum of the reciprocals of the four observations. The weight is defined as ? = $1/se^2$. The weights are then used to estimate the combined effects for the FARS data and the same technique is used to compute the weights for the SDS data. The combined effects are estimated by the means of the log odds method as described by Fleiss. These calculations were used with the FARS and SDS data presented in the following sections.

DRL Effectiveness in Fatal Crashes

The target crashes are two-vehicle crashes where the vehicles are traveling in different directions. The target crashes include head-on, sideswipe opposite direction and angle crashes. The remainder of the two-vehicle crashes consists of the first comparison group of crashes.

Table 5 shows the cross tabulation of the target and other two-vehicle crashes under daytime and nighttime conditions for vehicles equipped with DRLs.

Table 5
DRL-Equipped Vehicles in Target and
Other Two-Vehicle Fatal Crashes, FARS 1995-97

Time of Day	Target Crashes	Other Two-Vehicle Crashes	Total
Daytime	412	64	476
Nighttime	195	69	264
Total	607	133	740

Table 6 shows the cross tabulation of the target and other two-vehicle crashes under daytime and nighttime conditions for the first comparison group of vehicles without DRLs, i.e. earlier GM, Saab, Volkswagen, and Volvo vehicles.

Table 6
Vehicles w/o DRL in Target and
Other Two-Vehicle Fatal Crashes, FARS 1995-97
1st Comparison Set of Vehicles - early GM etc.

Time of Day	Target Crashes	Other Two-Vehicle Crashes	Total
Daytime	806	111	917
Nighttime	400	98	498
Total	1206	209	1415

Table 7 shows the cross tabulation of the target and other two-vehicle crashes under daytime and nighttime conditions for the 2nd comparison group of vehicles without DRLs, i.e. Fords.

Table 7
Vehicles w/o DRL in Target and
Other Two-Vehicle Fatal Crashes, FARS 1995-97
2nd Comparison Set of Vehicles - Fords

Time of Day	Target Crashes	Other Two-Vehicle Crashes	Total
Daytime	513	78	591
Nighttime	239	70	309
Total	752	148	900

Table 8 shows the cross tabulation of the target and other two-vehicle crashes under daytime and nighttime conditions for vehicles equipped with DRLs. This time the comparison crashes are fatal single vehicle crashes. Fatal single vehicle crashes include fatal crashes where a non-occupant fatality may occur. For example, a bicyclist or a pedestrian may be the only fatality in the crash.

Table 8
DRL-Equipped Vehicles in Target and
Single-Vehicle Crashes, FARS 1995-97

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	412	227	639
Nighttime	195	321	516
Total	607	548	1155

Table 9 shows the cross tabulation of the target and other two-vehicle crashes under daytime and nighttime conditions for the first comparison group of vehicles without DRLs.

Table 9
Vehicles w/o DRL in Target and
Single-Vehicle Crashes, FARS 1995-97
1st Comparison Set of Vehicles - early GM etc.

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	806	457	1,263
Nighttime	400	612	1,017
Total	1206	1074	2,280

Table 10 shows the cross tabulation of the target and other two-vehicle crashes under daytime and nighttime conditions for the second set of comparison vehicles without DRLs.

Table 10
Vehicles w/o DRL in Target and Single-Vehicle Crashes, FARS 1995-97
2nd Comparison Set of Vehicles - Fords

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	513	279	792
Nighttime	239	410	649
Total	752	689	1,441

Using the formulae shown on pages 11 and 12, estimates of DRL effectiveness were obtained by comparing the target crashes, i.e., head-on, sideswipe opposite direction and angle crashes, as a group to other two-vehicle fatal crashes and to single-vehicle fatal crashes for both sets of comparison vehicles. Table 11 presents the results of these calculations using the FARS data. In this table (and other subsequent, similar tables), a positive effectiveness indicates a safety benefit, .i.e., that DRLs are reducing target crashes.

Table 11
Estimates of DRL Effectiveness in Fatal Crashes
FARS 1995-97

Analytic Approach	Effectiveness	Statistically Significant?
1st Comparison Set of Vehicles - GM etc.		
Odds Ratio - Other 2 Vehicle	-28%	No
Simple Odds - Other 2 Vehicle	5%	No
Odds Ratio - Single-Vehicle	-10%	No
Simple Odds - Single-Vehicle	-1%	No
2nd Comparison Set of Vehicles - Ford		
Odds Ratio - Other 2 Vehicle	-18%	No
Simple Odds - Other 2 Vehicle	5%	No
Odds Ratio - Single-Vehicle	5%	No
Simple Odds - Single-Vehicle	0%	No

Estimates were calculated by combining estimates shown in Table 11 using the methods described in Fleiss (1981). The combined estimate of effectiveness using the odds ratio results was -8 percent for vehicles equipped with DRLs. The same data produced a combined effectiveness of 2 percent for vehicles equipped with DRLs when the simple odds approach is used. Neither estimate was statistically significant at the p=0.05 level. A result is statistically significant at the p = .05 level if the probability that the result occurred by chance, i.e., by the luck of the draw, is less than 5 percent.

DRL Effectiveness in Non-Fatal Crashes

Data obtained from Florida, Maryland, Missouri and Pennsylvania were also used to analyze the effectiveness of DRLs. Florida, Maryland, Missouri and Pennsylvania sent NHTSA their crash data files. The files were then converted into a common file structure suitable for analysis. These state files do not contain data concerning the relative direction or motion of vehicles, i.e., different direction or same direction. Therefore, all two-vehicle crashes become the set of target crashes and there is only one set of comparison crashes, namely single vehicle crashes. The Missouri crash data do not have the necessary information to determine if a vehicle is parked. Therefore, to maintain consistency among the states, two-vehicle crashes involving a parked vehicle were used in this portion of the analysis for all four states. The sets of target and comparison vehicles are identical to those used in the previous section to analyze fatal crashes, see Tables 3 and 4.

Florida and Maryland have wiper laws, that is when the windshield wipers are in use, the headlamps or DRLs must be on. The statistical technique used in this report may slightly under estimate the effectiveness of DRLs in these two states.

For the state crash data, target crashes, i.e., those crashes for which use of DRLs would be beneficial, are all two-vehicle daytime crashes. All single-vehicle crashes were used as the set of comparison crashes. Table 12 shows the cross tabulation of the Florida target/single-vehicle crashes vs. light condition daytime/nighttime for vehicles equipped with DRLs. Tables 13 and 14 show the cross tabulation of the Florida target/single-vehicle crashes vs. light condition of daytime/nighttime for both comparison groups of vehicles without DRLs. Tables 15, 16 and 17 present data using the same cross tabulations from Maryland. Missouri’s data is presented in Tables 18, 19 and 20, while Tables 21, 22 and 23 present similar crash data from Pennsylvania.

Table 12
DRL-Equipped Vehicles in Target and
Single-Vehicle Crashes, Florida 1995-96

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	3,475	262	3,737
Nighttime	1,203	228	1,431
Total	4,678	490	5,168

Table 13
Vehicles w/o DRL in Target and
Single-Vehicle Crashes, Florida 1995-96
1st Comparison Set of Vehicles - early GM etc.

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	10,001	623	10,624
Nighttime	2,855	529	3,384
Total	12,856	1,152	14,008

Table 14
Vehicles w/o DRL in Target and
Single-Vehicle Crashes, Florida 1995-96
2nd Comparison Set of Vehicles - Fords

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	8,179	582	8,761
Nighttime	2,682	595	3,277
Total	10,861	1,117	12,038

Table 15

DRL-Equipped Vehicles in Target and Single-Vehicle Crashes, Maryland 1995-96

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	1,283	294	1,577
Nighttime	311	66	377
Total	1,594	360	1,954

Table 16
Vehicles w/o DRL in Target and Single-Vehicle Crashes, Maryland 1995-96
1st Comparison Set of Vehicles - early GM etc.

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	3,823	698	4,521
Nighttime	857	194	1,051
Total	4,680	982	5,572

Table 17
Vehicles w/o DRL in Target and Single-Vehicle Crashes, Maryland 1995-96
2nd Comparison Set of Vehicles - Fords

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	2,419	522	2,941
Nighttime	598	154	752
Total	3,017	676	3,693

Table 18
DRL-Equipped Vehicles in Target and Single-Vehicle Crashes, Missouri 1995-96

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	1,683	190	1,873
Nighttime	533	253	786
Total	2,216	443	2,659

Table 19
Vehicles w/o DRL in Target and Single-Vehicle Crashes, Missouri 1995-96
1st Comparison Set of Vehicles - early GM etc.

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	6,221	691	6,912
Nighttime	1,767	650	2,417
Total	7,988	1,341	9,329

Table 20
Vehicles w/o DRL in Target and Single-Vehicle Crashes, Missouri 1995-96
2nd Comparison Set of Vehicles - Fords

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	4,041	503	4,544
Nighttime	1,283	578	1,861
Total	5,324	1,081	6,406

Table 21

DRL-Equipped Vehicles in Target and
Single-Vehicle Crashes, Pennsylvania 1995-96

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	1,247	339	1,586
Nighttime	400	331	431
Total	1,647	670	2,317

Table 22
Vehicles w/o DRL in Target and
Single-Vehicle Crashes, Pennsylvania 1995-96
1st Comparison Set of Vehicles - early GM etc.

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	4,590	1,085	5,675
Nighttime	1,312	982	2,294
Total	5,902	2,067	7,969

Table 23
Vehicles w/o DRL in Target and
Single-Vehicle Crashes, Pennsylvania 1995-96
2nd Comparison Set of Vehicles - Fords

Time of Day	Target Crashes	Single-Vehicle Crashes	Total
Daytime	2,510	626	3,136
Nighttime	773	580	1,353
Total	3,283	1,206	4,489

Again using the formulae shown on pages 10, 11, and 12, separate estimates of DRL effectiveness were obtained by comparing the target crashes to both sets of comparison crashes using the Florida, Maryland, Missouri, and Pennsylvania data shown in Tables 12 through 23. These estimates for the first and second groups of comparison vehicles are presented in Table 24 and Table 25, respectively.

Two different measures of DRL effectiveness were calculated using data from each of the four states, yielding the eight percentage changes shown for each group of comparison vehicles. Eleven of the sixteen measures show a reduction in the crash rate associated with the presence of daytime running lamps. Of these eleven, six are statistically significant at the p = .05 level.

Table 24
Estimates of DRL Effectiveness in Non-Fatal Crashes
Florida, Maryland, Missouri, and Pennsylvania 1995-96
1st Comparison Set of Vehicles - early GM etc.

State	Analytic Approach	Effectiveness	Statistically Significant at p = .05?
Florida	Odds Ratio	15%	No
	Simple Odds	18%	**Yes**
Maryland	Odds Ratio	25%	No
	Simple Odds	13%	**Yes**
Missouri	Odds Ratio	-27%	No
	Simple Odds	14%	**Yes**
Pennsylvania	Odds Ratio	4%	No
	Simple Odds	14%	**Yes**

Note that only the simple odds provides statistically significant results. Recall that the square of the standard error is estimated to be the sum of the reciprocals of the observations. In the case of the odds ratio, for both daylight and night, one has four observations, namely TD, CD, TN, and CN, however the simple odds combines three of these observations CD, TN, and CN into a single observation CD+TN+CN. The reciprocal of this combined observation is smaller than the sum of the reciprocals of CD, TN, and CN thus the square of the standard error of the simple odds is smaller than the square of the standard error of the odds ratio and the associated estimate is more likely to be statistically significant.

Table 25
Estimates of DRL Effectiveness in Non-Fatal Crashes
Florida, Maryland, Missouri, and Pennsylvania 1995-96
2nd Comparison Set of Vehicles - Fords

State	Analytic Approach	Effectiveness	Statistically Significant at p = .05?
Florida	Odds Ratio	19%	No
	Simple Odds	3%	No
Maryland	Odds Ratio	22%	No
	Simple Odds	-1%	No
Missouri	Odds Ratio	-16%	No
	Simple Odds	-1%	No
Pennsylvania	Odds Ratio	-1%	No
	Simple Odds	8%	**Yes**

Estimates were calculated by combining the estimates shown in Tables 24, and 25 using the methods described in Fleiss (1981). The combined estimate using the odds ratio produced an effectiveness of 5 percent for vehicles equipped with DRLs. The same data combined to produced an effectiveness of 7 percent, using the simple odds procedure, for vehicles equipped with DRLs and was statistically significant at the p=0.05 level.

DRL Effectiveness for Pedestrians

As drivers are more likely to avoid a crash with a vehicle equipped with daytime running lights, a pedestrian may also be more likely to avoid a crash with a DRL-equipped vehicle. To answer that question one can modify the approach used above. The Fatality Analysis Reporting System, FARS 1995 to 1997, can again be used for this analysis. However, the analysis must be performed at the person level, rather than the vehicle level. The target group of persons will be pedestrians, the comparison group of persons is vehicle occupants. The crash type will be restricted to single-vehicle crashes. The target time period is daytime, including dawn and dusk and the comparison time period is night. The results follow:

Table 26
SingleVehicle Crashes FARS 1995-97
Vehicle DRL Equipped

Time of Day	Pedestrian Deaths	Occupant Deaths	Total
Daytime	40	210	250
Nighttime	82	272	356
Total	123	482	605

Table 27
SingleVehicle Crashes FARS 1995-97
1st Comparison Set of Vehicles - early GM etc.

Time of Day	Pedestrian Deaths	Occupant Deaths	Total
Daytime	101	402	503
Nighttime	155	506	661
Total	256	908	1,164

Table 28
SingleVehicle Crashes FARS 1995-97
2nd Comparison Set of Vehicles - Fords

Time of Day	Pedestrian Deaths	Occupant Deaths	Total
Daytime	71	236	307
Nighttime	109	350	459
Total	180	586	766

Table 29
Estimates of DRL Effectiveness for Pedestrians
FARS 1995-97

Analytic Approach	Effectiveness	Statistically Significant?
1st Comparison Set of Vehicles - GM etc.		
Odds Ratio	24%	No
Simple Odds	25%	No
2nd Comparison Set of Vehicles - Ford		
Odds Ratio	35%	No
Simple Odds	31%	No

Estimates for both the odds ratio and simple odds were calculated for the data shown in Table 29 using the methods described in Fleiss (1981). The odds ratio combined estimate, gives an effectiveness of 29 percent in pedestrian fatalities for vehicles equipped with DRLs. The simple odds combined estimate, gives an effectiveness of 28 percent in pedestrian fatalities for vehicles equipped with DRLs. The combined estimate for the simple odds is statistically significant at the p=0.05 level.

These results are among the most striking of this report. Although beyond the scope of this report, additional analysis can be performed to measure the effect of DRLs on pedestrians. For example, the comparison group for pedestrians was the set of occupants of single vehicle crashes can be repeated using drivers of single vehicle crashes. In addition, as additional data become available the estimates should become more robust.

Conclusions

The effectiveness of daytime running lamps was analyzed in the preceding sections using data from FARS and four SDS states (Florida, Maryland, Missouri, and Pennsylvania). FARS data were from calendar years 1995 to 1997. SDS data were from calendar years 1995 and 1996. The FARS results were inconclusive for two-vehicle fatal crashes. Using the FARS data the combined odds ratio technique shows an increase in fatal crashes of 8 percent for vehicles equipped with DRLs, the combined simple odds results show a decrease in fatal crashes of 2 percent. Neither result is statistically significant.

Florida, Maryland, Missouri and Pennsylvania non-fatal crashes produce a combined estimated reduction of 5 percent for vehicles equipped with DRLs using the odds ratio technique. When the simple odds approach is used, the statistically significant reduction of 7 percent for vehicles equipped with DRLs is obtained.

In addition to the analysis of two vehicle crashes, the effectiveness of DRLs in reducing pedestrian fatalities was examined. Four measures were examined. Each measure showed that DRLs reduced pedestrian deaths during daylight in single-vehicle crashes. The four measures showed improvements of 24 percent to 31 percent. None of the four single measures were statistically significant at the $p = 0.05$ level. However, when the estimates were combined to obtain estimates for the odds ratio a reduction of 29 percent was obtained. A similar estimate for the simple odds was obtained, a reduction of 28 percent, which was statistically significant at the $p=0.05$ level.

The historical studies reported in Table 1, examine the effectiveness of DRLs for crashes of all severities. The analysis using data from Florida, Maryland, Missouri, and Pennsylvania uses non-fatal crashes and estimates the effectiveness of DRLs to be 5 to 7 percent. This is consistent with the previous results.

Appendix

The following SAS® code was used to partition FARS 1996 vehicle crashes. The code for the SDS is similar.

```
/* COMPARISON CRASHES SINGLE VEHICLE CRASHES */

LIBNAME FARS96 'L:\FARSSAS\FARS96';

DATA CRASH;
  SET FARS96.ACCIDENT(KEEP = ST_CASE LGT_COND VE_FORMS MAN_COLL
WEATHER);

LENGTH TGT_CRSH $8;

*  IF TWO VEHICELES CRASH AND;
*  HEAD-ON  OR  ANGLE  OR  SIDESWIPE DIFFERENT DIRECTIONS;

IF (VE_FORMS EQ 2) AND
        ((2 EQ MAN_COLL) OR (4 EQ MAN_COLL) OR (6 EQ MAN_COLL))
        THEN TGT_CRSH ='MUL TGT';

/* ELSE SINGLE VEHICLE CRASHES */
ELSE IF (VE_FORMS EQ 1) THEN TGT_CRSH = 'SINGLE';
ELSE DELETE;

*DEFINE THE DICHOTOMOUS VARIABLE D_CRASH;

IF (VE_FORMS EQ 2) AND
        ((2 EQ MAN_COLL) OR (4 EQ MAN_COLL) OR (6 EQ MAN_COLL))
        THEN D_CRASH = 1;

/* ELSE SINGLE VEHICLE CRASHES */
ELSE IF (VE_FORMS EQ 1) THEN D_CRASH = 0;
ELSE DELETE;

LENGTH LIGHT $7;

*IF DAYLIGHT DAWN OR DUSK;
IF (LGT_COND EQ 1 OR 4 LE LGT_COND LE 5) THEN LIGHT = 'DAYTIME';
```

```
*IF DARK OR DARK AND LIGHTED;
ELSE IF (2 LE LGT_COND LE 3) THEN LIGHT = 'NIGHT';
ELSE DELETE;

*  DEFINE THE DICHOTOMOUS VARIABLE D_LIGHT;
IF (LGT_COND EQ 1 OR 4 LE LGT_COND LE 5) THEN D_LIGHT = 1;
ELSE IF (2 LE LGT_COND LE 3) THEN D_LIGHT = 0;

* DEFINE THE DICHOTOMOUS VARIABLE MUL_DAY;
* THIS IS FOR THE SIMPLE ODDS CALCULATION;

IF (D_CRASH = 1 AND D_LIGHT = 1) THEN MUL_DAY =1;
ELSE MUL_DAY = 0;
```

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