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# RELATIONSHIPS AMONG DRIVER AGE, VEHICLE COST, AND FATAL NIGHTTIME CRASHES

JOHN M. SULLIVAN
MICHAEL J. FLANNAGAN

UMTRI
UNIVERSITY OF MICHIGAN
TRANSPORTATION RESEARCH INSTITUTE

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John M. Sullivan
Michael J. Flannagan

The University of Michigan
Transportation Research Institute
Ann Arbor, Michigan 48109-2150
U.S.A.

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16. Abstract

The ratio of crashes in darkness to those occurring in daylight has been used to assess the relative sensitivity of certain risk factors to ambient light level. When applied in a way that maintains control over exposure level, use of dark/light ratios can be helpful in identifying crash factors that are particularly sensitive to darkness. For example, during daylight saving time changeovers, dark/light ratios have been used to demonstrate the high vulnerability of pedestrians in darkness. In this report, we examine the application of the night/day ratio to evaluate changes in crash risk in darkness associated with vehicle characteristics. We find that correlations between driver age, vehicle cost, and patterns of driving suggest that links between vehicle equipment and crash risk in darkness cannot be asserted without also taking these factors into account. Younger drivers drive proportionally more miles at night, and show proportionally higher risk of fatal crash involvement at night than older drivers. Young drivers also drive proportionately less expensive vehicles than middle-aged and older drivers, and they drive an increasing proportion of originally expensive vehicles as the age of the vehicle increases. These changes in driver age demographics must be considered when evaluating nighttime crash countermeasures.

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# Introduction

In previous reports that investigated the effects of darkness on crash risk, we used the ratio of crashes in darkness to crashes in light as a dependent measure (Sullivan & Flannagan, 2004, 2006). The key assumption in using that ratio is that it provides an unbiased measure of risk in darkness. Comparisons are thus made between different crash types, and those that are significantly affected by light level can be identified. The dark/light ratio, however, cannot be interpreted in this way without first controlling those factors that are typically confounded with day and night. This was accomplished in the cited studies by restricting the analysis to the same one-hour time interval on days before and after changeovers to and from daylight saving time. The assumption made was that people and traffic conditions would be similar at the same time over different days, and that the most influential difference between days before and after the changeover would be the level of ambient light. Thus, other factors that may differ between day and night—for example, fatigued driving—are assumed to have the same level of influence. That is, we assume that fatigued driving is more related to time of day than to sun position and level of natural light. This kind of control is important because fatigued driving may influence some types of crashes more than others. Single-vehicle road departure crashes, for example, are associated with driver fatigue (Najm, Mironer, & Fraser, 1995) and driver fatigue is more prevalent late at night. Because darkness and driver fatigue are both associated with night, an analysis based on time of day alone will not be able to separate the two effects.

In the present analysis, we are interested in determining how vehicle characteristics might influence crash risk in darkness. At first glance, it might seem that vehicles would not be subject to the kinds of confounds with darkness that crash types are subject to—a driver might be expected to be equally tired for a given hour of the day regardless of the model vehicle driven. Differences found in nighttime crash risk between two vehicle models might thus be attributed to differences in how the respective vehicles are equipped. Differences in vehicle sales numbers could be normalized to daytime crashes to avoid comparisons based on absolute numbers. However, before applying such a strategy, it is important to ask whether there might be any reason to observe differences in a vehicle's nighttime risk level that is unrelated to how the vehicle is equipped. One potential intermediary factor is the age of the driver and the association of age with the time of day a vehicle is driven and the kind of vehicle driven. In a study by Massie, Campbell, and Williams (1995), young drivers were found to have an especially high risk per mile for fatal collisions at night compared to day. Young drivers also drive disproportionately more miles at night than older drivers. Thus, young drivers have both a greater nighttime exposure level and a greater nighttime crash risk than other drivers. If there are age differences among the population of drivers for different vehicles, differences in the nighttime crash risk for those vehicles might be observed that are unrelated to vehicle equipment.

In the following analysis, age differences in driving habits and nighttime risk are illustrated using the Fatality Analysis Reporting System (FARS) database and the 2001 National Household Transportation Survey (NHTS). Following this analysis, all vehicles involved in fatal crashes spanning the years 1994 to 2007 are decoded to identify their inflation-adjusted sales prices along with the age of the driver and vehicle. This analysis allows us to examine how driver age is distributed among low, medium, and high-priced vehicles and among vehicles as they age. Using the VINDICATOR database, the cost range of HID-equipped vehicles is examined and compared to other passenger vehicles to understand how these vehicles are distributed with respect to cost. Vehicles equipped with HID headlamps are one example of a newly introduced technology whose assessed impact might be altered by driver demographics.

## Drive Age and Travel Time of Day

In the first analysis, the relative nighttime exposure is examined within different age groups of drivers. To do this, the 2001 National Household Transportation survey was used to compile annual travel miles for trips starting at night (defined here as 9:00 p.m. to 6:00 a.m.) versus day (6:00 a.m. to 9:00 p.m.) for drivers in 13 five-year age groups ranging from 16 to greater than 75 years. As drivers get older, there is a steady decline in the proportion of driving at night (see Figure 1). That is, younger drivers show comparatively greater levels of nighttime exposure than older drivers. Likewise, the overall population makeup of drivers at night shifts toward younger drivers (Figure 2).

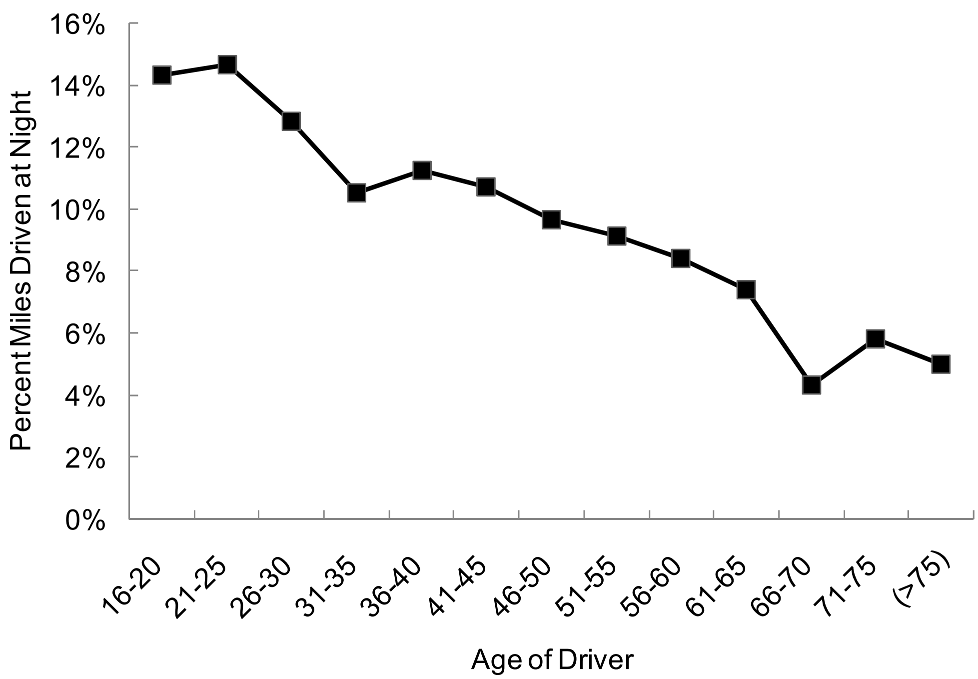


Figure 1. Proportion of driving during the night by age of driver.

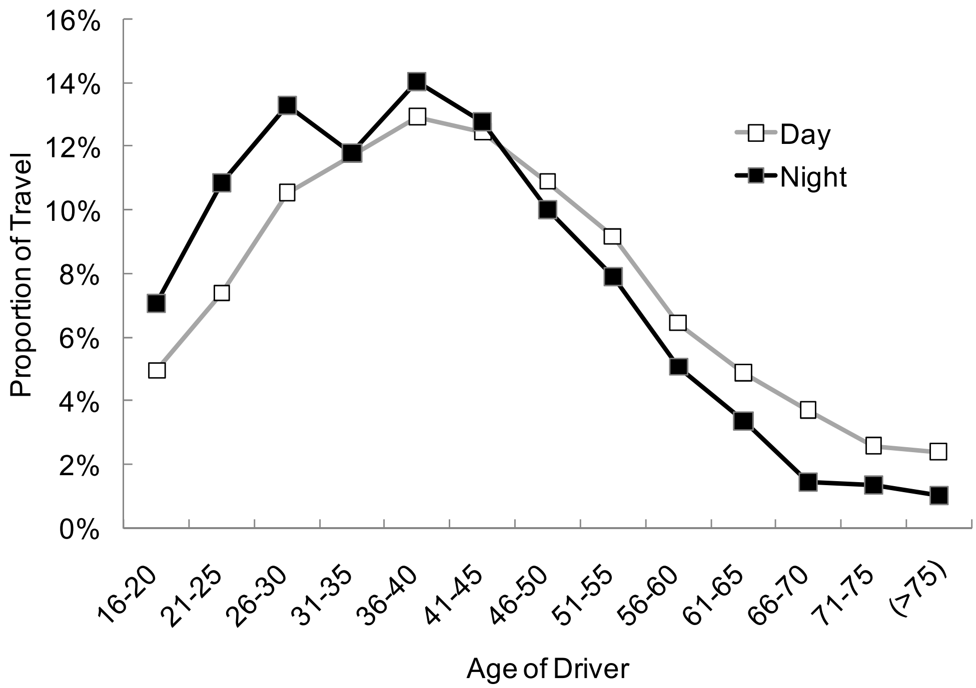


Figure 2. Proportion of all miles travelled by age of driver and time of day.

It is important to consider these age-related exposure differences in nighttime driving because, if a comparison is made between the night/day crash ratios of two vehicle models, vehicle models that are predominantly driven by younger drivers will have higher ratios simply because of differences in exposure levels. This can be illustrated with an extreme example based on the percent nighttime driving data shown in Figure 1. Note that the percent values in Figure 1 can be converted to night/day ratios (an odds ratio) using the following formula:

$$Odds = \frac{Percent}{1 - Percent}$$

Suppose we are comparing the night/day ratios of two models of car: Model O and Model Y. Model O is driven exclusively by older drivers, 66-70 years of age; Model Y is driven exclusively by younger drivers, 21-25 years of age. The odds of a trip occurring at night are 0.17 for Model Y and 0.045 for Model O. The ratio of these odds is 3.8. That is, the odds of driving Model Y at night are nearly four times greater than those of driving Model O. It is important to note that this odds difference is entirely related to exposure differences between the two vehicle models. Even if both driver groups have the same likelihood of involvement in a crash per mile, the difference in nighttime exposure alone would cause Model Y to have a disproportionately higher number of crashes at night than Model O. If we factor in age-related differences in likelihood of crash involvement in day versus night, we shall see that this nighttime difference is even further accentuated by the risk characteristics of young drivers at night.

## Driver Age and Nighttime Crash Risk

This analysis updates one of the analyses described by Massie et al. (1995) that examined age-related involvement in fatal crashes by time of day. Age-related day and night travel estimates from NHTS 2001 were combined with averaged annual fatal crash rates from FARS spanning a five-year interval, from 1999 to 2003. In the analysis, all drivers involved in fatal collisions were counted and binned into each of the 13 age groups used in the preceding exposure analysis. Likewise, night was also defined as 9:00 p.m. to 6:00 a.m. and day was defined as 6:00 a.m. to 9:00 p.m. Risk estimates for each age group by time of day were calculated as fatal crashes per 100 million miles of travel. The results are shown in Figure 3.

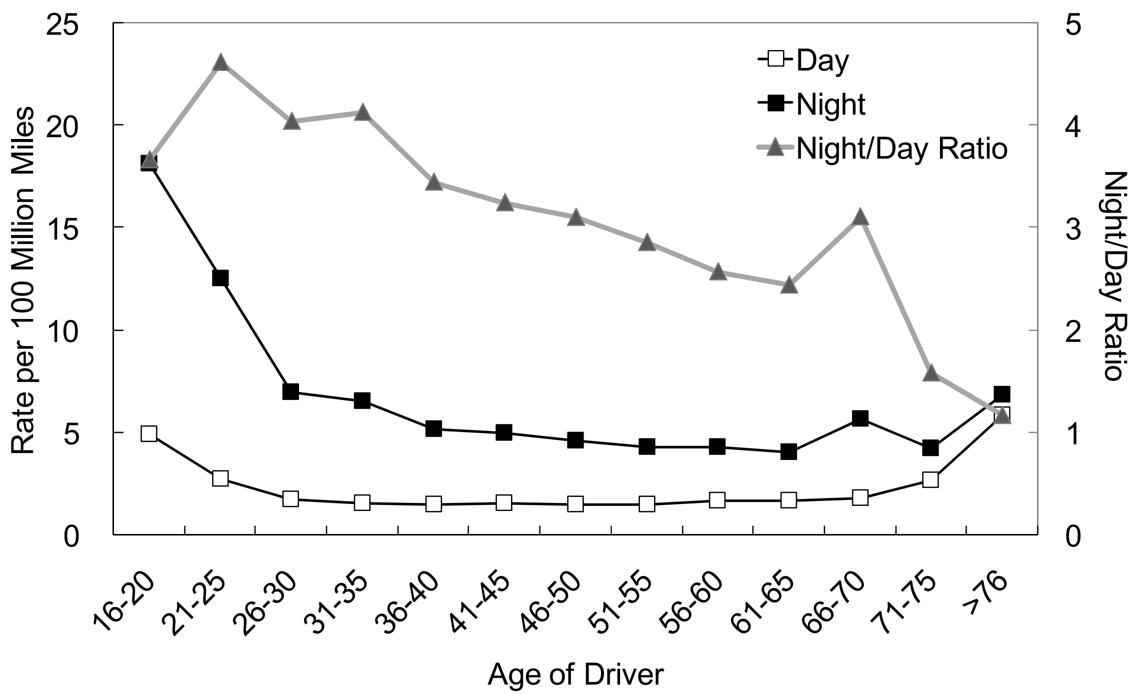


Figure 3. Rate of involvement in fatal crashes per 100 million miles travelled for day and night by driver age. The triangles illustrate the night/day risk ratio by driver age.

It is immediately apparent that nighttime crash risk among young drivers is much higher at night than it is for older drivers. Indeed, the relative risk of fatal crash involvement at night for 21- to 25-year-old drivers is about 4.5 times the daytime involvement, while it is about 3 times higher for 66- to 70-year-old drivers. The ratio of these odds suggests that the young driver group is about 1.5 times more likely to be involved in a nighttime crash than is the older driver group. Thus, there are differences between both age-related nighttime risk and exposure that multiply the influence of age on crash likelihood. With both exposure differences and risk differences factored in, the young drivers in this example are about 5.6 times as likely to be involved in a fatal nighttime crash as the older group of drivers. If Model Y were driven exclusively by 21- to 25-year-old drivers, and Model O were driven exclusively by 66- to 70-year-old drivers, the crash record would show that Model Y's night/day crash involvement ratio is 5.6 times Model O's, without regard to how these two vehicles are equipped.

Thus, driver characteristics can play a significant role in influencing the observed night/day crash risk, and it is important to recognize whether such differences may occur between vehicles of interest.

## Driver Age and the Base Price of a Vehicle

The next analysis examines how driver age is distributed among vehicles drawn from three cost brackets. The analysis is based on FARS crash data from 1994 to 2006. That is, all vehicles and drivers in this analysis were involved in a fatal crash, and it should be recognized that such a sample could be biased in some ways. Indeed, here it is assumed that driver age and base vehicle price do not substantially interact to affect the likelihood of fatal crash involvement. VIN (vehicle identification) codes that were unique to the first 10 digits were drawn from this database and decoded using the VINDICATOR database (Highway Loss Data Institute, 2008). Note that not all VINs retrieved from FARs were successfully decoded. Some VINs were incorrectly coded in the crash dataset and failed to match known vehicles; likewise, buses, heavy trucks, snowmobiles, campers, and ATVs are not recognized by VINDICATOR. From an initial set of 962,022 vehicle crash records from FARS (1994-2006), 511,151 records were matched to the VINDICATOR dataset.

In this analysis, the original base price of each vehicle was obtained from the VINDICATOR dataset. The new-vehicle prices were then adjusted to 2007 dollar amounts using the Consumer Price Index for new vehicles, available through the Bureau of Labor Statistics. Finally, vehicle prices were binned into three cost categories, based on the adjusted new vehicle price: less than $18 K, $18 K to $28 K, and $28 K to $200 K. Vehicles above $200 K were not included in the analysis.

The distribution of driver age among vehicles at different price ranges is shown in Figure 4. Note that the points in the line for each vehicle are normalized within each vehicle—that is, the points of each line sum to 100%. The figure shows that the drivers of inexpensive vehicles are generally younger drivers, while the drivers of expensive vehicles are more evenly distributed among the age groups. Alternatively, we can examine the distribution of vehicle prices within age groups (see Figure 5); here the points within each age group sum to 100%. Figure 5 shows that while expensive vehicles make up only a small proportion of vehicles within all age groups, they are proportionately smallest among young drivers.

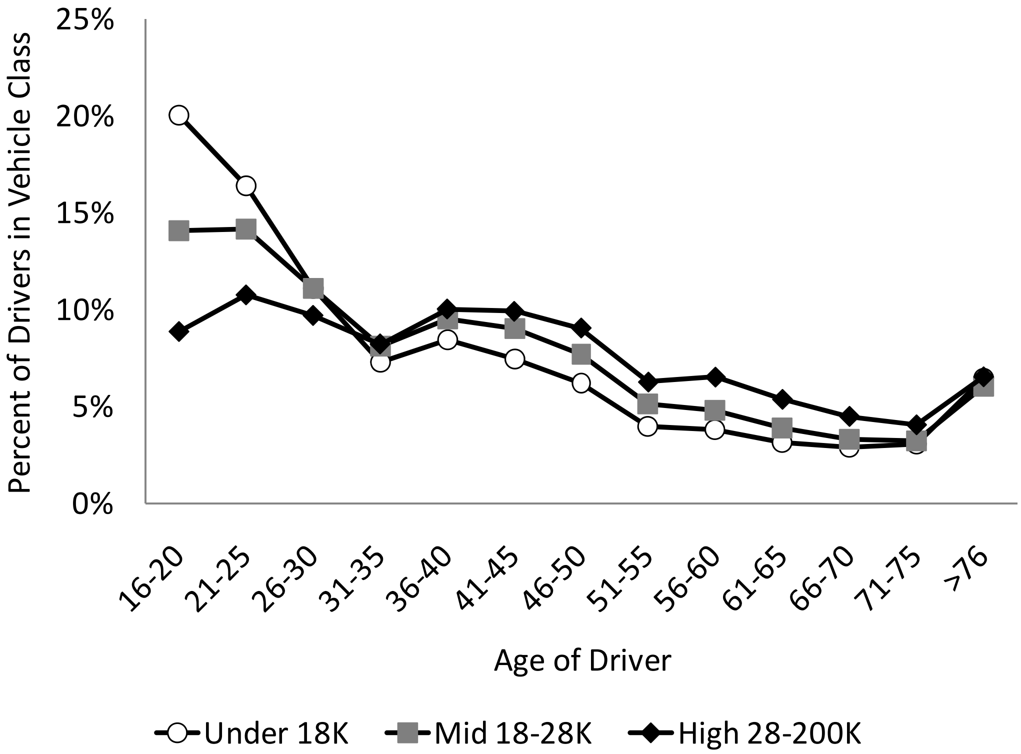


Figure 4. Distribution of driver ages among three vehicle price ranges.

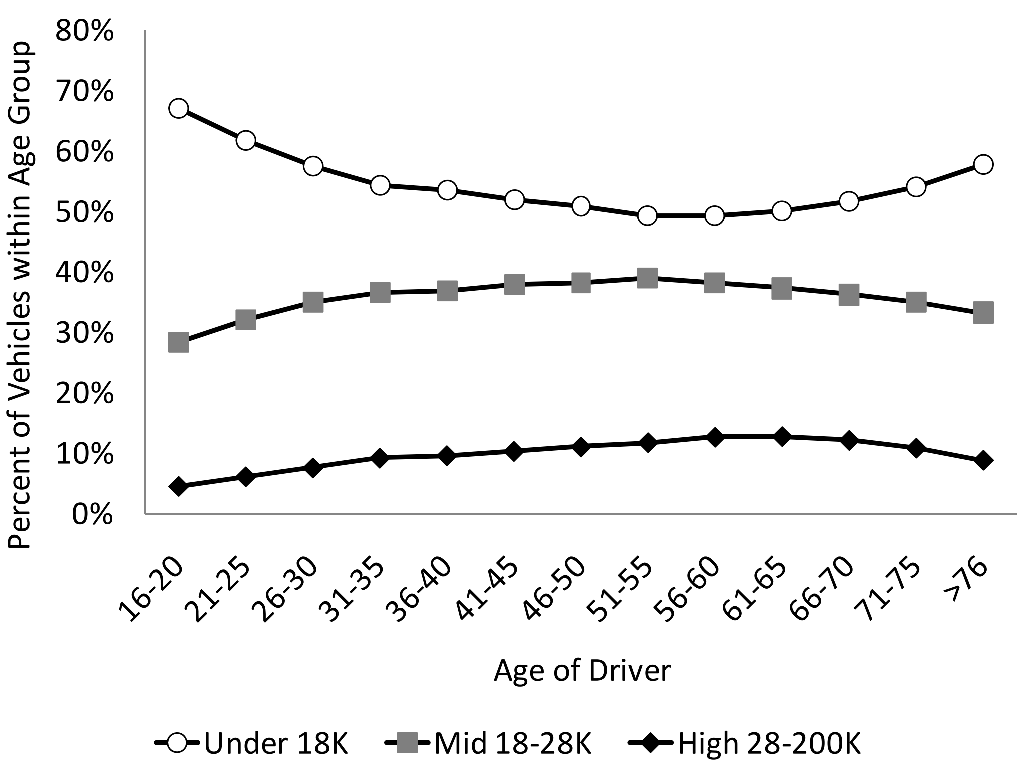


Figure 5. The relative distribution of vehicle price ranges among driver age groups.

The preceding analysis appears to show that young drivers, who likely are more limited in financial means, appear to drive proportionately more inexpensive vehicles than older drivers. While this makes intuitive sense, it should be recognized that the analysis made no effort to factor in the age of the vehicle in determining the vehicle's value. That is, only the sale price of the vehicle when it was new was used rather than the actual value of the vehicle at the time of the collision. As a vehicle ages, it depreciates in value. Thus, young drivers may indeed drive vehicles that had high original prices, but they might not drive them before they have depreciated in value sufficiently to bring them within their financial means. The distribution of drivers from four age ranges was examined for each of the three vehicle cost ranges used in the preceding analyses over the age of the vehicle. This is shown in Figures 6, 7, and 8. In Figure 6, the youngest driver age group makes up less than 15% of the drivers of new and expensive vehicles; however, they make up nearly 25% of the drivers of models more than 10 years old. Notably, older drivers show a similar pattern: Older drivers drive proportionally smaller numbers of expensive new vehicles and proportionally larger numbers of older vehicles. The two middle-aged groups dominate the driver populations of new expensive vehicles.

In Figure 7, a similar trend among younger drivers can be seen for mid-priced vehicles: The youngest driver group comprises 20% of the drivers of new mid-priced vehicles and rises above 30% for models that are more than 10 years old. In Figure 8, which shows the distribution of driver age among low-priced vehicles, the distribution of driver age is relatively stable throughout the lifespan of the low-priced vehicles. Thus, the driver demographic among low-priced vehicles appears relatively stable throughout the lifespan of the vehicle. On the other hand, for mid-priced and high-priced vehicles, the age demographic shifts significantly.

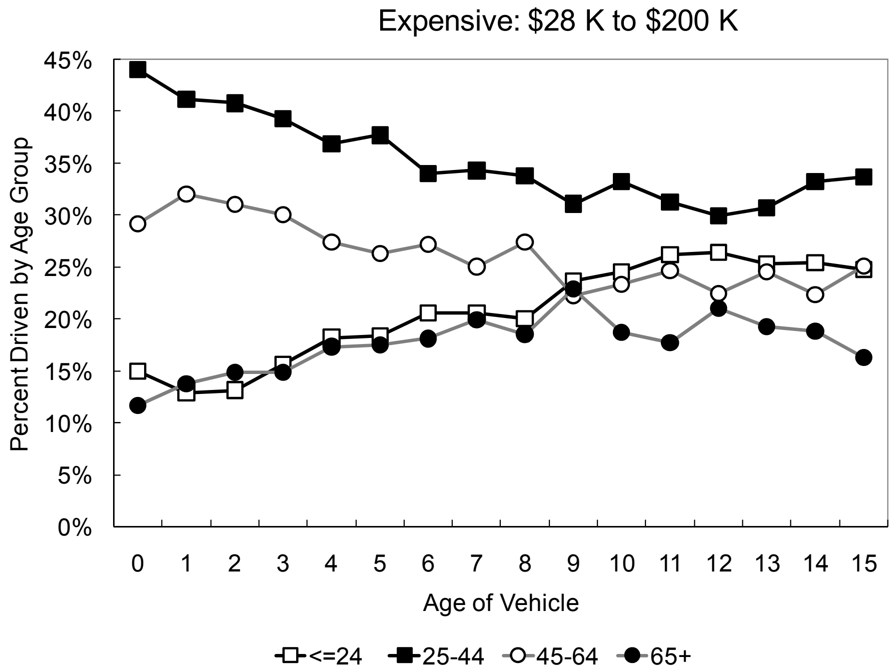


Figure 6. Proportion of drivers by age group for expensive vehicles by vehicle age.

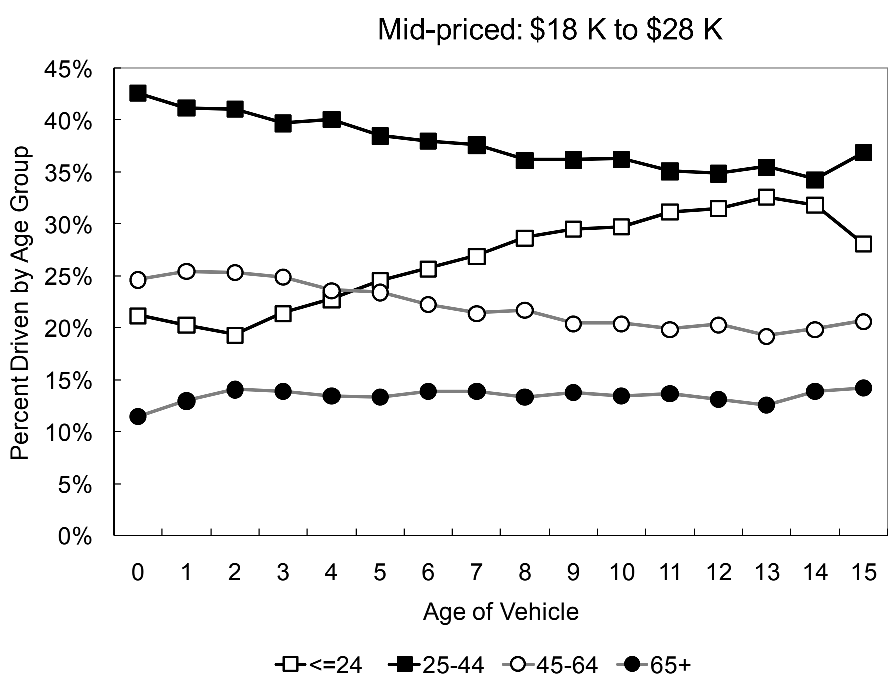


Figure 7. Proportion of drivers by age group for mid-priced vehicles by vehicle age.

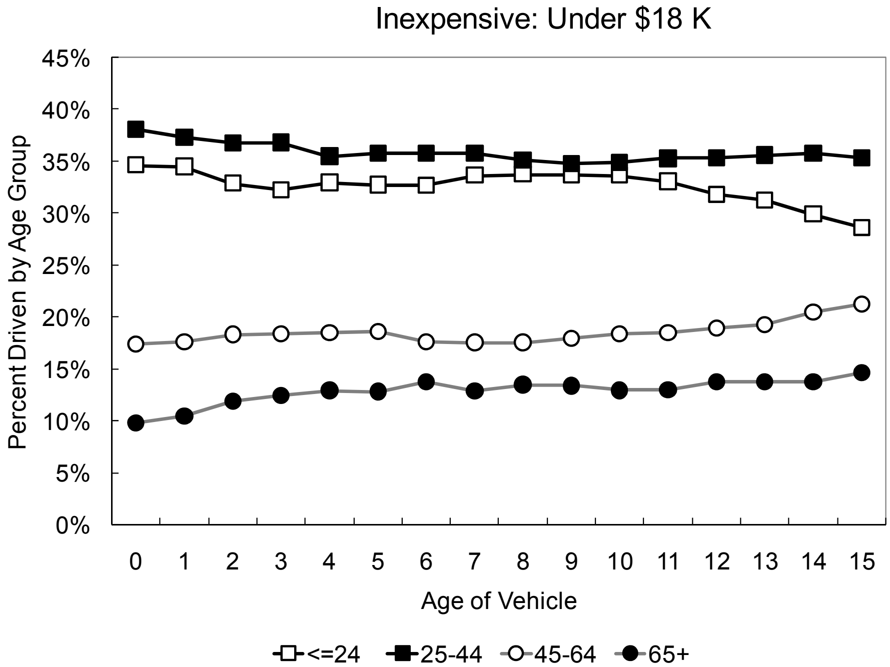


Figure 8. Proportion of drivers by age group for inexpensive vehicles by vehicle age.

It is important to consider how these changes in age distribution among vehicles might affect evaluations of nighttime crash countermeasures such as night-vision enhancement systems, pedestrian detection systems, or advanced vehicle forward-lighting systems. Many of these enhancements first appear on expensive luxury-model vehicles and are less likely to be driven by a young driver population. Moreover, these innovations also appear on newer vehicles, again making them less likely to be driven by young drivers. This suggests that even if a crash analysis is made within a selected vehicle model in which new nighttime crash countermeasures have been introduced, shifts in the driver age population between the older (and unequipped) versions of the model and the newer (equipped) versions of the same vehicle may influence the observed night/day crash ratio even more than the countermeasure. In both cases, the high crash risk of younger drivers at night, coupled with the lower likelihood that those drivers would be driving a vehicle equipped with nighttime crash countermeasures, could contribute to differences in the dark/light crash ratio that might magnify the apparent influence of the countermeasure to reduce crash risk at night. A countermeasure might thus appear to reduce nighttime crash risk when in fact driver age may be the primary influence. In view of this, it is surprising that only a mild nonsignificant trend toward lower dark/light crash ratios among luxury-model vehicles was observed in our previous report that compared the dark/light ratio of luxury- and nonluxury-model vehicles (Sullivan & Flannagan, 2008, page 20). In that report, driver age was not explicitly modeled in the analysis and could have influenced the observed results. In view of the high nighttime risk among young drivers, analyses like these should always include driver age as a predictor in the model.

## Price Distribution of HID-Equipped Vehicles

In this analysis, the assumption that high-intensity discharge (HID) headlamps are generally found on vehicles in the higher price range is examined in more detail. Vehicle makes, models, and model years for which HIDs were offered as standard or optional equipment were identified in a supplemental database. All other vehicles were assumed to have conventional tungsten-halogen headlamps. This dataset was then joined with the VINDICATOR dataset to include cost information and vehicle identification (VIN) data. All vehicles in the FARS datasets from 1994 to 2006 were then sorted into HID and non-HID equipped categories, crossed with price range, and counted. Proportions of vehicles in each cost range were then calculated for the HID and non-HID equipped categories. Note that using the crash record to obtain the relative cost distributions of vehicles is not ideal and may introduce biases if there is a systematic relationship between vehicle price and involvement in fatal crashes. Here we are provisionally assuming that such a bias does not exist or is small enough to be negligible. The results are shown in Figure 9. Nearly 70% of all HID vehicles fall into the high-cost range. In contrast, less than 10% of the non-HID vehicles are in the high-cost range. It is also worth noting than most of the HID-equipped vehicles are newer models. Thus, it is likely that proportionately fewer HID-equipped vehicles are driven by young drivers because such vehicles are both new and expensive. The actual distributions of driver age groups by vehicle type are shown in Figure 10. A contingency-table analysis of the distribution suggests that age is distributed differently between the vehicle types ($\chi^2(3, n = 470{,}667) = 99.3$, $p < .001$). There are fewer young drivers and more old drivers driving HID vehicles compared to non-HID vehicles.

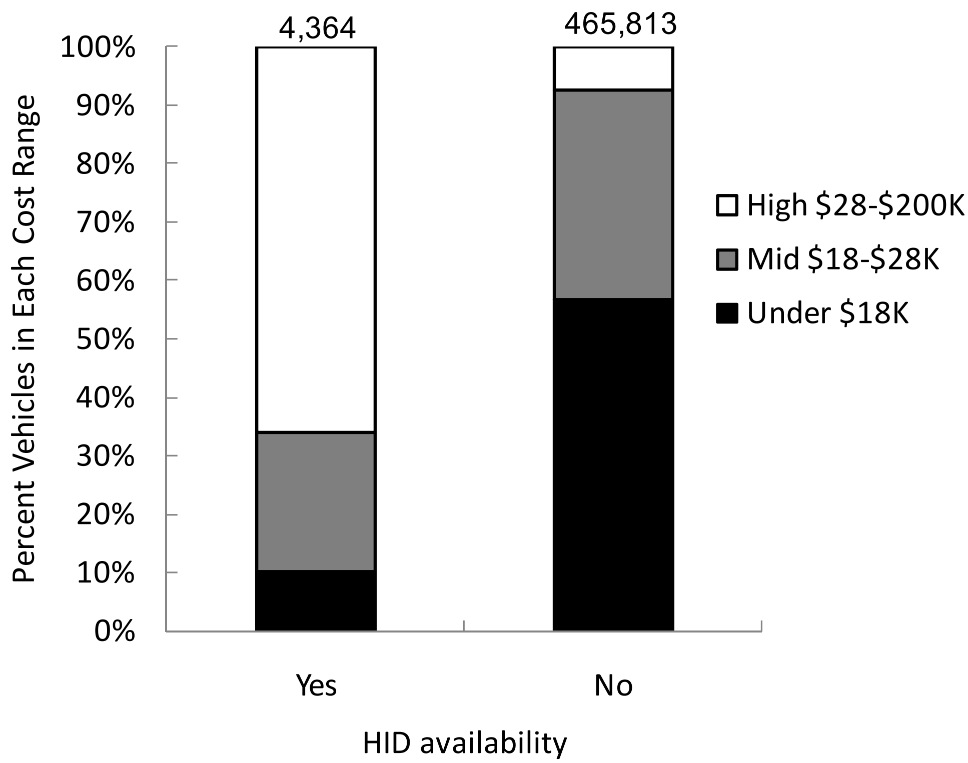


Figure 9. Percentage of vehicles in each cost category based on whether the vehicle is equipped with HID headlamps.

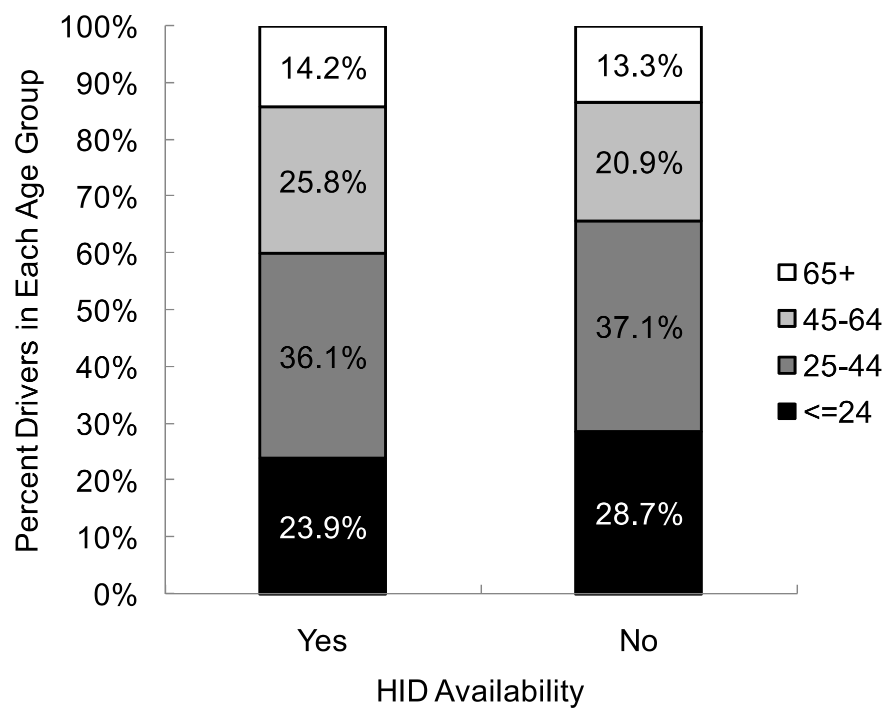


Figure 10. Distribution of driver ages between HID and non-HID equipped vehicles.

# Conclusions

The preceding series of analyses show that the driver age distribution varies systematically with respect to the time of day that a vehicle is driven, the level of nighttime fatality risk observed, the base price range of the vehicle, and the age of the vehicle. Because of this, it is important that some way of accounting for driver age be considered whenever the effectiveness of a nighttime crash countermeasure is evaluated using night/day or dark/light crash ratios. Younger drivers drive proportionally more miles at night, have proportionally higher involvements in fatal crashes in darkness per vehicle miles travelled, drive proportionally more inexpensive vehicles, and drive an increasing proportion of expensive vehicles as the age of the vehicle increases.

Because innovative technologies are frequently introduced in newer, luxury-model vehicles, it is important to consider how these differences in driver demographics might influence the observed crash risk among vehicles, especially with respect to nighttime crash countermeasures. Comparisons between vehicles equipped with new technologies and those not so equipped are likely to involve different populations of drivers—for example, fewer younger drivers may drive vehicles equipped with new technology. Such differences in driver population may occur as a hidden confounds in any analysis of the effectiveness of nighttime crash countermeasures, resulting in the possible distortion of observed effectiveness.

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