"New, Improved, Comprehensive, and Automated Driver's License Test
and Vision Screening System"
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SURVEY OF DRIVER'S LICENSE BUREAU DIRECTORS OR THEIR REPRESENTATIVES

As part of our project to determine if the current vision testing practices in the State of Arizona require enhancement, a comprehensive survey on the visual acuity testing methods of drivers was developed. Questionnaires were faxed or e-mailed to the directors of all driving licensing agencies of all 50 U.S. states, Commonwealth of Puerto Rico, Canada, New Zealand, the United Kingdom, and Australia from January 28 to April 16, 2004. Some officials were telephoned for follow-up interviews. We received responses from 100 percent of all national and international driver's license bureau directors or their representatives. Our aim was to review and learn about the policies and practices of other driver's licenses bureaus within the United States and overseas in order to provide a recommendation on a suitable comprehensive automated driver's license testing system to ADOT. The results of this survey are presented in Appendix B of this report.

Our visual acuity survey covers all 50 U.S. states and the Commonwealth of Puerto Rico, all 10 provinces and 3 territories of Canada, all of New Zealand, all of the United Kingdom, and the 6 states and 2 territories of Australia. The provinces of Canada include Newfoundland and Labrador, Nova Scotia, Prince Edward Island, New Brunswick, Québec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia. The territories of Canada include Nunavut, Yukon, and Northwest Territories. Nunavut constitutes nearly one-fifth of Canada's land mass yet has the smallest population. Approximately 85 percent of the 28,000 residents of Nunavut are Inuit, an indigenous people formerly called Eskimos. The states of Australia include New South Wales, Queensland, South Australia, Victoria, Tasmania, and Western Australia; the territories, Australian Capital Territory and Northern Territory.

ANALYSIS OF COLLISION DATA

Introduction

Consequences from traffic collisions include injuries, fatalities, *and/or* property damage. In order to ultimately design an all-new pre-pilot vision test for ADOT, it is necessary to consider the histories, modes, and trends of collisions between states. In this study, the states of Arizona and Florida are selected. In addition to descriptive statistics, risks for undesired events are estimated using some very basic risk concepts and risk analyses through statistical data we obtained through ADOT Motor Vehicle Crash Statistics Unit, Traffic Records Section, ADOT Motor Vehicle Division, and Florida Department of Highway Safety and Motor Vehicles.

Methodology

The trends and risks of the drivers of the states of Arizona and Florida are gauged with data from the Accident Location Identification and Surveillance System (ALISS) of Arizona and the Florida Highway Safety and Motor Vehicle Department of Florida databases. The data stem from the Arizona Traffic Accident Report and Florida Long Form Traffic Crash Reports provided by law enforcement agents in both states. All data are processed through special coding and programming developed by ESRA Consulting Corporation in Matlab 6.0, Release 13. All tables are produced in Microsoft Excel; all statistical figures, Matlab.

Where values are calculated based on the number of licensed drivers (hereafter referred to as "licensees") in the states of Arizona and Florida, linear regression techniques are used to obtain the numbers of licensed drivers in the State of Arizona for years 1991 to 1996. In most exercises, we eliminate 15-year-old drivers from these analyses and calculations due to the Graduated Driver's license Program that took effect in Arizona in 1996.

The Framework

The Haddon Matrix provides us with an epidemiological framework for injury assessments through environmental, human, and vehicular factors (Haddon, 1972). This allows us to ultimately define the likelihood and significance of injuries, for example.

Table 1. **The Haddon Matrix** (Songer, T., 2004).

	HUMAN	VEHICLE	ENVIRONMENT
PRE-EVENT			
EVENT			
POST-EVENT			

We can evaluate a collision sequence through pre-collision, collision, and post-collision events. However, in our study, we are primarily interested in the pre-collision event and how it relates to driving or human factors and the environment. Vehicle maintenance, failure, design, speed, and illumination all influence the vehicle factor. The driving or human factor includes age, alcohol, fatigue, gender, driving experience, training, legislation, and penalties. Road, traffic, and weather conditions constitute environmental factors (Rodrigue *et al.*, 2004; Songer, 2004).

Rodrigue *et al.* (2004) indicate that direct observation, induced measurements, and survey techniques are the three widely accepted modes of exposure data collection. Exposure, a scale factor, defines the quantity of collisions in the numerator of a ratio. It simplifies the process of comparing data from two states by eliminating variables such as size and motor vehicle mileage.

Thorpe (1964) pioneered the induced exposure method to allow for a variety of risk comparisons. This led to calculations of Relative Accident Involvement Ratio (RAIR), refined by Stamatiadis and Deacon (1997), whereby each motor vehicle collision consists of an at-fault (responsible) driver and not-at-fault (not responsible) driver.

COMPARISON OF RELATIVE ACCIDENT INVOLVEMENT RATIO (RAIR) OF COLLISIONS OF ARIZONA AND FLORIDA DRIVERS, YEARS 1991 TO 2001

In the year 2000, 76 percent of all traffic fatalities involving older drivers included another vehicle (U.S. DOT, 2000.) The propensity of these fatal collisions, and many others that transcend driver age, reinforces the need to evaluate, among other factors, the impact of roadway lighting and other features of driver vision, perception, and performance. When these collisions occur at night, they may be attributable to a driver's inability to notice delineation, warnings, and other possible road safety controls. Night severely restricts driver's visual range to about 262 feet (80 meters) and impacts a driver's ability to discern details and steadily react to stimuli (Hollnagel and Källhammer, 2003). Adverse weather conditions affect pavement markings. At night, any quantity of ice, snow, or water can cause pavement markings to appear nearly indiscernible. Interestingly, however, dry pavement accounts for 81 percent of fatalities during both day and night times (Opiela *et al*., 2003). As a result of this growing interest in at-fault collision involvement studies, and its underlying causes, the calculations and applications of the Relative Accident Involvement Ratio (RAIR) are presented. In order to achieve a representative sample of drivers from both Arizona and Florida, nine age groups are selected: 16 to 19 years, 20 to 29 years, 30 to 39 years, 40 to 49 years, 50 to 59 years, 60 to 69 years, 70 to 79 years, 80 to 89 years, and 90 years and older.

RAIR measures the likelihood of involvement in a collision. It is a ratio of the number of at-fault drivers of a certain age group divided by the total number of at-fault drivers to the number of not-at-fault drivers of a certain age group divided by the total number of not-at-fault drivers. RAIR stems from the pioneering work of Thorpe (1967) and Carr (1970). Its applications are valuable in many transportation engineering studies and analyses. Stamatiadis and Deacon (1995) utilized RAIR to study collision-related trends among drivers on the bases of age cohorts and gender.

According to Stamatiadis and Deacon (1995), accident propensity, a term used to describe RAIR calculations, is sometimes applied to measures of the ratio of accident involvement quantity to the miles of travel. Since these tend to lack accuracy because of the need for exogenous travel estimates, the RAIR approach seems most practical when direct exposure estimates are unfeasible or lacking.

As shown by Chandraratna *et al.* (2002), we define RAIR as follows:

$$\text{RAIR}_{i,j} = \frac{\dfrac{D1_{i,j}}{\sum\sum D1_{i,j}}}{\dfrac{D2_{i,j}}{\sum\sum D2_{i,j}}}$$

Where:

i = type of drivers
j = type of conditions
$D1_{i,j}$ = number of at-fault drivers of driver type i for type j conditions.
$D2_{i,j}$ = number of not-at-fault drivers of driver type i for type j conditions.

RAIR values greater than 1.0 denote a driver group more likely to be at-fault in motor vehicle collisions. RAIR values less than 1.0 designate a driver group that is less likely to be at-fault (Robertson and Aultman-Hall, 2001).

Over (1998) addresses the possibility that the classification scheme of at-fault and no-fault drivers may be open to gender bias. He also encourages the indication of the type of collision because some drivers are more susceptible to severe consequences than others.

In order to compare millions of collisions involving Arizona and Florida drivers during the years 1991 to 2001, data were compiled in Microsoft Excel format. Programs in Matlab 6.0, Version 13 were developed and ran to divide and analyze at-fault and no-fault drivers in each type of collision and state. The literature was reviewed on at-fault driver calculations and predictions.

Interestingly, Robertson and Aultman-Hall (2001) used RAIR to quantify the effects of dry, wet, and snowy/slushy roads on Kentucky drivers age 65 years and older who were involved in collisions. They determined that these drivers, when compared to drivers younger than age 65 years, were more likely to be at-fault when roads were dry. Wood and Troutbeck (1992) found possible connections between reduced contrast sensitivity and at-fault motor vehicle collisions.

However, Owsley and Ball (1993) determined a correlation between Useful Field of View (UFOV), the visual information extraction area that functions in a single glance without eye or head movement, and at-fault motor vehicle collisions. A study of drivers in Vancouver, British Columbia in 1986 indicated more at-fault automobile collision involvement among drivers age 55 years and older than drivers age 36 to 50 years (Cooper, 1990). In Germany, while accident involvement of drivers age 65 years and older is low, the percentage of at-fault drivers is high. In 1989, however, drivers age 70 years and older represented the largest percentage (71.3 percent) of at-fault drivers as compared to drivers under age 30 years at 56.7 percent (Schlag, 1993).

Bathtub Curves

Bathtub curves are usually associated with product failure and reliability engineering. These curves illustrate an expected failure rate of, for example, an electronic component, with respect to time. Three regions define the bathtub curves: Early Failure Period (sometimes called the Infant Mortality Period, the High Initial Failure Rate, or the Burn-in Failure), Intrinsic Failure Period (also referred to as the Stable Failure Period) and Intrinsic Failure Rate, or Useful Life Period, and the Wear-out Failure Period. The Useful Life Period is sometimes called the Chance Failure or Random because it exhibits random failures of the product.

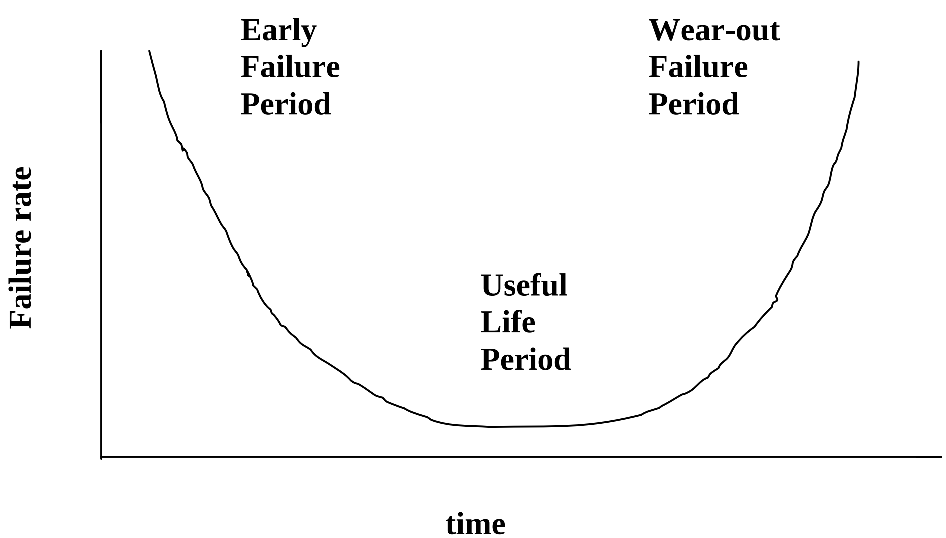

Figure 2. The Bathtub Curve

The failure probability density function illustrates the type of behavior shown in a bathtub curve:

$f(t) = b\theta(\theta_{tt})^{b-1} \exp [-(e^{(\theta b)^{b}} - \theta t^{b} - 1)]$ for $b > 0$, $\theta > 0$, $t \geq 0$

where:

b = shape parameter,

t = time,

and θ = scale parameter

R(t), the component reliability function, as an approximate fit, is defined as:

$R(t) = \exp [-(e^{(\theta t)^{b}} - 1)]$

h(t), Hazard rate, which explains probability of failure changes over the lifetime of the component (Modarres, *et al.* 1999), is represented by:

$$h(t) = \frac{f(t)}{R(t)} = b\theta(\theta_{tt})^{b-1} e^{(\theta t)^{b}}$$

Interestingly, many of our RAIR graphs 30 to 43, Appendix G, appear in the shape of bathtub curves up until the age 80 to 89 years cohorts, where the Wearout Period tends to end and retirement, in most cases, begins. This may be expected because older drivers are most vulnerable to collision-related injury or death due to frailty associated with older age. Similarly, fatigue causes deterioration of mechanical and electrical components and susceptibility to external stresses. Design or defects of a product sometimes contributes to brittle behavior of a material. Therefore, in order to maximize safety of both people and products, it is necessary to seek to minimize these stress factors. In traffic-related collisions, these may be due to visual, cognitive, or motor impairments, or any combination thereof, of the drivers. Through improvements to driver's license testing methods, we may have an edge on screening at-risk drivers. Through a follow-up medical evaluation, these drivers may seek possible remedies to continue to drive or consider alternative methods of transportation.

However, it is possible that the sudden drop this study observes within the majority of these RAIR figures, following the ages 80 to 89 years cohorts are due to random fluctuations, missing data, or changes in policy or driver behavior. George (2000) explains that nonparametric failure rate functions may describe this "premature wear out and retirement" because no family of distribution functions fits these failure rate functions. Retirement follows the onset of the Wearout Failure Period and causes failure rate functions to decrease.

Unreported collisions may also reduce failure rate functions and occur late in product life, or, in our study, late in driver life. Interestingly, a similar decline is observed immediately after the ages 75 to 79 years cohorts in Western Australia, through driver collision involvement by age, on the basis of rates per 100 million kilometers driven (Ryan and Legge, 1998).

According to the Information Technology Laboratory of the National Institute of Standards and Technology (2004) empirical evidence demonstrates that repairable systems can also be illustrated by bathtub curves when the ordinate is the Repair Rate or the Rate of Occurrence of Failures (ROCOF). However, some but not all devices may illustrate this type of general shape. For example, only 72 percent of United Airlines commercial aviation equipment tends to follow infant mortality rates (Smith, 1992). Different components, like different kinds of human populations, exhibit varying levels of behavior associated with stresses. Hence the three regions may differ according to variables, populations, and time.

Bathtub curves are quite familiar in the literature, especially as these apply to certain product life analyses in reliability engineering. However, these are typically referred to as U-shape distributions in transportation engineering studies and are often associated with one distribution skewed relative to the other. Burg was one of the first to characterize traffic-related collisions in the form of U-shaped (or bathtub-shaped) curves. Burg (1967) and Hills and Burg (1977) showed that the measured visual performance of drivers progressively declined after about age 45 years. It was fairly constant until that age. The U-shaped curve was represented for all types of collisions when the collision rate was plotted on the ordinate and age cohorts were plotted on the abscissa. Young and adult drivers demonstrated significantly higher collision rates. Yet, noticeable increases in collision risk beginning at about age 50 years were evident. Hills and Burg (1977) also identified collision risk, with respect to static or dynamic acuity, in drivers age 54 years and older. In Australia, where drivers age 70 years and older are estimated to comprise 14 percent of Australian fatalities by 2005, a skewed bathtub curve now defines the relative risk of driver fatality per million kilometers traveled. However, the random period appears considerably shorter and the onset of the Wearout Period begins at ages 45 to 49 years. High levels of involvement in a fatal collision are apparent for ages 17 to 20 years and ages 75 to 79 years (Australian Transportation Safety Bureau, 1996).

Similar U-shaped or bathtub curves appear in various traffic violations per 100,000 miles among California driver age cohorts (State of California Department of Motor Vehicles, 1982.) In 1990, U.S. drivers ages 16 to 19 years had the highest collision rate and U.S. drivers age 75 years and older had the highest fatality rate. The fatality rate per 100 million miles, was represented as a U-shape or bathtub curve, where drivers ages 16 to 19 years had the second highest rate of fatalities followed by a decrease. An increase in fatality rate per 100 million miles was evident among the age 55 to 59 years cohorts. Collision rates per million miles were highest for drivers age 16 to 19 years and second highest for drivers age 75 years and older (Massie, *et al*., 1995). Kim (1996) showed, in the form of a U-shaped distribution, that males ages 15 to 24 years and females age 65 years and older were most likely at-fault in collisions in Hawaii from 1986 to 1993.

Odds of fault were placed on the ordinate, age cohorts on the abscissa. Driver fatality rates, on the bases of age and gender, in 1996, demonstrated that the cohorts age 85 years and older and the cohorts age 16 years constituted the highest fatality rates per 100 million vehicle miles traveled (U.S. DOT, 2000). A bathtub curve illustrated these rates.

In the United Kingdom, however, a different shaped curve emerges: Half of a U where male and female novice drivers are most accountable for collisions. However, the ordinate posts self-reported accident liability, and the abscissa indicates age. (DETR, 2000.) A bathtub curve is observed when accident involvements per year per 1,000 drivers, on the bases of fatal and serious accident liabilities by driver age group (ages 50 years and older) and gender, are illustrated (Maycock, 2002).

To the best of our knowledge and research, there exist no studies that have associated trends in RAIR with bathtub curves. However, in order to identify trends in Figures 30 to 44, it is useful to consider the various regions of the bathtub curves as bases for measurement since our figures, in one form or another, tend to take on the bathtub curve in appearance. More importantly, all of these figures appear to demonstrate the very start of the Wearout Failure Period for both Arizona and Florida begins at approximately age 50 to 59 years. Drivers with visual defects involved in automobile collisions in both states, as shown in Figure 43, seem to have bathtub curve features similar to those of environmental conditions and manner of collisions, especially dawn or dusk lighting conditions as shown in Figure 42. This finding establishes a link between collision involvement and visual defects. This finding also underscores the need for ambient lighting changes and/ or contrast sensitivity testing during vision testing.

Additionally, our RAIR values, especially for the drivers age 80 years and older, are in very good agreement with those computed for Michigan drivers by Stamadiatis and Deacon (1998). Their trends of observed effect of driver age on RAIR also follow a bathtub curve, or U-shaped distribution, as do our RAIR results.

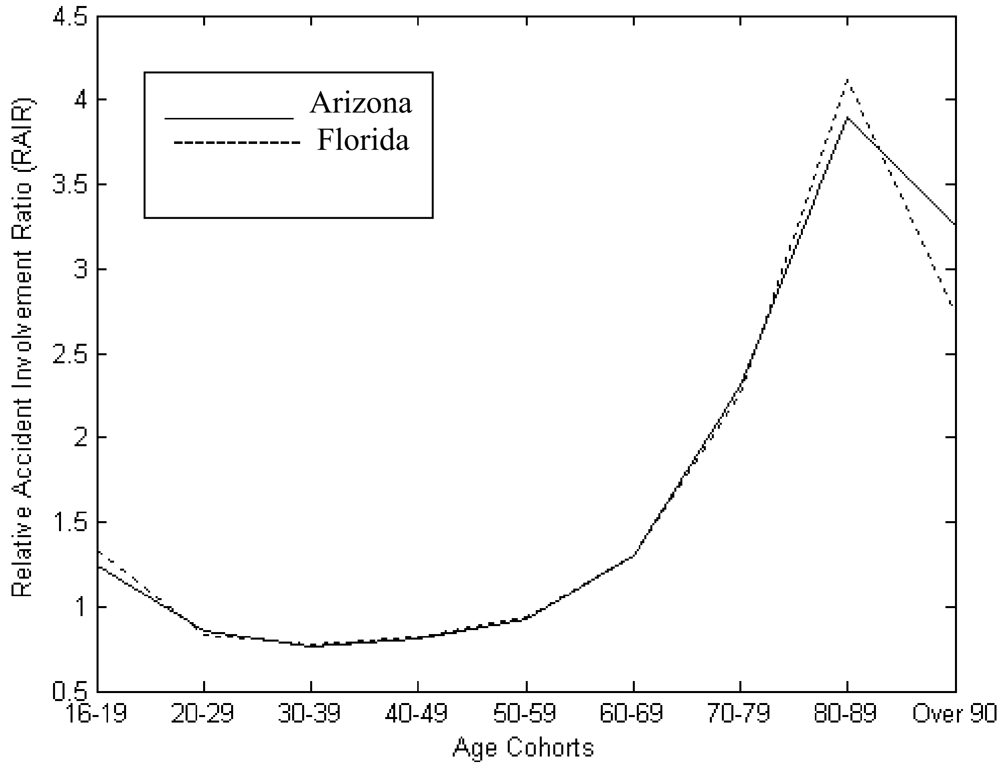

Figure 3. Comparison of Left Turn Manner of Collisions Among Drivers in Arizona and Florida for years 1991 to 2001

According to Figure 3, the Early Failure Period is very short. While both Arizona and Florida drivers feature the onset of the Wearout Period at about the cohorts age 50 to 59 years (RAIR~ 1), a peak occurs among the cohorts age 80 to 89 years (Arizona RAIR ~ 3.9; Florida RAIR~ 4.25) and retires. Drivers age 16 to 19 years are three times less likely to be involved in collisions due to left turns than drivers age 80 to 89 years. Notice how the RAIR values of both Arizona and Florida drivers age 80 to 89 years surpass those of any other age group for left-turn manner of collisions. The results of this study are somewhat in agreement with the findings described by Chandraratna *et al*. (2002). The general shape of our RAIR for left turn collisions by driver age group appears to be considerably similar except for the component of age 89 years and older cohorts. Although the RAIR values for the ages 16 to 19 years are the same, the RAIR for the age 80 years and older Kentucky cohorts are approximately double the RAIR values of Arizona and Florida drivers. Chandraratna *et al*. suspect that left turns at intersections may account for these discrepancies among older drivers.

Appendix G includes detailed results and analyses of RAIR values of collision risks associated with environmental factors. Our most interesting RAIR findings are summarized on the following pages.

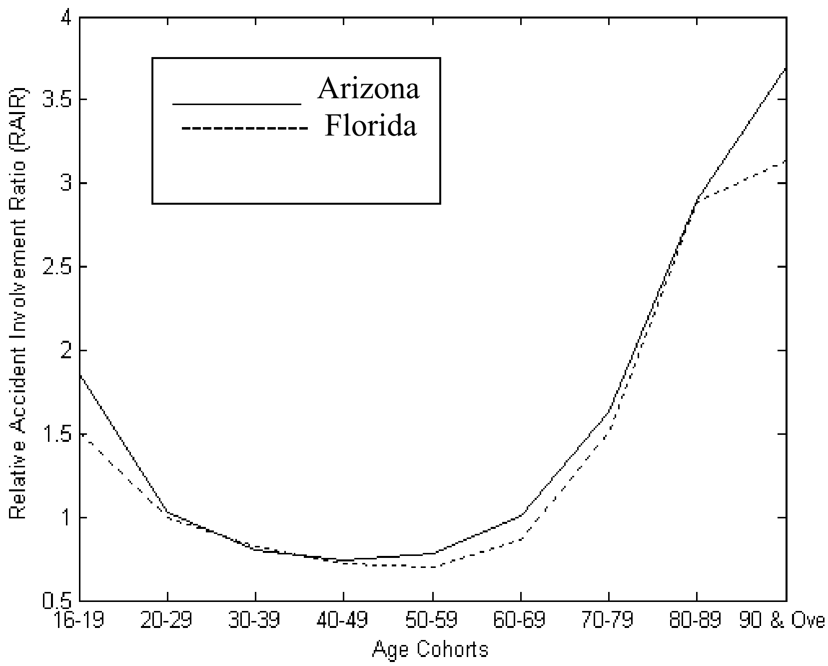

Figure 4. Comparison of Dawn or Dusk Related Collisions Among Drivers in Arizona and Florida for Years 1991 to 2001

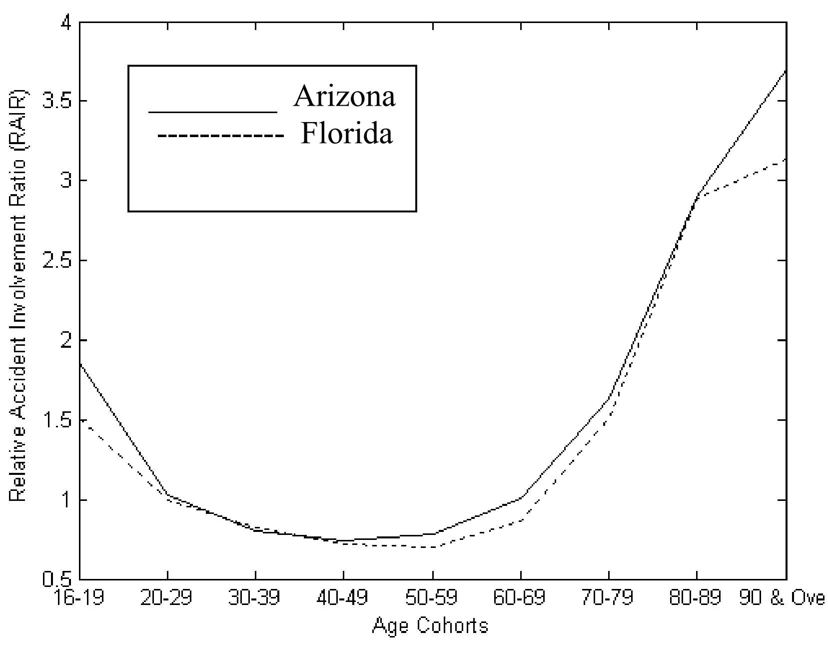

Figure 5. Comparison of Collisions Among Drivers with Visual Defects in Arizona and Florida for Years 1991 to 2001

- The relative involvement of dawn or dusk-related collisions among both Arizona and Florida drivers are evaluated. Arizona drivers (RAIR~3.6) and Florida (RAIR~ 3.1) drivers age 90 years and older are about twice as likely to be at-fault in a dawn or dusk-related collision than the cohorts ages 16 to 19 years (Arizona RAIR~ 1.8; Florida RAIR~ 1.5). The onset of the Wearout Period begins at ages 50 to 59 years for both Arizona and Florida drivers (Figure 42, Appendix G).
- The relative involvement of corrective lenses-related collisions among both Arizona and Florida drivers are observed. Arizona drivers (RAIR~3.6) and Florida (RAIR~ 3.1) drivers age 90 years and older with visual defects are about twice as likely to be at-fault in a corrective lenses-related collision than the cohorts ages 16 to 19 years (Arizona RAIR~ 1.8; Florida RAIR~ 1.5). The onset of the Wearout Period begins at ages 50 to 59 years for both Arizona and Florida drivers (Figure 43, Appendix G).
- Drivers ages 80 to 89 years in Arizona (RAIR ~ 3.5) are about twice as likely to be at-fault in angle manner of collisions compared to the Arizona drivers age 16 to 19 years (RAIR ~ 1.5). Similarly, the drivers ages 80 to 89 years in Florida (RAIR ~ 3.25) are about twice as likely to be at-fault in angle manner of collisions compared to the Florida drivers age 16 to 19 years (RAIR ~ 1.5), as shown in Figure 30, Appendix G.
- Drivers ages 80 to 89 years in Arizona (RAIR ~ 1.8) are about 1.5 times as likely to be at-fault in backing manner of collisions compared to the Arizona drivers age 16 to 19 years (RAIR ~ 1.25). Similarly, the drivers ages 80 to 89 years in Florida (RAIR ~ 2.15) are about twice as likely to be at-fault in backing manner of collisions compared to the Florida drivers age 16 to 19 years (RAIR ~ 1.2), as shown in Figure 31, Appendix G.
- Drivers ages 80 to 89 years in Florida (RAIR ~ 3.25) are about twice as likely to be at-fault in head-on manner of collisions compared to the Florida drivers age 16 to 19 years (RAIR ~ 1.5). However, the drivers 90 years and older in Arizona (RAIR ~ 2.85) are about 1.5 times as likely to be at-fault in head-on manner of collisions compared to the Arizona drivers age 16 to 19 years (RAIR ~ 1.9), as shown in Figure 32, Appendix G.
- Drivers ages 80 to 89 years in Arizona (RAIR ~ 3.8) and Florida (RAIR ~ 4.15) are about three times as likely to be at-fault in left-turn manner of collisions compared to the drivers age 16 to 19 years in Arizona (RAIR ~ 1.25) and Florida (RAIR ~ 1.45), as shown in Figure 33, Appendix G.
- Florida drivers ages 16 to 19 years (RAIR~ 2) are more likely to be at-fault in a rear end collision due to higher RAIR values than the cohorts ages 80 to 89 years (RAIR~ 1.9). Contrastingly, Arizona drivers age 80 –89 years (RAIR ~ 2.19) are more likely to be at-fault in a rear end collision due to higher RAIR values than the cohorts ages 16 to 19 years (RAIR~ 1.95), as shown in Figure 34, Appendix G.
- Arizona and Florida drivers age 80 –89 years are about twice as likely to be at-fault in a sideswipe manner of collision due to higher RAIR values than the cohorts ages 16 to 19 years (RAIR~ 1.5), as shown in Figure 35, Appendix G.

- Arizona (RAIR~ 2.45) and Florida (RAIR~ 2.75) drivers age 80 to 89 years are about twice as likely to be at-fault in a clear weather-related collision than the cohorts ages 16 to 19 years, as shown in Figure 36, Appendix G.
- Florida (RAIR~ 2.75) drivers age 80 to 89 years are about twice as likely to be at-fault in a cloudy weather-related collision than the cohorts ages 16 to 19 years (RAIR~ 1.75). Arizona (RAIR~ 2.95) drivers age 90 years and older are about twice as likely to be at-fault in a cloudy weather-related collision than the cohorts ages 16 to 19 years (RAIR~ 1.75), as shown in Figure 37, Appendix G.
- Florida (RAIR~ 2.55) and Arizona (RAIR~ 2.35) drivers age 80 –89 years are about twice as likely to be at-fault in a rain-related collision than the cohorts ages 16 to 19 years (Arizona RAIR~ 1.8; Florida RAIR~ 1.9), as shown in Figure 38, Appendix G.
- Florida (RAIR~ 2.6) and Arizona (RAIR~ 2.6) drivers age 80 –89 years are about twice as likely to be at-fault in a fog-related collision than the cohorts ages 16 to 19 years (Arizona RAIR~ 1.55; Florida RAIR~ 1.85), as shown in Figure 39, Appendix G.
- Florida (RAIR~ 2.8) drivers age 80 to 89 years and Arizona (RAIR~ 2.65) drivers 90 years and older are about twice as likely to be at-fault in a daylight-related collision than the cohorts ages 16 to 19 years (Arizona RAIR~ 1.75; Florida RAIR~ 1.75), as shown in Figure 40, Appendix G.
- Florida (RAIR~ 2) drivers and Arizona drivers (RAIR~1.9) age 80 –89 years are about equally as likely to be at-fault in a darkness-related collision as compared to cohorts ages 16 to 19 years (Arizona RAIR~ 1.5; Florida RAIR~ 1.4), as shown in Figure 41, Appendix G.
- Arizona drivers (RAIR~3.6) and Florida (RAIR~ 3.1) drivers age 90 years and older are about twice as likely to be at-fault in a dawn or dusk-related collision than the cohorts ages 16 to 19 years (Arizona RAIR~ 1.8; Florida RAIR~ 1.5), as shown in Figure 42, Appendix G.
- Arizona drivers (RAIR~3.6) and Florida (RAIR~ 3.1) drivers age 90 years and older with visual defects are about twice as likely to be at-fault in a corrective lenses-related collision than the cohorts ages 16 to 19 years (Arizona RAIR~ 1.8; Florida RAIR~ 1.5), as shown in Figure 43, Appendix G. This seems to demonstrate that these drivers are most likely impacted by dawn and dusk, yet the shape of these skewed bathtub-shape curves also reveals that various lighting, weather, and manners of collision may also significantly affect vision, especially visual defects.
- Arizona and Florida drivers age 80 –89 years are about twice as likely to be at-fault in a sideswipe manner of collision due to higher RAIR values than the cohorts ages 16 to 19 years (RAIR~ 1.5).

DESCRIPTIVE STATISTICS AND CALCULATED RISKS OF VIOLATIONS/BEHAVIOR-RELATED COLLISIONS IN THE STATE OF ARIZONA, YEARS 1991 TO 2001

The collision rates per 100,000 licensed Arizona drivers on the basis of driver's license restrictions over an 11-year period, from 1991 to 2001 (Appendix R) are calculated. Drivers ages 25 to 34 years are selected as a baseline since this group surpasses all other age groups with the greatest number of collisions, injuries, and fatalities in both the states of Arizona and Florida (Appendix C and Appendix D). This group is also one of the most populous. The following are determined:

- The collision rate of licensed Arizona drivers age 75 years and older, may be as high as twice the rate of drivers ages 25 to 34 years (Figure 82, Appendix B) on the basis of any one of the following:
    - corrective lenses
    - failed to yield right of way
    - made improper turn

These findings support Wick and Vernon (2002). They indicate that higher rates of citations, collisions, and at-fault collisions characterize some groups of visually impaired non-commercial drivers. Collision risks are seemingly greater among drivers with higher levels of impairment and restriction.

- The collision rate of drivers Arizona drivers age 75 years and older, may be as high as three times the rate of drivers age 25 to 34 years on the basis of any one of the following:
    - automatic transmission
    - left outside mirror
    - full hand controls

- The collision rate of Arizona drivers age 75 years and older, may be as high as seven times the rate of drivers age 25 to 34 years on the basis of "daylight hours" driver's license restrictions.

COMPARISON OF AVERAGE INDIVIDUAL RISKS OF COLLISIONS, INJURIES, AND FATALITIES OF ARIZONA AND FLORIDA DRIVERS, YEARS 1991 TO 2001

Risk calculations are often used to quantify radioactive releases and predict nuclear power reactor accident sequence frequencies (McCormick, 1981). Risk methodologies are also useful as a method of ranking risks and prioritizing measures to prevent collisions. In order to manage the underlying causes of traffic-related collisions, injuries, and fatalities, it is necessary for us to identify, estimate, and evaluate the risks associated with these events. Calculations of Average Individual Risk of collisions, injuries, and fatalities of Arizona drivers and Florida drivers allow us to initiate this process. In order to obtain a representative sample of all age cohorts, in accordance with Minimum Uniform Car Crash Criteria (MUCC), ages 16 to 19 years, 20 to 24 years, 25 to 34 years, 35 to 44 years, 45 to 54 years, 55 to 64 years, 65 to 74 years, and 75 years and older, are observed. These results are tabulated in the Appendix Q.

According to the American Institute of Chemical Engineers (2000), we define Average Individual Risk as:

$$IR_{AV} = \frac{\sum_{x,y} IR_{x,y} P_{x,y}}{\sum_{x,y} P_{x,y}}$$

Where

IR_{AV} = average individual risk in the exposed population (yr^{-1})

$IR_{x,y}$ = individual risk at location *x, y* (yr^{-1})

$P_{x,y}$ = number of people at location *x,y*

On the basis of these calculations, our study shows the following:

- Arizona drivers in all age cohorts have higher Average Individual Risk of collisions than Florida drivers.
- The greatest Average Individual Risk of collision, Average Individual Risks of Injury, occur among both Arizona (1.14E-01) and Florida drivers (6.71E-02) age 16 to 19 years. This may be due to inexperience, high speeds, and, possibly, alcohol and narcotics.
- Arizona drivers age 75 years and older are more than four more times as likely to be at Average Individual Risk of collision than Florida drivers of the same age group.
- The greatest Average Individual Risk of injury occurs among both Arizona and Florida drivers age 16 to 19 years.

- Arizona drivers age 75 years and older are more than four times as likely to be at an Average Individual Risk of Injury than Florida drivers of the same age group.
- Arizona drivers age 75 years and older are more than four times as likely to be at an Individual Risk of injury than Florida drivers of the same age group.
- The Arizona driver age groups with the greatest Average Individual Risk of fatalities include: age 75 years and older cohorts (6.65E-04).
- The Average Individual Risk of fatalities among Florida drivers is highest among age 16 to 19 years cohorts (2.41E-04). According to Table 2, this quantity warrants public spending to control the hazard.
- Arizona drivers age 75 years and older are more than 3.3 times as likely to be at an Average Individual Risk of Fatality than Florida drivers of the same age group.
- According to the Thresholds of Annual Fatality Risk Levels (Table 2, below), the Average Individual Risk of fatalities may encourage people to control these safety hazards.

Table 2. Thresholds of Annual Fatality Risk Levels According to Otway and Erdmann

Annual fatality Risk level, yr^{-1}	**Conclusion**
10^{-3}	This level is unacceptable to everyone. Accidents providing hazard at this level are difficult to find. When risk approaches this level, immediate action is taken to reduce the hazard.
10^{-4}	People are willing to spend public money to control a hazard (traffic signs/ control and fire departments). Safety slogans popularized for accidents in this category show an element of fear, i.e., “the life you save may be your own”
10^{-5}	People still recognize the risk. People warn children about these hazards (drowning, firearms, poisoning). People accept inconveniences to avoid the risk, such as avoiding air travel. Safety slogans have precautionary ring: “never swim alone, “ “never point a gun,” “never leave medicine within a child’s reach.”
10^{-6}	Not of great concern for the average person. People aware of these accidents but feel that they can’t happen to them. Phrases associated with these hazards have element of resignation: “lightning never strikes twice,” “an act of God”
10^{-7}	Acceptable risk of death to an individual from nuclear power plant accidents.

H. J. Otway and R. C. Erdmann, 1970, *Nuclear Engineering Design,* **13,** 365, as cited in McCormick, p.370.

In addition to our global surveys of officials of driver's license bureaus, statistical studies and risk analyses are generated to determine the possible impacts of vision impairments on collision trends among drivers of various age cohorts in two states with increasing older driver populations. This study seeks to identify cutting edge vision testing equipment that offers improvement over the current vision testing techniques. Comprehensive studies, surveys, and literature reviews are performed. When testing equipment is not identifiable, testing methods previously perceived as "off the beaten track" in driver's license bureaus are considered: computer automated vision screening and driving simulators.