EVALUATION OF THE TRANSPORTATION SAFETY NEEDS OF OLDER DRIVERS

FINAL REPORT

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ABSTRACT

Recent statistics on population trends indicate that older drivers account for a larger and more significant portion of the driving population than in the past; this number is also expected to increase in the future. First, a survey aiming to examine and identify specific driving maneuvers whose unsuccessful undertaking can result in crashes involving these drivers was conducted. Then, an analysis was performed to evaluate potential problem maneuvers that may lead to higher crash involvement. These crashes are: 1) Left turns against oncoming traffic, 2) Gap acceptance for crossing non-limited access highways, 3) High speed lane changes on limited-access highways, and 4) Merging and weaving on limited-access highways at ramps. Older and younger drivers’ crash propensities are measured using Kentucky crash data. The findings of the analysis show that older drivers are more likely to be involved in crashes related with these maneuvers compared to younger drivers; older male drivers are safer than older female drivers in left turns and gap acceptance related crashes and having a passenger beside the older drivers makes for a safer driving environment. The findings of this study can be used to improve our understanding of the needs of elderly drivers to create a safer environment for all. Potential counter-measures aiming to reduce the accident rates of older drivers are discussed.
1.0 INTRODUCTION

In today’s society, older drivers are the fastest growing segment of the driving population (1). This will be even more significant in the future, as many Baby Boomers become older. Data from the Bureau of the Census indicate that the population growth rate of the elderly--those at the normal retirement age of 65 or older--between 1970 and 2000 was almost three times larger than the total population growth (2). In 2000, the elderly accounted for 12.4 percent of the U.S. population and is estimated that persons 65 and over will make up 20 percent of the total population in 2030 (3).

There are many different reasons for this large increase in population. Advances in technology and health have provided Americans with a longer life than in the past. These improvements have also allowed many people to remain very active and healthy into their older years. Older Americans are no longer feeling limited in their activities by their age, but rather staying very active and mobile for many years to come. As a result, an increasing number of older individuals are licensed to drive. In 1970, older drivers accounted for 8 percent of the U.S. driving population and 14.3 percent in 2000 (4). Burkhardt and McGavock conservatively estimated that the total annual mileage driven by male older drivers would increase from slightly less than 100 billion miles up to 400 billion miles in the 1990 to 2020 period (3). Furthermore, they predicted that elderly drivers would account for 18.9 percent of all vehicle miles driven which is almost triple the 1990 figure, 6.7 percent.
On the other hand, older drivers are experiencing high crash involvement ratios, and these ratios have been increasing over time. These drivers are the party at fault in disproportionately more crashes than other age groups of drivers in a variety of traffic conditions (5). Over the last decades, the traffic safety community has been increasingly concerned with the traffic safety of elderly. This leads many states to improve their roadway system to accommodate this growing and large group of elderly drivers.

Thus, the objective of this study is to understand and identify problems of elderly drivers to improve their safety. A survey was first conducted to allow for a better understanding of the thought and physical processes completed by older drivers as they attempt basic driving maneuvers. Then, specific maneuvers were analyzed to improve the current understanding of the crash mechanism of this group. Statistical analysis is performed on both survey results and crash data to determine if there is any correlation between age and potential driving errors. A literature review was also performed to gain an insight into the current and past research that has been completed regarding the traffic safety of older drivers.
2.0 BACKGROUND INFORMATION / LITERATURE REVIEW

The amount of elderly drivers on the roads today is increasing at a very fast rate and the fastest growing segment of the population is people aged 85 years and older (1). People over the age of 65 accounted for 12.4 percent of the total population in the United States at 34.9 million in the year 2000 (2). In 2000, there were approximately 27.3 million licensed, older (over the age of 65) drivers on the roads, making up 14.3 percent of all licensed drivers (4). Since the previous decade, there has been a 27 percent increase in elderly drivers as compared with a total increase of licensed drivers of only 15 percent.

Another interesting trend in the demographics of older drivers is the increase in women licensed drivers. The increase of older female drivers during the 1970-2000 period indicates a growth of approximately 379 percent (4). There has been a 35 percent increase in the miles driven by elderly women in the past 30 years (3). Additionally, in 1983, only 76.2 percent of adult women held driver’s licenses as compared with 85.3 percent in 1995.

Like all Americans, older drivers are dependent on the freedom of movement provided by their cars, which is used in 92 percent of all surface travel (6). Travel trends show that 50 percent of elderly drive for daily living activities such as taking care of the household and/or themselves. It can be assumed that the elderly will be taking more trips, driving further, and continuing to drive much later in life in the future.
A recent survey has been conducted among the various transportation professionals within the state of Florida to find out and rank the most critical highway safety issues of six special population groups, namely: older drivers, young drivers, international tourists, school-aged children, new immigrants, and persons with disabilities (7). The study revealed that the most critical special population group was the older drivers group. Issues related with location and size of traffic sign and lettering, night time visibility, perception-reaction time, gap acceptance, deficiencies in driving knowledge, narrow lanes, driving in congestion, maneuvering curves and freeway driving appear in descending order.

Specific types of crashes that have been identified as causing the most problems for elderly drivers include illegal turns, starting improperly into traffic, failing to yield to the right of way, and ignoring traffic signals (8). Some researchers have also identified at grade intersections as a point of concern for elderly drivers. However, after studying a questionnaires administered to a sample of drivers in different age groups, Cooper revealed that older drivers had mentioned changing lanes was the most difficult vehicle maneuver whereas the intersection negotiation was the second (9). The majority of recent research indicate that the most difficult aspects for older drivers are issues related to intersections, merging and weaving, and interpreting a variety of traffic signs and signals.

A recent report written identified five main deficiencies present in older drivers. These include sensory, perceptual, cognitive, physical, and general driving knowledge deficiencies (10). Sensory deficiencies include deficiencies in any of the five senses:
sight, sound, touch, taste, and smell. A loss in any of these could greatly impact a person’s ability to properly operate a motor vehicle. Sight and sound are two of these that are particularly important and both have been found to decrease significantly as a person ages. Light sensitivity, visual acuity, visual field, night vision, color vision, and spatial resolution are all parts of sight that are sensitive to decreases with age (11). Identifying objects and surroundings are related to a person’s perceptual abilities, while cognitive abilities include a person’s thinking and mental reaction to certain driving situations (10). As can be self-inferred, physical deficiencies relate to a person’s decrease in agility or ability to make certain bodily maneuvers necessary to driving. A decline in head and neck mobility reduces an older driver’s ability to see blind spots effectively. This may create problems to recognize conflicts during turning and merging maneuvers at intersections. A decrease in driving knowledge relates to a lesser understanding of basic driving practices and laws. It is not hard to see why a decrease in any one of these areas could have a detrimental effect on a person’s driving capabilities. It is essential that each one of these areas be specifically addressed when studying the needs and abilities of older drivers.

A loss in any of these areas increases a person’s risk of being involved in a vehicular crash. Aside from young drivers, older drivers have the highest risk of being involved in a fatal crash (12). Past research has shown (Figure 1) that, as the driver’s age increases there is a general decrease in fatality rates until the age of 55 when the values begin to rise again. Moreover, the number of older drivers killed in crashes nationwide increased by 39 percent from 1989 to 1999 while at the same time that overall fatalities declined by
9 percent (6). There were 3,307 older drivers killed in fatal crashes in 1999, compared to 2,387 in 1989. At the same time, overall traffic fatalities dropped from 45,582 in 1989 to 41,345 in 1999. After studying the 1996 Motor Vehicle Crash Data from FARS and GES from 1982 to 1996, Burkhardt and McGavock also highlighted that the 1996 older driver fatality number was 41 percent higher than 1982, while overall number declined 19.6 percent during same period (3). Furthermore, they predicted this number would increase by three to four times in the period of 1996-2030, assuming no changes to current crash-related fatality rates occur. Stamatiadis and Puccini revealed that older drivers in multi-vehicle crashes comprised the group most likely to cause fatal crashes by studying at fault drivers’ crash data of the Southeast region (13). In fact, for drivers aged 80 and above, more than half of all fatal crashes occur at intersections, compared to one in four for drivers less than 50 years old (14).

Figure 1: Driver fatality rate per 100 million VMT per age group
There are several important factors that contribute to higher crash involvement. As people become older, their bodies become frail and their bone densities begin to decrease. With less bone density and a weaker immune system, it becomes much more difficult for an older person to withstand the impact and injury incurred from a vehicular crash. Even a minor crash could have serious implications, health wise, for an older person than from a younger person suffering the same injuries (3). Another reason that this number is so much higher in the older driving population is due to the type of crashes that older drivers are usually involved. Research has shown that multi-vehicle angle and side impact collisions account for a majority of crash specific types. Infact, side impact crashes are twice as likely to occur with older drivers rather than younger drivers (15). Due to the severity of these types of crashes, it is generally harder for an older person to recover than a younger driver.

The observed trend for fatalities is also evident in the crash involvement rates (Figure 2) including all crash types for older drivers (12). As stated earlier, there are certain characteristics of aging that impact driving behavior. These deficiencies also help to explain the high crash and fatality rates of elderly drivers. In order to help decrease these rates, it is very important that a person be able to identify when a driver suffers from sensory, perceptual, cognitive, physical, or knowledge deficiencies (10). In a study conducted by the National Public Services Research Institute, particular behaviors were identified to assist people in identifying deficient drivers (16). The behaviors determined to show inefficient drivers from this study include driving the wrong way, failing to yield or stop, turning across oncoming traffic, driving excessively slow, leaving the roadway,
backing up, failing to yield to pedestrians or bicycles, having rear end collisions, and crossing lane markings. In order to determine which of these behaviors is the most prevalent and frequent, police officers were asked to keep track of violations, crashes, and observations of elderly drivers. As it can be seen in Table 1, traveling the wrong way and failure to yield or stop were the most frequent behaviors, while traveling off of the road was also fairly frequent. It should also be noted that each one of these driving behaviors could be easily associated with one of the five deficiencies noted earlier.

Figure 2: Crash involvement rates per 100 million VMT per age
Table 1: Frequency of behaviors observed by officers, crashes, and violations

In order to better understand the specific driving characteristics of older drivers, it is beneficial to examine particular driving maneuvers in certain driving situations. In a study performed by the Federal Highway Administration (FHWA), certain scenarios were examined and evaluated to determine recommendations to accommodate older drivers. This study identified five particular situations that need attention including at grade interchanges, grade separated interchanges, roadway curvature and passing zones, construction zones, and highway-rail grade crossing (14). There are several important difficulties that older drivers have when negotiating at grade intersections. It has been found through in-car observations, that older drivers have a very difficult time responding to traffic signals and performing left and right turns. The driver also often failed to signal
his/her turn. Poor positioning was also a problem when turning left, along with a general lack of caution. This was also a problem with traffic signals and stop signs, along with failure to stop and jerky, abrupt stops.

McKelvey and Stamatiadis reported that older drivers rates, because of angle collision and crash involvements at intersections controlled by stop signs rather than by traffic signals, are higher than that of young or middle-aged drivers (17). In addition, they revealed that older drivers are fined more often than other drivers for failing to yield the right-of-way. Furthermore, Stamatiadis, et al. pointed out that drivers older than age 65 and younger than age 25 were more likely to be involved in crashes at both signalized and nonsignalized intersections (18).

An analysis on crash databases from five States (Illinois, Michigan, Minnesota, North Carolina, and Utah) over a 3-year period found that older drivers were more involved in single-vehicle run-off-road crashes, possibly from the effects of fatigue (19). The same study also found that older drivers were slightly more involved in multiple-vehicle sideswipe, failure to yield/improper lane use, and merge/lane-change maneuver collisions. Furthermore, this analysis indicated that older drivers were more than twice as likely to be cited for failure to yield, improper lane use/passing, or speed violations. It also indicated that older drivers were 63 percent more likely to be merging or changing lanes just prior to the crash and that they were five times more likely than younger drivers to be cited with failure to yield when merging or changing lanes.
Brainin, et al. conducted a study on three age groups (25-44, 60-69, 70+) and they found that older drivers had problems on freeways with lane tracking and positioning and negotiating horizontal curves (20). Furthermore, the study revealed that older drivers take improper turns because elderly tended to not be cautious, to use improper lane positioning during the turn, and to not signal prior to the turn.

Staplin and Lyles revealed that drivers over age 75 were more represented for their level of exposure for crashes related with failure to yield and improper lane use than younger drivers. Furthermore, they pointed out that older drivers were more likely to be guilty of failure to yield and lane violations (21). Another significant factor was older drivers from ages 56-75 and ages 75 were over represented in this type of crash when compared to the other drivers. They were more likely to turn left and collide with other drivers, but there was a less chance to be going straight and collide with left-turning traffic.

Mourant has studied the ability of young and older drivers to obtain information from an in-vehicle display (22). This study revealed that older drivers had considerable difficulty staying in their lane when using the In-Vehicle display and they spend more time driving outside of their lane compared to younger drivers. In another study, Staplin et al revealed that old drivers required longer response times to make lane-change decisions compared to that of young drivers (23).

McCoy et al. conducted a two-year study of older drivers in which not only several factors relative to the mental and physical status were measured but also their driving
knowledge and on-street driving performance were evaluated (24). The characteristics evaluated were vision, visual perception, cognition, reaction time, range of motion, and driving knowledge. Stepwise multiple regression analysis was used to determine the combination of factors that accounted for the most variability in the on-street driving performance. According to the findings, a number of factors associated with vision, visual perception, cognition and driver knowledge were significantly correlated with the driving performance of the older drivers.

During the second phase of the same study, countermeasures to improve the safety of the older drivers were identified and selected for demonstration and evaluation. Four countermeasures selected were physical therapy, perceptual therapy, driver education, and engineering improvements. Evaluation of both primary and secondary effects of these countermeasures by using before and after studies indicated that all of them were significantly improving the driving performance of older drivers. Combinations of the countermeasures were also found to be effective where the perceptual therapy with driver education provided the greatest improvement, followed by the engineering countermeasures with driver education and either physical or perceptual therapy.

Hall made an evaluation of the traffic crashes in New Mexico and confirmed the earlier findings that older drivers were over-represented in urban, multi vehicle crashes during the daylight hours (25). The study examined selected highway, driver and environmental characteristics of crashes involving older and young drivers. Selection was based on the fact that they could be susceptible to treatment through the application of engineering
countermeasures. Contingency table analysis was used in this study to examine whether the observed distribution of young and elderly driver crashes were different from the distribution if the results did not depend on driver age. The study suggested two general conclusions. First, all crash characteristics including light condition, weather, roadway system, driver residence, crash severity, type of crash, and highway design features exhibited a dependence on age. While some of the dependencies were statistically stronger than others, elderly drivers had, on the average, a different crash pattern than young drivers. Second, crashes involving elderly drivers could occur under the same conditions observed for young drivers. However, they occurred less frequently than expected.

A study of 664 older drivers was conducted in 1993 to identify the elements of highway design and traffic operations whose importance to older drivers had increased and to identify the driving activities, which had become more difficult for them over years (26). According to the findings of this study, driving activities had become harder for 12 percent to 62 percent of the older drivers, depending on the type of activity. The greatest increase in difficulty was for nighttime driving, followed by driving in heavy traffic, driving at high speed on freeways, and driving through construction zones. Also, difficulties increased for approximately 25 percent of the respondents in reading street signs, reading freeway signs, intersection crossing, finding the beginning of left turn lanes, and making left turns. Certain driving tasks such as following pavement markings had become easier for a small group of drivers and difficult for some other. Driving at night and at high speeds on freeways had become more difficult for female drivers than
for male drivers, but the reverse was true for driving across and making a left turn at intersections. The difficulty for daytime driving, following pavement markings, finding beginning of left turn lanes and driving in construction zones had also increased with the age of the senior drivers.

All highway design elements had increased in importance for survey respondents and the changes in importance appeared to be universal across both gender and age. The roadway design features were more important for 41 percent to 62 percent of the senior drivers. The top three features that had the highest increase in importance were all intersection related elements. Those were intersection lighting, pavement markings on intersections, and the number of left turn lanes. Highway related elements like pavement markings on hills and curves, width of travel lanes, and length of freeway entry lanes had become more important for about half of the senior drivers. Among the intersection features, the importance of concrete guide lanes increased as the age of respondents increased.

Eventhough freeways are characterized by the highest safety level, Taylor and McGee revealed that erratic maneuvers are a common occurrence at freeway exit ramps, and that the number of crashes there is four times greater than at any other freeway location (27). In addition, older drivers rely mostly on their side and rearview mirrors while driving which increases their risk of crash since mirrors do not show drivers their “blind spots” due to diminished physical capabilities, such as neck soreness and lack of agility. Thus, older drivers are likely to experience more difficulties than others on freeway ramps related elements. In a survey, 25 percent reported that older drivers stop on a
freeway entrance ramp before merging onto the highway, and 17 percent indicated that they have trouble finding a large enough gap in which to merge onto the mainline (28). The results of a survey revealed that because of the higher traffic densities, older drivers are now more concerned with the length of the freeway entry lanes and they wish entrance lanes were longer.

Age related decline in the sensory/perceptual skills not only affects the ability of older drivers to effectively operate the motor vehicle, but also creates a higher risk of crashes. Yi examined the gap acceptance of elderly drivers on rural highways (28). Specifically, he presented the results of field studies at two-way stop-controlled (TWSC) rural intersections on how elderly drivers judge the speed and gap time of an approaching vehicle based on their own driving experience before deciding whether to initiate a roadway entry. The study found distinctive gap selection and utilization patterns of older drivers when compared to other drivers. The critical gap for entering through right turns at TWSC intersections used by older drivers was 7.36 seconds whereas that of other drivers was only 5.19 seconds. The longer critical gap required by elderly drivers indicated that it was generally more difficult for them in roadway entry from an unsignalized minor approach. This problem was more pronounced at the busier roads where the average size of available gaps in the traffic stream for intersection entry was small. In addition, the fact that elderly drivers tend to reject more usable gaps leads to capacity reduction, specially, at a single-lane minor approach. Perhaps the most noteworthy concern is the speed impedance to main road traffic caused by elderly drivers. The risk for crashes increases with the speed of the approaching vehicle.
Sight distance is a key concept in highway design. It underlies numerous design
guidelines, such as stopping sight distance, decision sight distance, intersection sight
distance, railroad-highway grade crossing sight distance, and passing sight distance. All
these are closely associated with the perception-reaction time, which is the time that
lapses from the first visibility of an event to the initiation of the appropriate response.
Lerner reviewed older driver perception reaction time and sight distance design criteria
(29). He concluded that even though there were some good reasons to believe that older
drivers’ perception-reaction time would be meaningfully longer for some situations, and
hence require longer sight distances, the need for revised design criteria was not
prejudged.

Later he conducted field experiments to check the adequacy of perception-reaction time
assumptions for intersection sight distance at stop controlled intersections, stopping sight
distance and decision sight distance (30). The study concluded that the existing design
models were adequate to accommodate most drivers.

Another study was conducted to show any difference in decision-reaction times between
age groups, area type and intersection type and to determine whether the existing design
decision reaction time of 2.0 seconds was adequate (31). The multivariate analysis of
variance conducted on the data revealed a significant difference between the younger and
older age groups at a 95 percent confidence level. Mean decision-reaction times at the
urban locations were statistically different from those at rural locations.
Another recent study about the perception-brake reaction time confirmed the fact that the 2.5 seconds design time used for designs encompasses the driving population (32). However, statistically significant differences in mean response times were noted between age and gender groups. For the expected object scenario, the mean perception-brake response time for the younger and older driver groups were 0.52 and 0.66 seconds, respectively. The mean value for this scenario was approximately 0.55 seconds. For the unexpected object scenario under controlled and open road conditions perception-brake reaction time was about 1.1 seconds. The 95th-percentile value for those same conditions was 2.0 seconds. The study recommended continues to use 2.5-second value for stopping sight distance situations. However, it suggested that different perception reaction times might be used, in locations or geometric features where something other than stopping sight distance may be the appropriate design control. For example, shorter perception reaction times may be appropriate for the traffic control design where drivers are more alert, and longer perception reaction times may be appropriate for intersection and/or intersection design where driver speed and/or path corrections may be required.

It is interesting to see how older drivers respond to the various traffic conditions on freeways. Research conducted by the FHWA in four cities (Washington, DC; San Diego, CA; Tampa, FL; and Phoenix, AZ) revealed that the most-disliked aspects of driving of older drivers on freeways included: the rudeness and dangerous actions of other drivers, large trucks, and high travel speeds (28). Participants were most concerned about congestion, inconsistent signing format and placement, inconsistent speed limits, too few police, short entrance ramps, construction zones, and inadequate rest areas. Furthermore,
the study revealed that problems with signage included: unclear directions, inadequate advance notice, too much information (especially in California), difficulty seeing shoulder-mounted signs (well-lit overhead signs were preferred, especially with arrows specifying lane destinations), and inadequate advance notice for right-turn only and exit-only lanes.

In order to help decrease the risk for older drivers, some basic recommendations have been made to change the roadways and make them more accommodating to mature drivers. Even though many of these recommendations may be quite costly, some of them should be considered. The cost of implementing the actual change and the cost of the current crashes that would be affected by the change should also be compared. Some of the aesthetic changes that have been recommended include increasing the size of traffic signals, providing lights at intersections, and increasing pavement markings at intersections (14). Implementing concrete, raised channelization guides, and increasing the width of travel lanes are all design modifications that may also be considered.

There is some discrepancy among the various states and their procedures for testing older drivers. Some states have very extensive testing programs, while other states may not have any requirements. A recent study found that there is an eight percent increase in fatality rates for drivers between ages 75 and 84 in states that do not have periodic testing (33). This increases to 71 percent for drivers over the age of 85. Another way that periodic testing requirements for older drivers decreases crash rates is that in certain cases, many people may not choose to take the exam because they are afraid of failing. In
this instance, it forces the less competent drivers off of the road. Through this study, a
definite relationship was found between testing and non-testing states and crash rates.
There is a significant decrease in crash rates in testing states as opposed to non-testing
states. This shows that it may be beneficial for states to consider periodic testing for older
drivers.

The literature review indicates that there is a significant body of research in the area of
elderly drivers. Many studies have been conducted to gain insight into the population
growth trends of elderly drivers, their diminished physical capabilities, their crash rates,
and their travel patterns. The literature review showed that there are problems with
interchanges, intersections, and signing. However, very little effort has been placed on
the thinking process of elderly drivers and their driving characteristics with certain
maneuvers. From this report, some insight into these topics is sought. Therefore, the
purpose of this research is to determine how elderly drivers will react in certain driving
scenarios and to determine if these reactions have the significant potential to cause
crashes by isolating specific maneuvers and identifying possible contributing factors.
3.0 METHODOLOGY

The main goal of this research effort is to identify a set of specific traffic safety needs for older drivers. To complete this, the project was divided into two phases. First, to obtain the older drivers perspective, an in-person questionnaire was administrated. Then, a Crash Database was explored to consider the relative involvement of older drivers in various types of crashes.

3.1 Survey of Perceived Hazards

For this research a driver’s survey was utilized, since it provides a direct and straightforward means for data collection. The first step involved the development of the survey content (Appendix A). The survey was divided into six sections each addressing a specific area of concern. The first two sections included background information and medical history to provide a database of the socioeconomic and health attributes of the particular participant. The next four sections included questions regarding specific maneuvers. They were merging situations, lane changes, nighttime driving, and left turning movements. In the section for traffic maneuvers, questions were presented that aimed at enhancing our understanding of the actual procedures that older drivers undertake while executing these maneuvers. Diagrams were shown depicting specific driving situations to facilitate understanding and participants were asked to choose from various options each describing a possible action. Along with this, participants were also asked to rank the various situations according to their perceived level of difficulty. Background and medical data were collected to determine if there were any other
conditions that exist that might be affecting their driving. For example, questions were asked about their current medications, their current medical conditions, and if they suffer from any loss of vision. All of these have been shown that they have a potential to greatly affect driving capabilities.

The completed survey contained 74 questions. These questions varied between multiple choice, short answers, and ranking questions. It generally took participants 20 to 25 minutes to complete the survey. The only requirement for participants was that they be over the age of 55 and have a valid driver’s license. We included the age group 55 to 65 since this is generally when the driving patterns of people begin to change due to retirement as past research indicated.

Finding people to participate in the survey proved to be a fairly difficult task. Some participants were found through the Donovan’s Scholars Program at the University of Kentucky and the Lexington Area Senior Citizen’s Center. The Donovan Scholar’s Program is a special program and curriculum for older aged students. The workers through the program were very accommodating in helping to receive completed surveys. Participants also included members of Christ Church United Methodist in Louisville, Kentucky. Eligible participants were found in four different Sunday school classes through the church. Through these two groups, eighty-one completed surveys were returned for analysis. A database of the completed responses was created and analyzed through the statistical software analysis program, SPSS.
Since many of the questions contained five possible answers, it was necessary to recode some of the responses so that they could be more easily evaluated. Correct answers were identified for each question based on vehicle laws and safety. In some cases, two possible answers were identified as being correct, or at least acceptable. Each correct answer was reassigned a value of 1 and each incorrect answer was given the value of 2. In the cases that involved more than one correct answer, they were both recoded as 1, indicating that they were given equal weight.

Once this was completed, the data was ready to be statistically analyzed. Since the purpose of the research was to determine whether or not older drivers were performing inadequate driving maneuvers, it was determined that a test that examined deviation from the mean values (i.e. correct responses) would be appropriate. In this case, a single variable t-test was performed for each question, including the diagram questions and the multiple-choice questions. A majority of the t-tests were centered on the value 1, since 1 was recoded to represent a correct answer to determine if a significant number of respondents were responding incorrectly to the questions. In each of the cases, the null hypothesis was that the mean equaled one; while the alternative hypothesis was that the mean did not equal one. If the two-tailed significance value was less than 0.05, representing 95 percent significance, then there was reasonable evidence to reject the null hypothesis. This indicates that there were a significant number of respondents that did not answer the question correctly and that the mean value of answers was not equal to one.

The t-tests were also performed for the multiple-choice questions. In these cases, the
acceptable answers were recoded as one and the non-acceptable answers were recoded as 2. Each one of these questions was also statistically analyzed to determine if a significant number of respondents were answering appropriately in the same manner as stated above.

3.2 Crash Data Analysis

It is evident from past research that the human error is not always the only factor for a given crash. There may be numerous other factors and/or interactions among factors in addition to the older drivers’ fault for a particular crash. Factors such as light condition, road characteristics and weather have been identified as possible influences on drivers’ crash involvement.

In this study, the Crash Database for the Commonwealth of Kentucky for the 1995-1999 period was used. The frequency of crashes for any given roadway, driver, and environmental conditions can be used for the numerator in calculating the crash rates with acceptable accuracy. However, accurate estimates of a driver’s exposure for the same variables are difficult or impossible to be made from available data. This creates a problem not only in finding the denominator to develop crash rates calculations but also performing statistical tests to find the significance of the variables in question.

In order to overcome this problem, researchers traditionally used estimates like miles driven, number of drivers licensed, registered vehicles, and so forth for the denominator. However, these estimates have some limitations and thus prohibit the development of exposure metrics for specific driver and situation combinations. For example, older
drivers who recognize their limitations often avoid peak hour and night travel. This results in changing older driver proportion in the driving population from time period to time period. This kind of difference is not accurately represented by traditional metrics of exposure such as vehicle miles of travel. Therefore, Thorpe (1967) introduced an induced exposure analysis method to estimate driver’s exposure from the crash database itself (34). Later Carr developed the Quasi-induced exposure method, which is used more frequently than any other induced exposure formulation (35).

Recent research indicates that alternative exposure measures that use data from the crash records seem to reduce these problems mentioned earlier (36). In the Quasi-induced exposure method, the estimate for the drivers’ exposure is derived from the distribution of not-at-fault drivers in the crash database. The key assumption is that the distribution of not-at-fault drivers closely represents the distribution of all drivers exposed to crash hazards. In other words, it is assumed to be a sample of the total population, which is exposed to the particular crash hazard. Therefore, it is necessary to identify at-fault and not-at-fault drivers in the database. Not-at-fault drivers are defined as drivers who were not cited as having human factors contributing to the crash. At-fault drivers are defined as those drivers who had one or more human factors contributing to the crash. Crashes in which more than one driver were assigned responsibility, were excluded in the analysis. This reduces the total number of “clean” multiple-vehicle crashes for all age groups from 490,505 to 464,072 in Kentucky during 1995-1999.

Since the characteristics of the not-at-fault drivers are used instead of the characteristics
of the total drivers in question, the relative crash involvement ratios (RAIR) are used to measure the crash propensities in this analysis. The RAIR is defined as follows:

$$RAIR_{i,j} = \frac{\sum \sum D1_{i,j}}{\sum \sum D2_{i,j}}$$

Where $RAIR_{i,j}$ is the relative crash involvement ratio for type i drivers and type j conditions; $D1_{i,j}$ is the number of at-fault drivers of driver type i for type j conditions, and $D2_{i,j}$ is the number of not-at-fault drivers of driver type i for type j conditions.

Although statistical procedures like Chi-square testing, multiple regression analysis, linear discriminate analysis can be used to identify the effects of each variable on others, Binomial (or binary) Logistic regression has been proven to be the most appropriate statistical technique to test these trends (37). The reason is that logistic regression is a form of regression, which is used when the dependent is dichotomy; that is it can have only two values (occurring and not occurring). Logistic regression technique is particularly advantageous when the effects of more than one independent variable are important. These independent variables can be continuous variables, categorical variables or both. In addition, logistic regression does not assume linearity of relationship between the independent variables and dependent, does not require normally distributed variables, and in general has less stringent requirements.

Logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable (the natural log of the odds of the dependent occurring or
In this analysis, the dependent variable is the fault status of the driver. Thus, the probability of occurrence of a crash is modeled as follows:

\[
\text{Prob} (\text{event}) = \frac{1}{1 + e^{-Z}}
\]

Where \( Z \) is the linear combination

\[ Z = B_0 + B_1 X_1 + B_2 X_2 + \ldots + B_N X_N \]

and the \( B \)'s are model parameters, estimated using the maximum-likelihood method, and the \( X \)'s are independent variables like age, gender, weather, and light condition. The independent variables can be either categorical or continuous, or a combination of both. Both main effects and interactions can generally be accommodated.

It can be noted that past research efforts were limited only to one not-at-fault driver per crash and thus ignored more than two-vehicle crashes. In the case of a multi-vehicle crash, the crash data are gathered only from the first two vehicles where ignoring the rest of available data. This may sometimes overlook important information, which may be useful for the calculation of crash rates. It is possible to assume that these ignored vehicles represent a better sample of the driving population, thus exposure, than the first two vehicles involved in the crash. It can be hypothesized that the randomness of the involvement of these vehicles in the crash is more reasonable than the first two vehicles because these drivers play no responsible role in crash when it occurred. In addition, the basis for assigning responsibility to one driver was the judgment of the investigating officer. Moreover, less capable drivers may be more likely to be involved in a crash due
to their less effective defensive driving technique. This approach was tested here to determine validity of the exposure data.

In the case of the left turns crashes, the driver exposure should be estimated using the not-at-fault drivers’ frequency in left turn crashes to ensure that all causal factors are the same. If the drivers’ exposure is estimated limiting to one not-at-fault driver per crash as per the conventional methods, at-fault and not-at-fault drivers’ maneuvers are different for each other. In these crashes, at-fault drivers were making left turns while not-at-fault drivers were going straight ahead just prior to the crash. This may raise questions regarding the randomness of the not-at-fault drivers sample. In an alternative method, the exposure is estimated excluding the first two drivers and using only the other drivers involved in a multi-vehicle crash to evaluate the randomness of the driver sample, since those drivers are neither limited to a particular maneuver nor responsible for the crash.

Figure 3 demonstrates the exposure distribution by age estimated by the two approaches mentioned above. Both exposure trends show almost the same pattern by the age of driver. Figures 4 and 5 also show the same trends for the other two maneuvers examined here (gap acceptance and high-speed lane change crashes). The Pearson Correlation Coefficients revealed that these trends are highly correlated to each other. Therefore, it can be concluded that both samples are either true or nearly true samples of the driver population with respect to the drivers’ age distribution. Thus, estimating relative crash propensities for any given driver type by using either exposure ratio will yield similar results. Therefore, the conventional method is used to estimate drivers’ exposure in this
analysis due to a larger sample size (more two-vehicle than multi-vehicle crashes).

Figure 3: Driver exposure ratios for left turn crashes by age

Figure 4: Driver exposure ratios for gap acceptance crashes by age
From the literature review, four main types of maneuvers have been identified as having high or questionable involvement of older drivers. These crashes are: 1) Left turns against oncoming traffic, 2) Gap acceptance for crossing non-limited access highways, 3) High speed lane changes on limited-access highways, and 4) Merging and weaving on limited-access highways at ramps. In addition to these four types, attempts were also made to identify other significant factors. This will enable us to gain a better understanding of the crash characteristics of older drivers not only in each of the aforesaid four selected types of crashes but also in other significant areas.

Unfortunately, the Kentucky database does not contain adequate data about ramp related crashes to perform the analysis. Therefore, a comprehensive analysis on ramp related crashes was not made. However, the other three possible maneuvers were examined here. Furthermore, statistical tests were carried out to identify the other significant categories of older driver maneuvers on certain facilities during certain conditions.
4.0 SURVEY RESULTS

As noted previously, the first two sections of the survey were used to gain some general statistics on the participants’ characteristics, while the remaining sections were used to determine an accurate and more precise picture of the driving characteristics of the respondents.

4.1 Background Information

The first section of the survey was intended to gain some background information pertaining to the characteristics of the participants. This includes age, driving history, and seatbelt usage. The age of the respondents was fairly well distributed. According to the responses, 11 percent were between the ages of 55 and 60, 19 percent were between the ages of 61 and 65, 13 percent were between the ages of 66 and 70, 24% percent were between the ages of 71 and 75, 17 percent were between the ages of 76 and 80, and 16 percent were over the age of 80. The average age group of the respondents was between ages 71 and 75. A majority of these drivers claim to drive on a daily basis. The survey indicated that 89 percent of the respondents drive daily and 10 percent drive weekly, while 1 percent indicated that they drive monthly. Only 1 percent of respondents reported being issued a driving citation by a police officer in the last month, 4 percent in the last two to twelve months, 67 percent over a year ago, and 28 percent reported never being issued a driving citation. Of these citations, 74 percent were for speeding, 6 percent were for parking violations, 3 percent for vehicle deficiencies, and 17 percent were for other reasons not given in the survey. When asked about seatbelt usage, 94 percent of
respondents indicate that they wear their seatbelt always while driving, 2 percent responded with occasionally, 4 percent responded with sometimes, and no respondents indicated that they never wear their seatbelt while driving. As far as seatbelt usage while a passenger, 88 percent indicated that they always wear their seatbelt as a passenger, 6 percent responded with occasionally, and 6 percent sometimes wear their seatbelt as a passenger.

4.2 Medical Background

In order to determine the medical condition of the respondents, some background questions were included. Only 1 percent of respondents indicated that their main healthcare provider has ever advised them not to operate a motor vehicle. Of the 82 respondents, 84 percent reported having an annual physical exam by their main healthcare provider, and of these respondents, only 3 percent report that their doctor asks them specific questions pertaining to their ability to operate a motor vehicle. Additionally, 4 percent of respondents indicate that they have operated a motor vehicle occasionally against the advice of a doctor to operate a vehicle due to medication, 3 percent reported this sometimes, and 92 percent never operate a vehicle while using altering medications. Pertaining to difficulty driving due to muscle pains, 3 percent of participants reported always experiencing muscle pain or tightness while driving, 5 percent reported this occasionally, 10 percent indicated this sometimes, and 82 percent reported never experiencing muscle pain or tightness while driving. When asked about annual eyesight exams, 69 percent reported seeing their optometrist annually. Additionally, 71 percent indicated always wearing glasses or contacts while driving, 8
percent indicated this occasionally, 4 percent sometimes wear glasses or contacts and 11 percent never wear them. There was a small percentage (6 percent) that indicated that they do not have to wear glasses.

4.3 Merging Situations

The first category of the traffic maneuvers examined was merging. There were a total of eleven diagram questions in this section that included scenarios where the driver was merging onto the roadway or where other cars entering the roadway were merging with the driver. The questions included situations where vehicles on the highway were clearly ahead or behind them (questions 21 and 23, respectively). The same situation was repeated where a vehicle was following them (questions 27 and 29) as well as where they had to merge between two vehicles with adequate space (question 30). Situations that did not involve much close contact with other vehicles were classified as easy questions. The questions that involved the participant as the driver on the primary road, rather than the merging lane, were classified as mid-difficulty level. These situations examined a clear merging and a close scenario (questions 24 and 25, respectively). The difficult questions involved the participant merging with a vehicle directly next to theirs, ahead or slightly behind, preventing the respondent from an easy merging situation (questions 20 and 22, respectively). The same situations were also repeated with a vehicle following the participant’s (questions 26 and 28). Please refer to Appendix A to view the diagrams.

All of the easy rated questions, produced significance levels greater than 0.05 besides question 30. For all easy questions but question 30, it could be concluded that elderly
drivers chose the correct response. However for question 30, the null hypothesis could be rejected indicating that a significant number of drivers were having problems with that situation (merging between two vehicles). The tests for the two mid-difficulty questions produced significance levels less than 0.05. Each of these questions posed the scenario in which the respondent had the right of way in the merging situation. These low significance values could indicate that elderly drivers are having a difficulty in identifying when they possess the right of way or how to handle merging situations while they have the right of way. This shows that elderly drivers are having a difficult time in performing difficult, but frequently encountered, merging maneuvers. The tests for the questions identified as difficult indicate that the null hypothesis could not be rejected. The significance values for each question can be found below in Table 2.

Participants were asked to rank the questions based on their perceived difficulty level. Approximately 60 percent of the respondents answered this question. Table 3 shows the ranking question responses. Question 28 was consistently ranked as the most difficult question. This could be due to the fact that there is a car behind and another car immediately to the left of the respondent. The easiest ranked question was 23, which involves a vehicle that is substantially further ahead than the driver that is merging. The ranking also showed that questions with a vehicle behind that of the participant’s were also ranked high in difficulty.
<table>
<thead>
<tr>
<th>Question Number</th>
<th>Rating</th>
<th>Number of samples</th>
<th>% Correct</th>
<th>t-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
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<td>80</td>
<td>82.5</td>
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<td><strong>0.007</strong></td>
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<td>Easy</td>
<td>80</td>
<td>96.3</td>
<td>1.754</td>
<td>0.083</td>
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<tr>
<td>22</td>
<td>Difficult</td>
<td>80</td>
<td>96.3</td>
<td>1.754</td>
<td>0.083</td>
</tr>
<tr>
<td>23</td>
<td>Easy</td>
<td>80</td>
<td>98.8</td>
<td>1.000</td>
<td>0.320</td>
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<td>24</td>
<td>Mid-Difficulty</td>
<td>80</td>
<td>65.8</td>
<td>6.344</td>
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<tr>
<td>25</td>
<td>Mid-Difficulty</td>
<td>79</td>
<td>39.2</td>
<td>10.427</td>
<td><strong>0.000</strong></td>
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<tr>
<td>26</td>
<td>Difficult</td>
<td>80</td>
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<td>3.359</td>
<td><strong>0.001</strong></td>
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<tr>
<td>27</td>
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<td>97.5</td>
<td>1.423</td>
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</tr>
<tr>
<td>29a</td>
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<td>77</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30</td>
<td>Easy</td>
<td>76</td>
<td>63.2</td>
<td>6.063</td>
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* t-value could not be computed because standard deviation is zero

Table 2: t-test results for merging situations (bold notation represents significant values)

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<td>1 12 6 5 7 0 4 6 1 3 0</td>
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<td>23</td>
<td>1 0 0 0 1 0 0 4 3 9 23</td>
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<td>27</td>
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</tr>
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<td>30</td>
<td>3 3 1 5 6 7 8 1 1 4 1</td>
<td>5.70</td>
</tr>
</tbody>
</table>

Table 3: Rankings for merging situations diagrams (bold notation represents the most difficult scenario)
There is a possibility that drivers may respond differently when more than one vehicles are present on the roadway. It can be hypothesized that the presence of other vehicles may place additional stress on these drivers and lead them to an inappropriate action. The results indicated that the presence of other vehicles behind the participant’s vehicle did not affect the choice of the correct answer. On the contrary, for cases where the vehicles were next or in front of the participant’s vehicle, the presence of more vehicles lead to a larger number of incorrect responses.

Each section also included a set of multiple choice type questions to evaluate hypothetical conditions and determine possible trends of driver behavior. The t-tests on these questions indicated that a significant number of older drivers (13 percent) do not drive on controlled access highways or interstates, and that a significant number (21 percent) does not drive at night on these same roads because of concerns about merging in the dark. A larger number of drivers (29 percent) also answered that they often find themselves merging into traffic at the end of the merging lane and do not use their rear view mirrors (18 percent) or their side mirrors while merging into traffic (9 percent). Respondents also indicated that they have a difficult time seeing lane markings on the road while merging (25 percent) and feel that there are not enough of these lane markings (42 percent).

4.4 Lane Changes
A set of diagrams regarding lane change situations was included in the next section of the survey. The easy question involved a simple lane change with a vehicle in the other lane
clearly ahead of the participant’s vehicle (question 43). The mid-difficulty question involved a vehicle clearly behind that of the participant’s (question 42). The difficult questions included situations with two vehicles in the left lane (question 41), one vehicle behind the participant in the same lane and another vehicle in the left lane also behind the participant (question 46), the participant in the left lane and two vehicles behind them one in each lane (question 48), three vehicles surrounding the participant in both lanes (question 45). Each one of these questions produced a significance level less that 0.05, indicating in each case that elderly have a higher tendency to respond inappropriately in these situations to reject the null hypothesis (Table 4). This could indicate that many elderly drivers are having a difficulty changing lanes and performing the maneuver in the proper manner. It should be noted that questions 44 and 47 were not analyzed in this case due to a significant number of negative feedback concerning the ambiguity and statement of the question from respondents.

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Rating</th>
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<th>t-value</th>
<th>Significance</th>
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<td>42</td>
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<tr>
<td>43</td>
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<td>78</td>
<td>55.1</td>
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<td>45</td>
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<td>82.1</td>
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<td>71.8</td>
<td>5.500</td>
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<td>48</td>
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<td>92.2</td>
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Table 4: t-test results for lane changes (bold notation represents significant values)
The ranking based on the perceived difficulty of the maneuver showed that Question 45 was ranked as being the most difficult and question 43 was ranked as easiest (Table 5). As in the merging case, question 45 contains 3 additional vehicles present on the roadway, while the easiest ranked question involve only one other driver. This shows again that older drivers are having a more difficult time with other drivers present.

Similar trends were noted for the comparison between scenarios with one and more than one vehicles as those observed in the merging maneuver. Therefore, a larger number of incorrect responses were noted for cases where the other vehicles were next or in front of the participant’s.

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<td>2</td>
<td>3</td>
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</table>

Table 5: Rankings for lane changing diagrams (bold notation represents the most difficult scenario)
The multiple-choice type questions aimed to better understand the thought processes or actions that are undertaken while making lane changes. The statistical tests showed that for all questions a significant number of respondents were not providing the appropriate answer. The results from this section indicate that 41 percent of respondents feel a mental overload of information while attempting to make a lane change, and 41 percent feel that the drivers around them are driving too fast or too recklessly. While 95 percent of drivers are using their side view mirrors, 8 percent are not using them to complete lane changes. Additionally, 7 percent of respondents are not checking to make sure that their mirrors are adjusted properly before they begin their trip. This lack of proper mirror usage could be a significant cause as to some of the problems involved with lane changes.

4.5 Night Driving

Night driving was the next aspect examined. There were no diagrams for the night driving section due to the nature of these questions. The results of this portion are fairly typical of what one would expect of older drivers given that aging affects vision, especially at night. The statistical tests of these questions showed that a significant number was answered inappropriately. A large number of respondents, 15 percent, indicated that they do not drive at night anymore on a regular basis and a significant portion, 33 percent also responded that they feel increased apprehension or nervousness while driving at night. The survey also showed that a significant number of drivers (36 percent) feel that the streets are not lit well enough at night and 24 percent of the respondents often find themselves confused about lane usage at night. In fact, a large number of drivers (13 percent) responded that they have changed their trip plan at night.
due to poor lighting and 11 percent change their trip due to poor lane markings on the roads. Additionally, 39 percent of the respondents felt that they had a more difficult time turning left at an intersection without a signal at night. Maneuvers such as slowing down to read traffic signs or taking longer to turn left all have the potential to slow down the traffic flow and increase crashes along the corridor.

4.6 Left Turning Maneuvers

Left turn maneuvers were the last part of the survey. The diagrams required the participant to complete a left turn in front of an oncoming vehicle close or clearly further away from the intersection (questions 65 and 68, respectively), in front of an oncoming vehicle followed by another vehicle (question 66), and in front of another vehicle with a vehicle behind them (question 67). The four diagrams were fairly basic in nature, but may have been difficult to understand since the speed of opposing vehicles was not given. In three of the four cases the null hypothesis could be rejected indicating a problem with completing left turn maneuvers (Table 6). The main problem that the respondents seemed to have with these questions involved judging the gap of the opposing vehicle. There is no apparent reason why there was a larger correct response for question 66 even though it was very similar to question 65.
### Table 6: t-test results for left turning maneuvers (bold notation represents significant values)

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<thead>
<tr>
<th>Question Number</th>
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<th>Number of samples</th>
<th>% Correct</th>
<th>t-value</th>
<th>Significance</th>
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<tbody>
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<td>76.3</td>
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</tr>
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<td>Difficult</td>
<td>77</td>
<td>39.0</td>
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</tbody>
</table>

The results from the ranking of these questions (Table 7) show the similar trend as those observed in the other sections. The more difficult questions are the ones that contain more than one other vehicle on the roadway. The easiest two questions involve only the respondent and one other vehicle. The paired tests with one versus more than one vehicle on the roadway also confirmed this. Table 8 shows the ranking if the same questions contained a traffic signal. There was no difference in the weighted rankings indicating that the presence of a traffic signal did not make much difference in the difficulty of the situation.
<table>
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<th>Weighted Score</th>
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<td>12</td>
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<tr>
<td>68</td>
<td>9</td>
<td>3</td>
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</table>

Table 7: Rankings of left turns at unsignalized intersections (bold notation represents the most difficult scenario)

<table>
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<tr>
<th>Question No.</th>
<th>Rank</th>
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</tr>
</thead>
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<td>65</td>
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<td>66</td>
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<td>67</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>68</td>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 8: Rankings of left turns at signalized intersections (bold notation represents the most difficult scenario)

The multiple-choice questions for this maneuver revealed some significant findings. Each one of the questions produced a p-value less than 0.05 indicating that a significant portion of respondents answered incorrectly to the questions. The portion of respondents reporting that they have difficulty judging the speed of opposing traffic when attempting to turn left was 23 percent, while 50 percent of respondents reported difficulty in turning
left onto a busy street or out of a busy shopping center without a protected left turn. Not surprisingly, 28 percent of respondents claimed to alter their trip to avoid turning left at an intersection without a signal. The last question asked was fairly alarming. It showed that 7 percent of respondents indicate as being involved in a “close call” accident at an intersection without a signal while attempting to turn left. The “close call” was defined as an incident in which the driver was visibly shaken; they needed to pull over to gain their composure; or another driver honked them.
5.0 CRASH ANALYSIS

5.1 Left Turns Against Oncoming Traffic

Past research showed that there is a higher risk involved in making left turn movements at intersections as compared to other intersection maneuvers. This is because two directional traffic flows cross each other and there is a higher risk involved in estimating speeds of oncoming traffic. Therefore, by examining this specific maneuver, it is possible to define factors involved in the driving characteristics of older people and thus have better understanding of their higher propensity for crash occurrence at intersections. Moreover, older drivers have higher involvement ratios at intersections as the literature review indicated.

Left turn movements were defined to be any crash taking place at an intersection where the at-fault driver/vehicle was completing a left turn movement on a roadway consisting of two or more lanes. In addition to this condition, the not at-fault driver must be going straight in the opposite direction with respect to the at-fault driver’s direction just prior to its turning. No differentiation was taken into account for the presence of turning lanes or for the type of operating traffic control devices at the intersection, since this information was not available from the crash data.

Figure 6 shows the crash ratios as a function of driver age. The data show a significant trend of increasing crash involvement as the driver ages over 65. A statistical analysis reveals that the odds of fault in left turn crashes against oncoming traffic is 3.166 times
higher in the older group than the younger group (age < 65) which is statistically significant. Furthermore, the statistical test shows that an increase in age by one year increases the risk of older drivers being involved in a left turn crash by 8 percent. Kentucky crash data shows that the risk of drivers’ ages of 85 or higher is more than 4 times than that of the 65 - 69 age group. It can be reasonably assumed that the exposure of older drivers is higher in going straight vehicle maneuvers than left turn maneuvers at intersections because those who can identify their weaknesses in left turn maneuvers may avoid as many as such maneuvers. Thus, there is a higher chance to be underestimating the older drivers’ risk, which is estimated by the left turn at-fault drivers’ frequency against ongoing not-at-fault drivers’ frequency. Therefore, it could be hypothesized that older drivers have a high risk when they perform left turn vehicle maneuvers at intersections.

**Figure 6: Relative accident involvement ratio for left turn crashes by age group**

It can be seen from Figure 7 that females have a higher chance being involved with left
turn crashes. Statistical tests show that the age and the gender interaction is significant (p=0.028). Older women are 1.27 times more likely to be involved in left turn crashes than older men. However, younger women are only 1.12 times more likely to be involved in left turn crashes than younger men. There are no indications of whether there are any reasons for this difference.

Figure 7: Relative accident involvement ratio for left turn crashes by age group and sex

Past research shows that factors associated with vision are correlated with the driving performance of the older drivers. Thus, it is important to see the significance of light condition on older drivers performance. As expected, tests show that the age and the light interaction is significant (p=0.013). Older drivers are 1.688 times more likely to be involved in left turn crashes in the darkness where there are no streetlights as compared
to daylight (Figure 8). Younger drivers have no difficulty in such conditions except in the darkness when the highway lights are on, where they have only 1.106 times higher risk to be involved in left turn crashes compared to daylight conditions. This means reduced visual acuity significantly affects older drivers’ driving in the nighttime. Furthermore, the results from the logistic regression test highlight that the probability that an older driver is involved in a left turn crash in the darkness increases by 1.079 times per year as he/she ages.

![Diagram](image)

**Figure 8: Older drivers' relative accident involvement ratio for left turn crashes by light condition**

Crash data was disaggregated with respect to rural urban criteria to analyze older drivers' behavior on them. Data show that older drivers have higher tendency to be involved in a left turn crash when the traffic volume is low on the road. Statistical tests show that age and rural/urban interaction is significant (p = 0.005). Older drivers are 1.167 times more
likely to be involved in left turn crashes in rural areas where the population is 25,000 or less compared to urban areas where the population is 250,000 and over. This may be attributed to higher speeds in rural areas and may be indicative of gap estimation problems. On the other hand, this may be due to the fact that rural roads do not have as many signalized intersections. Unfortunately, the effects of traffic control devices at intersection cannot be evaluated, since this information is not available in our crash database.

The severity of the crash has also been evaluated here. If an older driver is responsible for a left turn related crash, the probability of the crash being fatal is 3.675 times higher than the younger group crashes (p=0.000). However, age difference is not a significant factor (p=0.324) in injury only crashes. It can be seen that the likelihood of a crash being only property damage among the younger group is slightly (5 percent) higher than the older group but it is not significant at 0.05 level (p=0.059). Figure 9 shows the Relative Crash Involvement Ratios for the left turn crashes by severity. One reason for the higher fatality rate prevailed among the older driver may be because of their weakened health conditions. However, the reason of the inability of older drivers to overcome the severity of a crash compared to younger drivers also cannot be ignored.

The effect of driving with a passenger on driving safety was also examined. The statistical analysis showed this effect is highly significant. If an older driver drives with a passenger, his/her chance of being involved in a left turn crash is lowered by 1.568 times. As mentioned earlier the driver has to judge the oncoming vehicle speed before the left
turn maneuver. There is a good reason to assume that the passenger in the vehicle may alarm the older driver about the oncoming vehicle irrespective of whether they are in danger or not.

![Relative accident involvement ratio of left turn crashes by severity](image)

**Figure 9: Relative accident involvement ratio of left turn crashes by severity**

The left turn from a two-way road to one-way road against oncoming traffic was also examined. Statistical tests show that age and road type interaction is significant (p=0.007). Older drivers are 1.644 times safer to take left turns on to one-way roads rather than on to two-way roads. This is understandable because the number of conflict points on one-way road intersection are fewer than those on two-way roads.

Another factor examined was the time of the day when the older drivers’ crash occurred. However, the statistical test did not show significant differences between frequencies of
older drivers left turn crashes with hour variation in the day. Similarly, variables like weather, road character, and road surface condition are not significant at .05 level for the left turn related crashes.

5.2 Gap Acceptance

Another type of maneuver in which older drivers are said to have higher incidence rate is associated with the gap acceptance. These are crashes that occur when the driver attempts to cross a road underestimating the available gap or the speed of the approaching vehicle. Such crash types are angle crashes occurred on non-limited highways when both vehicles were going straight prior to the crash.

Figure 10 highlights the effect of age on the gap acceptance crash propensity of older drivers. The typical increase for older drivers is noted here. The statistical test shows that an increase in age by one year increases the risk of older drivers being involved in a gap acceptance crash by 6.5 percent. The risk of a driver age 85 or greater involved in a gap acceptance crash is more than 3.8 times that of the 65 to 69 age group. In addition, the odds of fault in this type of a crash is 1.8 times higher in the older group than the younger group (age < 65); a statistically significant observation. Thus, it can be assumed that the high increase in crashes after the age of 65 may be demonstrating the reduced ability to make decision regarding the available gaps.
The gender of the driver may also play an important role and tests reveal that females are at a greater risk than males with respect to gap acceptance crashes. As in left turn crashes, statistical tests show that the age and the gender interaction is significant in these crashes with older women being 1.27 times more likely to be involved in such a crash than older men. No significant differences were observed between younger women and younger men. The absence of the difference between men and women for the younger age groups may indeed indicate that there are differences among elderly which could be attributed to possible cohort effects and lack driving experience (37).

Past research revealed that the difficulty of crossing a road increases dramatically when the average size of available gaps reduces with traffic volume. Therefore, older drivers
crash data was disaggregated to rural and urban areas. Although the crash pattern of younger drivers confirms past research, the analysis did not show that older drivers have a higher tendency to be involved in such crashes when traffic volume is high. Statistical tests reveal that older drivers are 1.27 times more likely to be involved in gap acceptance crashes in the rural areas having population of 25,000 or less compared to the urban areas having population of 100,000 or more. This may be attributed to the potential alternate routes that older drivers may take instead of crossing a busy road in populated areas. However, in rural areas, selection of alternate routes is limited and thus, they do not have a choice but to cross the road bearing the risk.

In this analysis, the severity of the crash has also been evaluated. If an older driver is responsible for a gap acceptance related crash, the probability of the crash being fatal is 6.3 times higher than the younger group crashes. Unlike in left turn crashes, age difference is a significant factor in injury only and property damage crashes. As discussed in the case of left turn crashes, one reason for the higher fatality rate prevailed among the older driver category may be their potential frailty.

The effect of driving with a passenger is also highly significant as in the case of left turn crashes. Older drivers with a passenger in the vehicle show a lower chance to be involved in a crash by 1.368 times. As stated previously, it can be assumed that the passenger in the vehicle may warn the older driver about the approaching vehicle.

It is understood that the average traffic volume has a correlation with the day of the week.
Thus, effects of the day of the week were examined. As expected, statistical analysis determined the day of the week to be of significance indicating that weekday crash involvement ratios are higher than that of weekend. The reason behind this is obviously that the available gap is less on weekdays compared to weekends because of higher traffic volume.

It is important to see whether light has a significant effect on older drivers' performance. However, no significant difference can be seen in disaggregated data based on the light condition. The analysis for weather conditions shows that the chance of older drivers being involved in such a crash is less on snowy days compared to other weather conditions. This is most probably due to the fact that the average vehicle speed is slower on such conditions. Hence, the likelihood of occurring gap acceptance crash is minimum.

The analysis is extended to identify the other possible causal factors or interactions between them for older drivers' associated crashes due to road crossing maneuvers on non-limited highways. However it is noted that variables like the hour of the day when the crash occurred, road characteristics, and road surface conditions are not significant at 0.05 level for the gap acceptance related crashes.

5.3 High-Speed Lane Changes on Limited-Access Highways.

A past survey revealed that older drivers mentioned that changing lanes was the most difficult vehicle maneuver for them. They are more likely to have difficulties in detecting vehicles in blind spots. Therefore, the significance of age for high-speed lane change
crashes is examined in this analysis. Due to possible discrepancies in the reported information given by crash database, same directional sideswipe crashes on limited highways while either overtaking or merging were also considered as high-speed lane changes crashes in addition to the lane changes crashes.

The same trend of increasing crash involvement as the driver ages was noted here (Figure 11). The statistical analysis showed that older drivers are 1.555 times more likely to be involved in such crashes than the other age group. However, this may be an overestimation due to limited data because only 838 cases are observed where older drivers were involved in such crashes out of available 464,072 cases for the analysis.

![Relative accident involvement ratio for high speed lane change crashes by age group](image)

**Figure 11: Relative accident involvement ratio for high speed lane change crashes by age group**

Out of all at-fault older drivers who were involved in high-speed lane change crashes, 82
percent were side-swipe crashes and 10 percent were rear-end crashes. Side-swipe presumably indicate problems with peripheral vision while rear-end crashes probably indicate inability to judge the distance to the leading vehicle. Unlike other drivers, none of older drivers was involved in angle crashes while they were changing lanes. This implies that they did not cross lanes aggressively like young drivers.

When this type of maneuver is examined in terms of the gender of the driver, statistical analysis showed no significant differences for drivers over 65. However, it should be noted that younger women are 20 percent less likely to be involved in lane change crashes than men. Similarly, older women are safer than men for lane changing maneuvers in ages 75 and over. In contrast, females have had higher crash involvement than males in the 65-74 age group.

The effects of other causal factors on older drivers’ characteristics were also examined. However, the statistical analysis conducted for these data found no significance in terms of factors such as light conditions, weather, number of passengers, rural urban category, highway type, day of the week and time of the day when the crash occurred.

5.4 Ramp Related Crashes

Overall, freeways are characterized by the highest safety level (lowest fatality rates) when compared with other types of highways in rural and urban areas. However, highway ramps are the most difficult road component to maneuver on limited highways. Especially on exits ramps, a driver must not only process a large amount of directional
information during a short period of time and at high speeds but also maintain or modify his/her position within the traffic stream.

Only 633 crashes could be identified as ramp related crashes from the Kentucky crash database. However, this number of crashes accounted for 18.7 percent of total older drivers involved crashes on limited highways during the period of 1995-1999. This ratio highlights how older driver’s crashes concentrate on ramps because the length of travel on ramp is presumably negligible compared to the total travel miles on limited highways in any given route. Older drivers over presentation can be justified in terms of driving task demands and age-related diminished driver capabilities.

Further analysis by which the ramp crashes is subdivided as per the crash type, determined that most of crashes on ramps could be categorized as rear end crashes. Rear end crashes accounted for 55.0 percent of ramp crashes while sideswipe crashes accounted for 9.3 percent. These crashes may occur because the older driver was overloaded due to the more complex road environment. In addition, the age-related reduction in processing speed may be the main reason for the high rear end crashes and decreased physical flexibility in the neck and upper body may be the factor for sideswipe crashes. On the other hand, it was observed that 16.0 percent of vehicles collided with road structures other than a vehicle. This is an indication of older drivers’ inability to control their vehicle in a complex situation.
6.0 CONCLUSIONS

Past research revealed that older drivers who accounted for the fastest growing segment of the population in the US are experiencing high crash involvement ratios. The maneuvers including left turns against oncoming traffic, gap acceptance for crossing non-limited access highways, high speed lane changes on limited-access highways, and merging and weaving on limited-access highways at ramps were identified as the most problematic through a literature review. Thus, a survey was first conducted to examine the viewpoint of elderly with respect to these maneuvers and other possible problematic maneuvers. Then, a crash analysis was explored to consider the relative involvement of older drivers in various types of crashes. The crash propensities are measured using the Kentucky crash database and quasi-induced exposure method. The statistical analysis was performed using logistic regression.

At the beginning of the crash data analysis, the validity of estimating the drivers’ exposure by only using one not-at-fault driver’s information is tested with respect to other not-at-fault drivers data in multi vehicle accidents. Tests show that both not-at-fault driver samples yield similar exposure trends. Thus, it can be concluded that both samples are either true or nearly true samples of the driver population with respect to the driver’s age distribution. Hence, the estimating the drivers’ exposure by only using one not-at-fault driver’s information was continued to use for this analysis.

As a summary, it can be gathered from this report that older drivers are having a difficult
time in left turns against oncoming traffic, gap acceptance when crossing non-limited access highways, high speed lane changes on limited-access highways, and merging and weaving on limited-access highway ramps. Similar results can be seen when survey data is examined. The survey results indicate that older drivers are having difficulties merging on access controlled highways, changing lanes, driving at night, and turning left. For all these cases, a significant number of respondents answered incorrectly or improperly the questions posed. There were also situations where they indicated that they were previously involved in a crash due to inappropriate response to the corresponding maneuver. The findings are very similar to what was found in the literature review of other projects completed in this field.

The examination of the relative crash propensity of driver groups by age in left turn crashes indicates that older drivers are more likely to be involved in left turn crashes compared to younger drivers and the risk of their involvement in left turn crashes increases 1.08 times each year the driver ages. However, having a passenger beside the older drivers makes for a safer driving environment for them. The elderly drivers not only find it more difficult to complete left turns during night than in daytime but also have higher tendencies to be involved in such crash in rural areas where the population is 25,000 or less. The probability of an older driver being involved in a fatal crash is higher than that of younger drivers and it was observed that older male drivers are safer than older females.

The survey results also showed that the presence of other drivers on the road seemed to
be the most significant factor in the left turning maneuvers. Another interesting result of the survey was that the addition of a signal at the intersection did not alter the ranking difficulty of the situation. This is an important finding that shows that the effects of traffic controls on older drivers’ driving characteristics cannot be evaluated from the available data in the database. This is a significant result that should be considered more in depth because a number of past studies indicate that more signals would aid older drivers. In this case, it did not seem to make a difference.

The crash factors of older drivers are similar in both left turn and gap acceptance maneuvers excluding light conditions and population. Light condition is not a significant factor. In contrast to left turns, older drivers’ crash involvement in urban areas is less than that of rural areas in gap acceptance maneuvers. This may be because they tend to avoid risking such vehicle maneuvers knowing their own limitations.

The only major factor among those examined that was found to significantly contribute to crash involvement while conducting lane changes on limited access highways was that of the driver’s age. Older drivers are more likely to be involved in crashes while they are changing lanes. Especially, the likelihood of committing errors increases dramatically with the aging process. In contrast to the non-limited access highway vehicle maneuvers, statistical tests show that female drivers are safer on limited access highways. Furthermore, the analysis shows that older drivers are not aggressive at all while they drive on limited access roads. But the main reason for them to be involved in a crash is because of the problems with peripheral vision. This involvement will be increased with
both higher speed and traffic on the road.

The results from the survey also indicate that the presence of multiple vehicles on the roadway seems to be the most difficult situations for the respondents. This is evident also in the rankings for each of the questions as well as in the paired tests between one and more than one vehicles. One possible explanation for this may be the increased mental load in these situations: a statement that was strongly supported by the participants.

Of the maneuvers studied, survey results highlighted that merging situations are the least difficult to maneuver due to the fact that the diagrammed questions had the highest t-value scores indicating the least amount of incorrect answers given. The significance values were lower, however, for the questions that contained more than one other vehicle on the roadway. The presence of other vehicles in the right hand lane next to the respondent in the merging lane resulted in incorrect responses as well. This shows that this situation should be studied further and is one that may be causing problems for older drivers.

The crash analysis indicates that older drivers’ crashes on limited highways highly concentrate on ramps rather than other road components. Unfortunately, this could not be tested statistically due to the lack of data. However, it is noticeable that vehicles of older drivers collided with road structures because of drivers’ inability to control under complex situations.
Driving at night poses a significant problem for elderly and a significant number of respondents feel an increased apprehension while driving at night. Many of the respondents also indicated that they have even stopped driving at night due to this nervousness. More streetlights and more reflective lane markings are all solutions that could be considered to remedy this problem.

The presence of other vehicles on the roadway was a significant factor in responding improperly to each of the maneuvers. This is similar to the little information found in the literature review. The findings here point toward a definite need for more research on this topic. It would be beneficial to determine if the increased sense of apprehension due to other vehicles on the roadway significantly affects the older drivers' chances of being involved in a crash. The analysis here indicates that this uneasiness has the potential to increase their chances to be involved in a crash.

When all crash types are examined, it is observed that older drivers are at a greater risk because of their diminished physical capabilities. Due to this, the driver's awareness of his or her own health condition is the only way to make him or her safer.

The results of this research indicate that more work needs to be done to enhance the driving environment for older drivers and advance our understanding of their driving habits. The survey participants have also indicated some potential solutions that they feel that they could improve their driving environment. For example, more street lighting and better reflective lane markings on all roads may help to greatly reduce the problems with nighttime driving. Longer merging lanes and more lighting along merging ramps could assist older drivers in merging. Additionally, more protected left turns along busy
corridors and lower speed limits around shopping centers may help with the left turning problems. From the part of older driver, having a passenger who may assist the driver will be helpful. A number of these countermeasures have the potential to benefit all drivers, not just those considered older.
7.0 REFERENCES


17. McKelvey, F.X. and Stamatiadis, N. Highway Accident Patterns in Michigan Related to Older Drivers. In Transportation Research Record 1210, TRB, National Research


APPENDIX A
Mature Drivers Survey

Thank you very much for your participation in this survey. The main purpose of this survey is to better understand the driving behaviors and patterns of mature drivers. There are many current projects throughout the United States aimed at improving the roadway conditions for mature drivers patterns. This survey will help to identify some of the changes that need to take place in this area. Therefore, your participation is greatly appreciated.

INSTRUCTIONS:

This survey is divided into six sections including: 1.) background information, 2.) medical history, 3.) merging situations, 4.) fast lane changes, 5.) nighttime driving, and 6.) left turning movements. Each of these sections contains a mixture of questions, open-ended questions, and multiple choice type questions. If you need more space to answer a question, or would like to elaborate more on your answer, please do so on the back of the respective page, but please indicate which question number you are referring to.

Thank you again for your participation in this survey. When you have completed your survey, please return it to the Senior Center for Mrs. Laura Mitchell to pick them up.

If you have any further questions please contact Mrs. Laura Mitchell at (859)257-4349 or lbtmitchell@hotmail.com, or Dr. Nikiforos Stamiadis at (859)257-8012 or nstamat@engr.uky.edu.
BACKGROUND INFORMATION

1. Age:
   - ☐ 55 – 60
   - ☐ 61 – 65
   - ☐ 66 – 70 years old
   - ☐ 71 – 75 years old
   - ☐ 76 – 80 years old
   - ☐ 80 and over

2. At what age did you receive your first driver’s license? ______________

3. Have you ever let your driver’s license expire?
   - ☐ Yes
   - ☐ No

4. If yes to the above question, for how long? ______________

5. How would you classify your current vehicle?
   - ☐ Sedan
   - ☐ Sports Car
   - ☐ Station Wagon/Van
   - ☐ Pickup Truck/Sports Utility Vehicle

6. How often do you drive your vehicle?
   - ☐ Daily
   - ☐ Weekly
   - ☐ Monthly

7. When was the last time that you received a driving citation from a police officer?
   - ☐ This Month
   - ☐ Two to Twelve Months Ago
   - ☐ Over A Year Ago
   - ☐ Never

8. If you have received a violation since the age of 55, what best describes the reason?
   - ☐ Speeding
   - ☐ Wreckless Driving
   - ☐ Parking
   - ☐ Expired Tags / License
   - ☐ DUI
   - ☐ Vehicle Deficiencies
   - ☐ Other ______________

9. How often do you wear your seatbelt while driving?
   - ☐ Always
   - ☐ Occasionally
   - ☐ Sometimes
   - ☐ Never
   - ☐ Not Applicable

10. How often do you wear your seatbelt as a passenger?
    - ☐ Always
    - ☐ Occasionally
    - ☐ Sometimes
    - ☐ Never
    - ☐ Not Applicable
MEDICAL BACKGROUND

12. Has your main healthcare provider ever advised you not to operate a motor vehicle?
   □ Yes  □ No

13. Do you have an annual physical exam?
   □ Yes  □ No

If yes, does your doctor ask you questions during your physical pertaining to your ability to operate a motor vehicle?
   □ Yes  □ No

14. Do you have an annual eyesight exam from a licensed optometrist?
   □ Yes  □ No

15. Please list any major medical conditions that you have. (Examples include diabetes, asthma, high blood pressure, etc....)

________________________________________________________________________________________________________________________
________________________________________________________________________________________________________________________
________________________________________________________________________________________________________________________

16. Have you ever been prescribed medication from your doctor and been advised by your doctor pharmacist not to operate a motor vehicle while taking the medication?
   □ Yes  □ No

17. Did you ever disobey your doctor’s or pharmacist’s advice & drive?

   Always  Occasionally  Sometimes  Never  Not Applicable
   □   □   □   □   □

18. Do you wear glasses or contact lenses while driving?

   □   □   □   □   □   □

19. How often do you experience muscle pain or tightness while operating a motor vehicle?

   □   □   □   □   □   □
MERGING ISSUES

Assume that you are merging at a reasonable speed and have accelerated adequately on the ramp.

20. In this case would you:
- Brake
- Slow Down
- Merge
- Accelerate
- Ride Into the Shoulder

21. In this case would you:
- Brake
- Slow Down
- Merge
- Accelerate
- Ride Into the Shoulder

22. In this case would you:
- Brake
- Slow Down
- Merge
- Accelerate
- Ride Into the Shoulder

23. In this case would you:
- Brake
- Slow Down
- Merge
- Accelerate
- Ride Into the Shoulder
24. In this case would you:

- [ ] Brake
- [ ] Slow Down
- [ ] Merge
- [ ] Accelerate
- [ ] Ride Into the Shoulder

25. In this case would you:

- [ ] Brake
- [ ] Slow Down
- [ ] Merge
- [ ] Accelerate
- [ ] Ride Into the Shoulder

26. In this case would you:

- [ ] Brake
- [ ] Slow Down
- [ ] Merge
- [ ] Accelerate
- [ ] Ride Into the Shoulder

27. In this case would you:

- [ ] Brake
- [ ] Slow Down
- [ ] Merge
- [ ] Accelerate
- [ ] Ride Into the Shoulder
28. In this case would you:
   - [ ] Brake
   - [ ] Slow Down
   - [ ] Merge
   - [ ] Accelerate
   - [ ] Ride Into the Shoulder

29. In this case would you:
   - [ ] Brake
   - [ ] Slow Down
   - [ ] Merge
   - [ ] Accelerate
   - [ ] Ride Into the Shoulder

30. In this case would you:
   - [ ] Brake
   - [ ] Slow Down
   - [ ] Merge
   - [ ] Accelerate
   - [ ] Ride Into the Shoulder

31. Please rank Questions 20 through 30 by difficulty with 1 being the most difficult.
   1. ________  2. ________  3. ________  4. ________  5. ________
   6. ________  7. ________  8. ________  9. ________ 10. ________
   11. ________

32. Have you ever been involved in a motor vehicle accident while merging onto a controlled access highway or interstate?

   - [ ] yes
   - [ ] no

If yes, please describe.

33. How early do you begin to plan your merge onto a controlled access highway or interstate? Please describe below.
<table>
<thead>
<tr>
<th>Question</th>
<th>Always</th>
<th>Occasionally</th>
<th>Sometimes</th>
<th>Never</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>34. How often do you drive on a controlled access highway or interstate?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>35. How often do you feel that there are not adequate markings while merging? (lane markings, arrows, etc.)</td>
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</tr>
<tr>
<td>36. How often do you have a hard time seeing these markings?</td>
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<tr>
<td>37. How often do you NOT drive at night because you are concerned about merging traffic in the dark?</td>
<td></td>
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</tr>
<tr>
<td>38. How often do you find yourself merging into traffic at the end of the merging lane?</td>
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<tr>
<td>39. How often do you use your rear view mirror while merging?</td>
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<td></td>
</tr>
<tr>
<td>40. How often do you use your side mirrors while merging?</td>
<td></td>
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</tr>
</tbody>
</table>
LANE CHANGES

Assume that you have decided to change a lane in the following scenarios:

41. In this case would you:
   - Brake / Stop
   - Slow Down
   - Move Into Left Lane
   - Accelerate
   - Wait for Vehicle 2 to Pass

42. In this case would you:
   - Brake / Stop
   - Slow Down
   - Move Into Left Lane
   - Accelerate
   - Wait for Vehicle to Pass

43. In this case would you:
   - Brake / Stop
   - Slow Down
   - Move Into Left Lane
   - Accelerate

44. In this case would you:
   - Brake / Stop
   - Slow Down
   - Move Into Right Lane
   - Accelerate

45. In this case would you:
   - Brake / Stop
   - Slow Down
   - Move Into Left Lane
   - Accelerate
   - Wait for Vehicle 2 to Pass

46. In this case would you:
   - Brake / Stop
   - Slow Down
   - Move Into Right Lane
   - Accelerate
   - Wait for Vehicle 1 to Pass
47. In this case would you:
☐ Brake / Stop
☐ Slow Down
☐ Move Into Left Lane
☐ Accelerate

48. In this case would you:
☐ Brake / Stop
☐ Slow Down
☐ Move Into Right Lane
☐ Accelerate

49. Please rank Questions 41 through 48 by difficulty with 1 being the most difficult.
1. _______ 2. _______ 3. _______ 4. _______
5. _______ 6. _______ 7. _______ 8. _______

50. Please describe your steps as you make a lane change.

51. Do you have any physical limitations that prevent or hinder you in making fast lane passing maneuvers?
☐ yes  ☐ no

If yes, please describe.

52. How often do you feel a mental overload of information while attempting to make a lane change?
☐ Always  ☐ Occasionally  ☐ Sometimes  ☐ Never  ☐ Not Applicable

53. How often do you feel that the drivers around you are driving too fast or wrecklessly?
☐ Always  ☐ Occasionally  ☐ Sometimes  ☐ Never  ☐ Not Applicable

54. How often do you use your rearview mirrors while making a fast lane change maneuver?
☐ Always  ☐ Occasionally  ☐ Sometimes  ☐ Never  ☐ Not Applicable

55. How often do you use your side mirrors while making a fast lane change maneuver?
☐ Always  ☐ Occasionally  ☐ Sometimes  ☐ Never  ☐ Not Applicable

56. How often do you make sure that your mirrors are properly adjusted before actually leaving for your trip?
☐ Always  ☐ Occasionally  ☐ Sometimes  ☐ Never  ☐ Not Applicable
### NIGHT DRIVING

<table>
<thead>
<tr>
<th>Question</th>
<th>Always</th>
<th>Occasionally</th>
<th>Sometimes</th>
<th>Never</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>57. Do you continue driving at night?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>58. How often do you feel apprehension or nervousness when driving at night?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>59. How often do you drive at night and feel that the street is not lit well enough?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>60. How often do you find yourself confused about lane usage at night?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>61. How often do you alter your trip or route at night due to poor lighting on roadways?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>62. How often do you alter your trip or route at night due to poor lane marking?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>63. How often do you slow down to read street or road signs at night?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>64. Do you find it more difficult to turn left at an unsignalized intersection at night?</td>
<td>☐ Yes</td>
<td>☐ No</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LEFT TURNING MANEUVERS

Assume you are making a left turn at an unsignalized intersection and you are at a stop. The arrows indicate the direction of the respective vehicles.

65. In this case would you:
- Brake / Stop and Complete Turn
- Slow Down and Complete Turn
- Cancel Turn and Continue Straight
- Accelerate and Complete Turn

66. In this case would you:
- Brake / Stop and Complete Turn
- Slow Down and Complete Turn
- Cancel Turn and Continue Straight
- Accelerate and Complete Turn

67. In this case would you:
- Brake / Stop and Complete Turn
- Slow Down and Complete Turn
- Cancel Turn and Continue Straight
- Accelerate and Complete Turn

68. In this case would you:
- Brake / Stop and Complete Turn
- Slow Down and Complete Turn
- Cancel Turn and Continue Straight
- Accelerate and Complete Turn

69. Please rank Questions 65 through 68 by difficulty with 1 being the most difficult.
1. _________ 2. _________ 3. _________ 4. _________

70. Assume that the turns are made at a signalized intersection and rank Questions 65 through 68 by difficulty with 1 being the most difficult.
1. _________ 2. _________ 3. _________ 4. _________

71. How often do you find yourself having a difficult time judging the speed of opposing traffic when trying to turn left?

Always  Occasionally  Sometimes  Never  Not Applicable

72. How often do you alter your driving route to avoid turning left at unsignalized intersection?

Never  Occasionally  Sometimes  Always  Not Applicable
73. How often do you alter your driving route to avoid turning left at signalized intersection?  
Always ☐  Occasionally ☐  Sometimes ☐  Never ☐  Not Applicable ☐

74. How often do you have a difficult time turning left onto a busy street or out of a busy shopping center without a left turn arrow?  
Always ☐  Occasionally ☐  Sometimes ☐  Never ☐  Not Applicable ☐

75. How often do you have “close call” accidents due to misjudgement in gap in opposing traffic? By close call, we mean were you visibly shaken, did you have to pull over to gain your composure, were you honked at?  
Always ☐  Occasionally ☐  Sometimes ☐  Never ☐  Not Applicable ☐

Thank you very much for your time and thoughts and work on completing this survey. Your input is greatly appreciated and of great use in furthering the work of this research project within the Civil Engineering Department at the University of Kentucky.

If you have any further questions or comments, please contact:

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lbtmitchell@hotmail.com