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Relationship Between Accidents of Elderly Drivers and Intersection Traffic Control Devices

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Nikiforos Stamatiadis

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Ph.D. degree in CEE

William C. Taylor
Major professor

Date July 6, 1990

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RELATIONSHIP BETWEEN ACCIDENTS OF ELDERLY DRIVERS AND INTERSECTION TRAFFIC CONTROL DEVICES

By

Nikiforos Stamatiadis

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
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ABSTRACT

RELATIONSHIP BETWEEN ACCIDENTS OF ELDERLY DRIVERS AND INTERSECTION TRAFFIC CONTROL DEVICES

By

Nikiforos Stamatiadis

The objective of this study is to identify the relationship between driver, roadway, environmental conditions, and accidents that occur at intersections and then to determine if certain aspects of intersection traffic control affect the aged drivers differently than the non-aged drivers.

The data consisted of 148,134 multi-vehicle accidents that occurred on the State of Michigan Trunkline system. The induced exposure method is used to derive accident involvement to exposure rates. This method is based on the assumption that the accident exposure by any age group of drivers is proportional to the innocent victim (driver not responsible for the accident) involvements in multi-vehicle accidents by that age group of drivers.

Using this technique, conditions are identified in which aged drivers experience higher involvement rates than younger drivers. For these conditions the data are further tested to examine the effect of the intersection traffic controls and their characteristics on the elderly accident involvement.

The results indicate that, in general, elderly drivers do not exhibit different accident patterns between signalized and non-signalized intersections under the conditions tested. Exceptions are female drivers at signalized intersections in snowy weather conditions and middle-old female drivers at non-signalized intersections on multi-lane two way roads. For non-signalized intersection accidents, it was concluded that elderly drivers, and mainly females, experience higher rates at night in snowy weather conditions than either other weather conditions or during the day. For signalized intersection accidents, it was found that elderly drivers experience significantly more problems at signalized intersections with multi-phase signals, while the other signal characteristics had no effect on elderly.

The predominant violation types for aged drivers are following too close, failing to yield the right of way, and improper turning; which indicate a failure to properly identify the available gaps and to properly react to traffic conditions. These violations lead to corresponding accident types, such as rear end, head-on while turning left, and right angle indicating that elderly have problems with turning maneuvers in complex traffic situations. These findings tend to support the hypotheses that elderly drivers experience a reduced ability to appropriately handle traffic situations due to a reduction in the basic skills required for safe driving.

This study documented the fact that elderly drivers experience difficulty as the complexity of the design and traffic control device application increases, indicating that the major contribution to safety may come from measures affecting the driver, such as licensing and training.

To my parents, Neofitos and Polymnia, and to my wife Anne Marie

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1. INTRODUCTION

In recent years the American society is experiencing an increase in longevity described as the "graying of America." Due to changes in lifestyle and medical advances, the number of elderly people is increasing continuously. Their continuous increase results in a growing percentage of elderly people in the population. Since the automobile continues to be an integral part of society and most of the aging individuals continue to drive their automobiles, this results in an ever-increasing percentage of elderly drivers.

The driving task is a multi-level process which incorporates the search for relevant cues or instructions, the processing and interpretation of these cues by the driver, and the consequent reaction to them. Part of the instructions and information is provided to the driver by the use of traffic control devices.

Traffic control devices take three basic forms: traffic signs, traffic signals, and pavement markings. Each form has a variety of colors and symbols but all have the immediate objective of informing the driver as clearly as possible.

Aging can impair the mental and physical facilities that are required for safe driving, such as visual acuity. Thus, there is concern in today's society about the effective utilization of traffic control devices by elderly drivers. Usually older people, and therefore older drivers, show deteriorating learning capability, longer reaction time to various stimuli, and longer processing time for information [34,14], all of which are very important for effective recognition and response to traffic control devices, safe driving, and the avoidance of accidents.

Based on the above concerns, the current study has the objective of identifying the relationship between driver, roadway, environmental conditions, and accidents that occur at intersections.

The first step of this study was a literature review and analysis of the findings on the issue of aging driver behavior and how this behavior could be associated with effective recognition and utilization of traffic control devices at intersections. The various components of the detection and recognition process are reviewed in the context of the natural effects of the aging process. Then an experimental design is established that includes the data preparation, the assumptions of this research, and the methodology to be followed to test the hypotheses of this research. The next step involves the testing of the hypotheses formulated based on the data analysis and results. Finally, the conclusions of this study and suggestions for future needs are stated.

2. LITERATURE REVIEW

2.1. Introduction

In the past decades an increase has been noted in the average lifetime of the population. Improvements in medical technology and increased health care have helped the aging of the population and increased significantly the number of elderly people. Elderly people tend to depend on private automobiles since today's society is closely attached to the use of the automobile and people depend on driving in order to fulfill their needs. The increased motorization of society and the increased number of aged people has produced a large number of elderly drivers. This trend will continue to increase.

From the outset it should be noted that the effects of aging occur along a continuum. This leads immediately to the problem of defining the terms "aged or elderly" driver. The dividing line between the age groups of drivers could be considered an arbitrary choice. With the Social Security Act of 1935, the United States defined the age of 65 as the time for retirement, and therefore from this age on a person can be generally considered as aged or senior. Thus, this age will be used as a starting point for the definition of aged (or elderly) for this study.

2.2. The Aging Driver

The american population has been growing older with an increased rate. In 1900 only 4 percent of the population was 65 years old or older while in 1984 the same group contains 12 percent of the population. The reason for this increase is attributed both to the Post World War II baby boom and the advancement in medicine. These two reasons have changed significantly the composition of the american population. This change is usually referred by demographers as the "squaring of the pyramid." This trend is shown in Figure 2.1, where the past, present and projected population pyramids are presented.

This figure indicates that in 1950 and 1980 the population followed a distribution resembling a pyramid, based on the data provided by the Bureau of the Census [44,45]. However, significant changes are expected in the future based on forecasts from the Bureau of the Census [43]. The forecasts show an increase in the middle-aged population by 2000 and a significant increase in the percentage of elderly by 2030. The age distribution by the year 2030 will abandon the pyramid look and will resemble a rectangle. In 1950 only 8.2 percent of the population was over 65 years old while in 1980 they accounted for 11.3 percent and they are expected to be 13.0 percent of the population by year 2000 and 21.2 percent by year 2030.

These data indicate a significant increase in the population of elderly during the past decades and it indicates that another growth should be expected in the future. Such an increase in the population was followed by a corresponding increase in the driving population of the elderly. During the past decades the proportion of elderly drivers

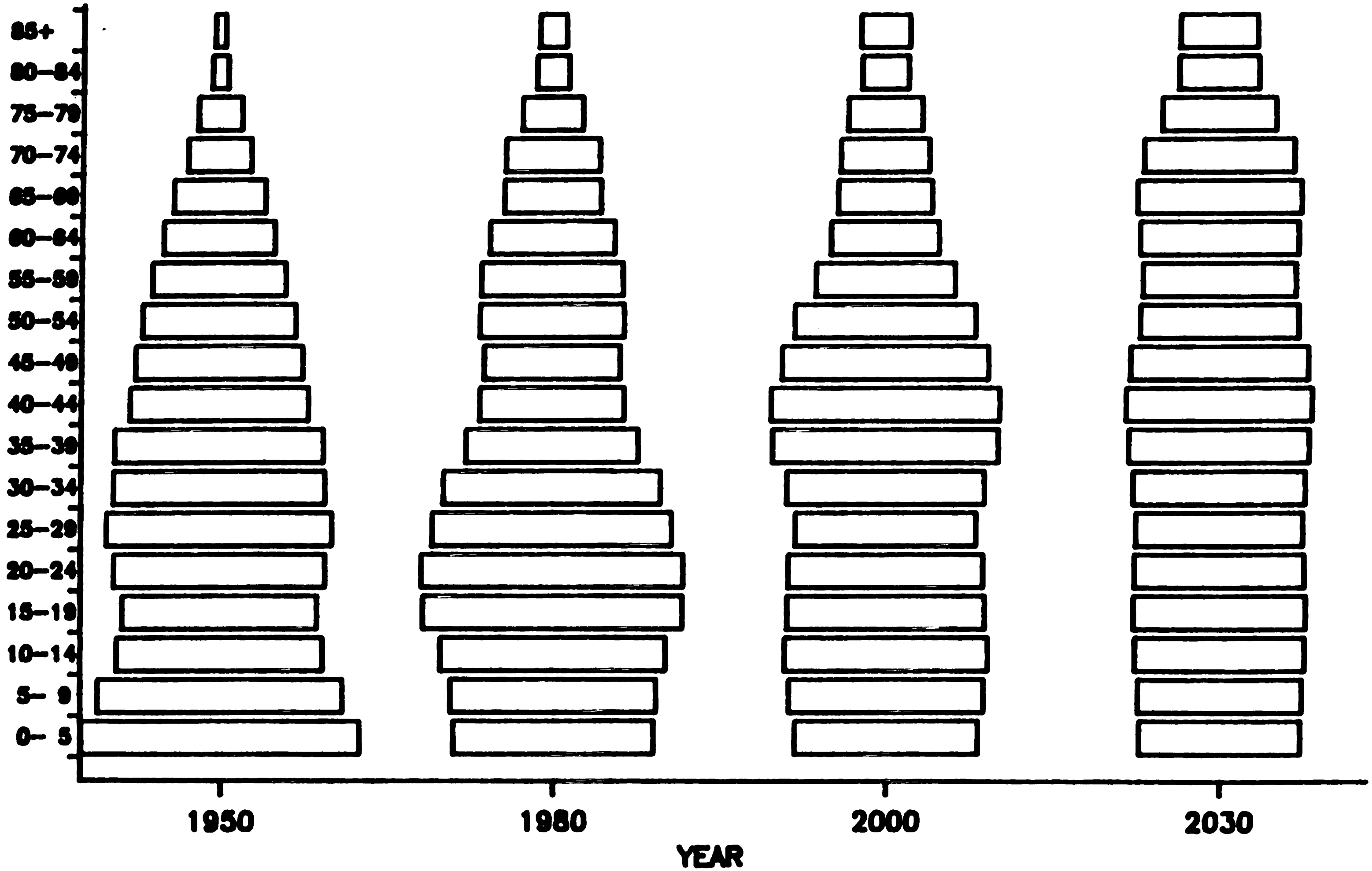

Figure 2.1. Changes in the population of United States (1950-2030)

has increased, which makes their group an increasingly significant part of the driving population. Table 2.1 presents the growth of the driving population during the period of 1965 to 1985. This table shows that in 1965, drivers age 65 and older accounted for 7.6 percent of the driving population in the United States; in 1975, 9.5 percent; and, in 1985, 11.9 percent [46,47]. The same table indicates that these percentages represent 7.48 million drivers in 1965, 12.35 million in 1975, and 18.64 million in 1985. The last two columns in this table present the percent increase for each age group between the 1965-1975 and 1965-1985 periods. It is apparent that in both periods elderly drivers showed the fastest growth by increasing 1.5 times in the 1965-1985 period. The percent increase for each age group of drivers is shown in Figure 2.2.

Tables 2.2 and 2.3 present the data from Table 2.1 broken down according to the sex of the driver. A significant pattern was observed in these tables. In 1965 male drivers over 65 years accounted for 9.3 percent of the male driving population while females over 65 accounted for 5.2 percent of the female driving population. Also, male drivers over 65 accounted for 72.2 percent of the total driving population over 65 years old. These figures have changed dramatically in 1985. For this year, male drivers over 65 represent 12.2 percent of all male drivers while female drivers over 65 represent 11.5 percent of the female driving population. Male drivers over 65 represent only 53.6 percent of the total elderly driving population. Also, female elderly drivers experienced the highest growth during the same period increasing their driving population by 3.2 times in the 1965-1985 period. The percent increase for both male and female drivers for each

Table 2.1. Growth of driving population for the 1965 to 1985 period

Age	1965		1975		1985		Percent Increase	
Group	Licenses	Percent	Licenses	Percent	Licenses	Percent	1965-1975	1965-1985
Under 25	20203	20.51	29328	22.60	28745	18.32	45.17	42.28
25-44	41523	42.15	51351	39.56	69808	44.50	23.67	68.12
45-64	29294	29.74	36767	28.33	39678	25.29	25.51	35.45
Over 65	7482	7.60	12345	9.51	18638	11.88	65.00	149.10
Total	98502	100.00	129791	100.00	156869	100.00	31.76	59.25

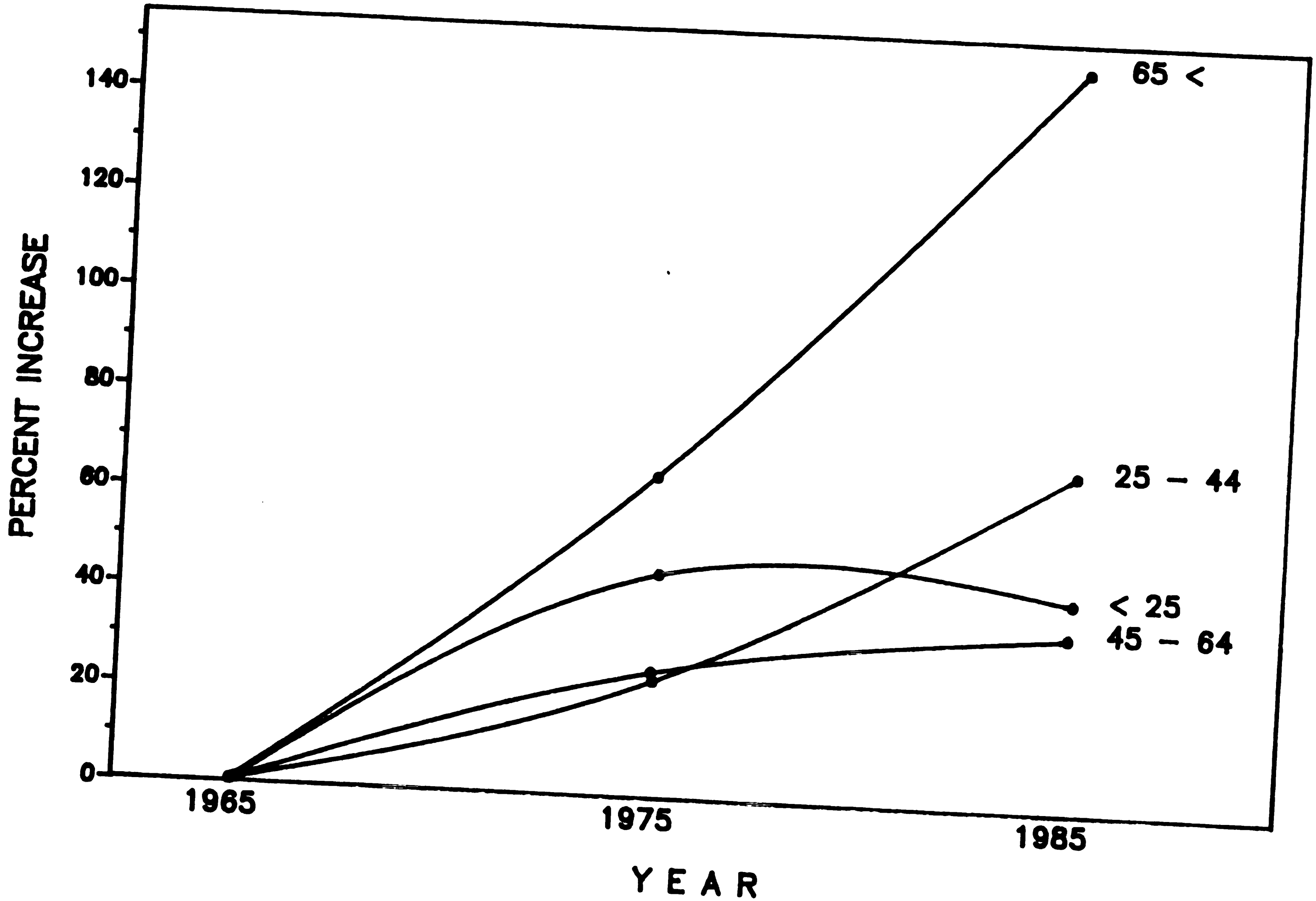

Figure 2.2. Percent increase of age groups of drivers (1965-1985)

Table 2.2. Growth of male driving population for the 1965 to 1985 period

Age	1965		1975		1985		Percent Increase	
Group	Licenses	Percent	Licenses	Percent	Licenses	Percent	1965-1975	1965-1985
Under 25	11708	20.08	15786	22.39	15169	18.59	34.83	29.56
25-44	23494	40.29	27104	38.44	35855	43.94	15.37	52.61
45-64	17704	30.36	20093	28.50	20572	25.21	13.49	16.20
Over 65	5402	9.26	7522	10.67	9996	12.25	39.24	85.04
Total	58308	100.00	70505	100.00	81592	100.00	20.92	39.93

Table 2.3. Growth of female driving population for the 1965 to 1985 period

Age	1965		1975		1985		Percent Increase	
Group	Licenses	Percent	Licenses	Percent	Licenses	Percent	1965-1975	1965-1985
Under 25	8495	21.13	13542	22.84	13576	18.03	59.41	59.81
25-44	18029	44.85	24247	40.90	33953	45.10	34.49	88.32
45-64	11590	28.84	16674	28.12	19106	25.38	43.87	64.85
Over 65	2080	5.17	4823	8.14	8642	11.48	131.88	315.48
Total	40194	100.00	59286	100.00	75277	100.00	47.50	87.28

age group is shown in Figure 2.3.

The ratio of drivers to non drivers of all people age 65 and over has also been increasing. In 1965 the percentage of drivers in the 65 and over population group who held a valid driver's license was approximately 41 percent, while in 1985 the figure had risen to 65 percent, indicating a 59 percent increase during the 1965-1985 period. The proportional increase was 27.3 percent for male drivers, whose ratio was increased from 68.1 to 86.7 percent during the same period, and 150 percent for female drivers, whose ratio was increased from 20.3 to 50.8 percent. The ratio of drivers to population for each group is presented in Table 2.4. The rise in this ratio is consistent with general population trends that indicate that the number of aged people in the United States has been increasing both absolutely and proportionately.

The continuous increase of the elderly population has generated concern regarding the physiological and mental effects of aging on driving performance [13,17]. These effects are examined in the following with the physiological ones due to the ageing process being examined first.

2.3. Characteristics of the Aged

It is well known that as people get older certain changes occur in their physical characteristics. According to Kaneto [13], there are three main groups of characteristics that define the changes in the physical characteristics of the aged: aging in morphology, with changes in the natural appearance; aging in metabolism, with changes in the way

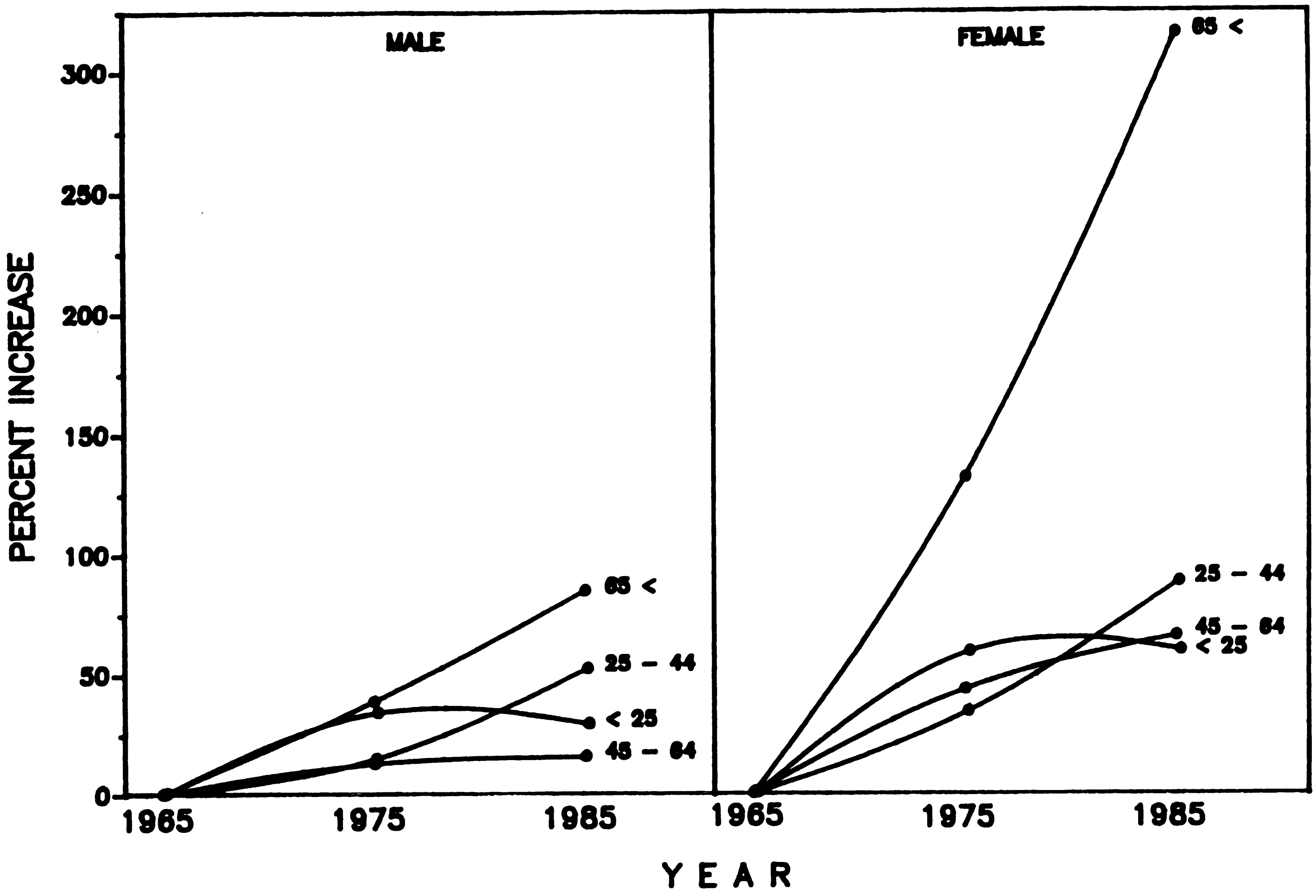

Figure 2.3. Comparison between male and female drivers of percent increase of drivers (1965-1985)

Table 2.4. Ratio of drivers to population for the 1965 to 1985 period

Age	Total			Male			Female		
Group	1965	1975	1985	1965	1975	1985	1965	1975	1985
Under 25	22.40	31.32	31.41	25.68	33.26	32.58	19.04	29.32	30.21
25-44	89.33	95.91	94.62	103.28	103.08	97.93	75.96	88.99	91.35
45-64	75.14	84.44	88.33	93.94	96.47	95.86	57.55	73.41	81.43
Over 65	41.21	55.11	65.33	68.11	82.02	86.71	20.34	36.46	50.83
Total	50.82	60.90	65.71	61.30	67.95	70.24	40.72	54.20	61.41

that the body is working; and aging in function, with deterioration of certain organs of the body.

In addition to the changes in the physical characteristics, certain psychological changes occur. The age of 65 represents the age of retirement and is equated with the adjectives of aged, elderly, and senior. Therefore, a person who does not have to work any more will undergo certain psychological changes, and it is possible that he will suffer from mental emptiness. Aging also reduces the speed of intellectual activities and it was shown by Kinsbourne and Barryhill [15] that elderly people lose the capacity to learn relative to younger people. All these changes depend greatly on the character of the individual as well as on the environment that surrounds them.

It has been postulated [30,13] that the automobile can be a very powerful means for the aged person to show to the rest of the world that he still exists and that there are certain things that he can do even at an "advanced" age. This may have increased importance since a national transportation study [49] has indicated that the predominant transportation mode among elderly is the automobile.

Finally, the emotional and physical changes that occur after one's retirement create many problems which sometimes lead them to "a feeling of loss of identity" as stated by Mann [20]. Both physical and psychological changes due to the aging process have an effect on one's driving performance. These changes and their effects on the performance of the aged driver will be discussed further.

2.4. The Driving Task and the Aged

The driving task is a sequence of functions that must be performed to operate a vehicle safely with minimal disturbance to the traffic flow and other drivers. Certain parts of the body are required to perform either individually or cooperate with others during the driving process. A driver has to make decisions concerning what they see, hear, and feel in relation to the rest of the traffic and to respond to certain stimuli. The coordination of decisions and actions is of great importance for safe driving and has to be quick and semiautomatic, since, in most cases, the available time for reaction is very small. A great number of stimuli for the driver come from traffic control devices.

The components of the driving task are to sense the stimuli, to process them, and to react to them. The elderly driver is facing a deteriorating ability in all these components due to age. The elderly driver's deterioration in visual acuity is combined with relatively lower ability to perceive and process information from stimuli during the driving task which has an immediate effect on his driving performance. Also the reaction time of the aged person to various stimuli is longer than that of younger drivers. The effects of age on these components are discussed in the following sections.

2.4.1. Vision

Visual acuity refers to the ability of the human eye to see clearly an object and how much detail can be distinguished. Medical studies have shown that the visual field starts to reduce in the late 30s [53], but no significant change in visual acuity generally occur from 40 to 50 years of age. As visual acuity decreases, it becomes more difficult to distinguish between objects. This results, for example, in a decrease in the ability to distinguish details in a traffic sign.

Accommodation refers to the ability of the human eye to see both far and near objects. This factor is reduced with age as shown in a study by Birren et al. [4]. According to this study, the aging process results in a stiffening of the muscles that control the lens of the eye, and therefore, the ability to focus is reduced, having as an immediate result reduction in the ability of the eye to focus quickly from far to up close and vice versa.

Another important factor that affects vision is glare, since the eye tends to be attracted to the brightest spot. The sensitivity to glare increases with age [16]. The muscles that control the lens of the eye and the lens itself become less elastic with age. Thus, the lens changes shape and becomes thicker. These changes result in a higher level of light scattering when light enters the eye.

The pupil of the eye responds to the changes in the amount of illumination by changing its size in inverse proportion to the illumination. The aging of the eye results in a reduction in the range of responses of the pupil to the illumination level [4] and combined with the effects of glare create some serious problems in the visual acuity of an aged driver. This increases the recovery time from glare. The effects of the increased recovery time from glare combined with the fact that a traffic control device has to be seen and perceived at the same time create additional problems for the aged drivers.

A characteristic of night vision is sensitivity to brightness [51]. The aged eye has a high sensitivity to brightness and instant changes in the level of illumination have a greater effect on the vision of an aged driver. Glare from headlights of oncoming vehicles combined with this sensitivity creates problems for night vision of an elderly driver. Not only does the aged eye have a lower level of visual acuity during nighttime, it also has a lower rate of adaptation to darkness. Thus, more time is required for their vision to reach the best possible level of acuity during the night.

All of the above indicate that the visual acuity of the aged is definitely lower and that there is a certain degradation in the visual capabilities of elderly people. In addition to all these natural causes for the diminished visual acuity by the elderly, the fact that diseases of the eye, such as glaucoma or cataracts, are more common among aged people creates an additional impairment in their vision.

2.4.2. Detection

While driving, the operator has first to detect the various occurrences on the roadway and its vicinity. This means that he has to detect the other vehicles around him and the traffic control devices in the area. Even though the human eye has a wide field of view, traffic control devices are expected in a specific area of the roadway. It is believed that drivers are concentrating the fixation of their fovea (the central part of the retina) in that area where they expect to find the traffic signs. A study by Mourant and Rockwell [27], in which eye movement patterns were mapped, showed that the most frequent fixation was on the right side of the road in areas where traffic signs are usually located.

No evidence was found associating age with the ability of a driver to visually detect traffic signs.

2.4.3. Perception and Recognition

The detection of a traffic sign or signal by the driver is followed by its perception and recognition.

The perception of a stimulus is an important part of identification of relevant cues during driving. A study conducted by Rabbit [32] showed that the elderly have a decreased ability to ignore irrelevant information during their visual search. This behavior can be partially explained by the precautions that aged people naturally take against their failing capacities. This means that it is possible that the aged are expressing more caution to compensate for their reduced physical and information-processing capabilities.

The use of economical rules of classification to sort information in memory is an important factor for reducing the range of information that has to be remembered and processed when a stimulus is perceived. Rabbit [31] showed that while aged people tend to process any information they get, they do not use economical rules to save memory space, nor do they use redundancy in order to perceive stimuli. Redundancy is a process where stimuli can be recognized and recalled immediately from the memory without any further process. A study by Rabbit and Birren [33] tested whether the repetitive use of stimuli will lead to faster reaction of older people to the stimuli. The study showed that even though the older subjects were aware of the fact that the stimuli were repeated, they appeared to pause every time and to analyze them before responding. This was seen as an indication that aged people do not make use of the redundancy process for the response tasks. The above factors combined with lessened ability to ignore irrelevant information are symptoms of diminished capacity to process information.

2.4.4. Decision and Reaction

After the detection and perception of the stimuli the driver has to decide what action is going to be taken. The decision process occurs in the time between the perception of the stimuli and the response to it.

Planek [29] showed that there is a greater failure rate among the aged to perceive the various stimuli when the stimuli are generated at a high pace. The ability to handle information decreases with age due to reductions in short term memory. The recalling process activates two parts of the memory, short and long term. The short term memory is activated first during the recalling process when stimuli have been detected. It creates the first identification and impressions of the stimuli and activates the long term memory where the stimuli will be fully recognized. A review of previous studies by Craik [6] showed that there are certain deficiencies in short term memory that occur with age.

Another important factor during the decision process is immediate recall. Talland [38] indicated that loss in the span of immediate recall occurs at about the age of 40 and then again at the age of 60. Various visual and audio messages are usually recorded in the memory in short segments, and that is how they are recalled. Since the immediate recall ability decreases with age, more time is required for the aged people to recall the various segments of the message.

The final step in the process of driving is the reaction to the stimuli. It is difficult to talk about reaction time to a stimulus as an individual parameter of human performance. Welford [52] stated "... the sensorimotor performance involves a whole chain of mechanisms, both peripheral and central. Limitations upon performance are commonly due to only one of these mechanisms in any given set of circumstances..." Therefore, the reaction time of the aged is longer than for younger people because of their overall deficiencies as previously stated. Their perception time is longer, their visual acuity is generally lower, and they require a longer time for the decision process.

As mentioned before, the aged driver has a lower ability than younger drivers to process information given at a fast pace. Thus, when they are compared with young drivers on fast-paced driving tasks, they perform poorly [19]. On the other hand when they are driving slower, their performance level increases significantly. This is an indication that when aged drivers are able to control their pace, they can deal better with the existing traffic conditions. However, when information has to be processed rapidly, and quick reactions are required, the aged show an increased reaction time.

2.5. Aged Drivers and Intersection Traffic Control

The characteristics of the driving task that are affected by age were examined in the preceding discussion. The relationship between the deficiencies of the aged drivers and the effective utilization of the intersection area traffic control devices will now be examined.

2.5.1. Traffic Signs

Traffic signs exist in a variety of combinations of legends and background colors. The objective of the existence of a sign is to inform the driver. Each color is associated with a special meaning. For example a sign with yellow background and black lettering or symbols is a warning sign, while one with black letters on a white background is regulatory.

Distinction of the color of the sign as well as its shape is of great importance to the communication process between sign and driver. The eye of the aged driver undergoes a yellowing of the lens, which acts as a filter to the shorter wave lengths [51]. Therefore bright colors are more visible to old drivers than paler ones. The yellowing of the lens results in a reduction in the sensitivity of the retina to blue light and possibly to the green and red parts of the spectrum [40]. Loss of color vision when it is associated with color blindness has severe effects on the driver's vision. The loss of color vision occurs due to the aging process and is associated with a decreased ability to identify ranges of colors, as opposed to color blindness, where the eye cannot distinguish between two or more colors.

Various studies have been conducted to examine the effects of the combinations of colors of the signs and their legibility. A study by Forbes et al. [8] examined the recognition of word signs as a function of luminance and color. The results showed that a 75 to 85 percent legend to sign contrast was required for legibility. The study concluded that certain color combinations, such as black on orange or white on brown, show significant decrease in acuity over white on blue or black on white color combinations.

A study was conducted by Holder [12] to determine the time that is required for a driver to perceive the message of a sign. His study showed that, for a sign that is located within 10 degrees from the driver's normal line of sight, the required time can be expressed by the function:

$$t = 1.94 + (0.31 * N)$$

where t is in seconds and N the number of words on the sign. This means that for a one-word sign 2.2 seconds are required for a driver to perceive the message.

The color and the shape of the sign are the first stimuli that a driver perceives. They are the first to activate the short term memory and create a link to the full recognition of the sign by retrieving information from the long term memory. The short term memory is reduced in capacity and ability with age as previously indicated. This means that the formula for determining the required time for sign recognition, as given by Holder, might need some adjustment for elderly drivers. In addition to the greater time that is required by an aged driver to perceive the meaning of a given sign, usually more time is required for the detection of the sign as well, due to deteriorating vision.

An important factor for sign recognition is its luminance. Usually a sign is more visible during daytime than nighttime. The only exception occurs in cases where the ratio of the color of the sign and the background color of the surrounding area of the sign is smaller than 3 to 1, as stated by Forbes [8]. The use of reflective materials has increased the visibility of the signs during the night. As Sivak and Olson [35] stated "no criteria now exist for establishing minimal sign luminance levels that are likely to meet with wide acceptance." In the same study they suggested optimal levels of luminance for two groups of signs. First, for signs with black legend on bright background color, such as white, orange, and yellow, the optimal luminance is 75 cd/m^2, (cd/m^2: candela per square meter) while for reflectorized signs the optimal legend-background ratio is 12 to 1.

The illumination of the surrounding area of the sign plays an important role in the visibility and legibility of a sign during night. Laboratory results from an experiment by Allen and Straub [1] showed that in areas with bright lights, higher sign brightness is necessary for legibility and the effects of irradiation are reduced. On the other hand, for dark roads, signs with high brightness showed reduced legibility due to the existence of high levels of irradiation. This is a phenomenon that occurs at night when the eyes of the driver are accustomed to low light levels, and they suddenly encounter a sign with high brightness. The results of this phenomenon are a great diffusion of white letters on dark background and disappearance of black letters on bright background.

The study by Sivak and Olson [35] defined the legibility levels for young and aged drivers based on the results from previous studies. Thus, the legibility was considered to be 50 ft./in of letter height and 40 ft./in of letter height for younger and older drivers, respectively. Assuming that a sign has 8 inch letters, which is the average height for signs used on freeways according to the Manual of Uniform Traffic Control Devices (MUTCD) [48], the legibility distance for a young driver is 400 feet while for an older driver it is 320 feet. Assuming that both drivers travel with a speed of 55 mph or 80 ft./sec, the 80 feet difference in this distance represents a second if the distance is translated in time. This difference decreases the available time of the driver for the appropriate reaction.

The one second difference is not as important if the sign in discussion is an information or services sign. Also for warning signs the MUTCD suggests that the minimum distance between the sign and the hazard of the road should be up to 700 feet for high speed facilities (55 mph). This means that the driver is warned 9 seconds ahead of the hazard at a 50 mph speed on a high speed roadway. Thus, the driver has a total of more than 14 seconds to see the sign, process its message, and respond to it, if he is a young driver, and 12 seconds if he is an aged one. Therefore the available distance for perception and reaction is reduced for an aged driver. The most crucial signs are the STOP and YIELD controls, since the only available distance for reaction is between the detection point and the point of their physical existence. Thus, the available stopping time and distance is reduced for an aged driver, because of their differences in perception and decision processes.

The effects of age on vision are intensified during night. The aged driver requires more time to adapt his vision to the dark as well as to recover from the glare that occurs from the headlights of oncoming traffic. These two deficiencies are intensified when they are associated with nighttime legibility and visibility of traffic signs.

A study was conducted by Sivak et al. [36] to determine the effects of nighttime legibility of traffic signs. During the study two age groups of drivers were tested, one with drivers aged 18 to 24 and the other with drivers aged 66 to 74. Several combinations of background and legend colors as well as contrast ratios were used in simulating real sign combinations. The results showed that the legibility distances for the older group were 65 to 70 percent of those for the younger group. Therefore more distance is available to the younger drivers, and thus more time, for acting on the information transmitted by the sign. The legibility distance was almost the same for all color combinations for the younger group, while variations were noted for the elderly group. The earlier remarks here concerning the available distance for stopping are also supported by this experiment. The results from the comparisons for the contrast ratios showing the reductions in the available distance are given in Figure 2.4.

The above study, using as a measure of performance the legibility distance of the signs tested, indicated that the elderly drivers performed worse than the younger drivers even though their visual acuity was the same under high luminance levels. The differences in the performance were partially attributed to their differences in visual acuity in the low luminance levels. The most important recommendation from that study was that the legibility and luminance of traffic signs are not reliable if their design is based only on

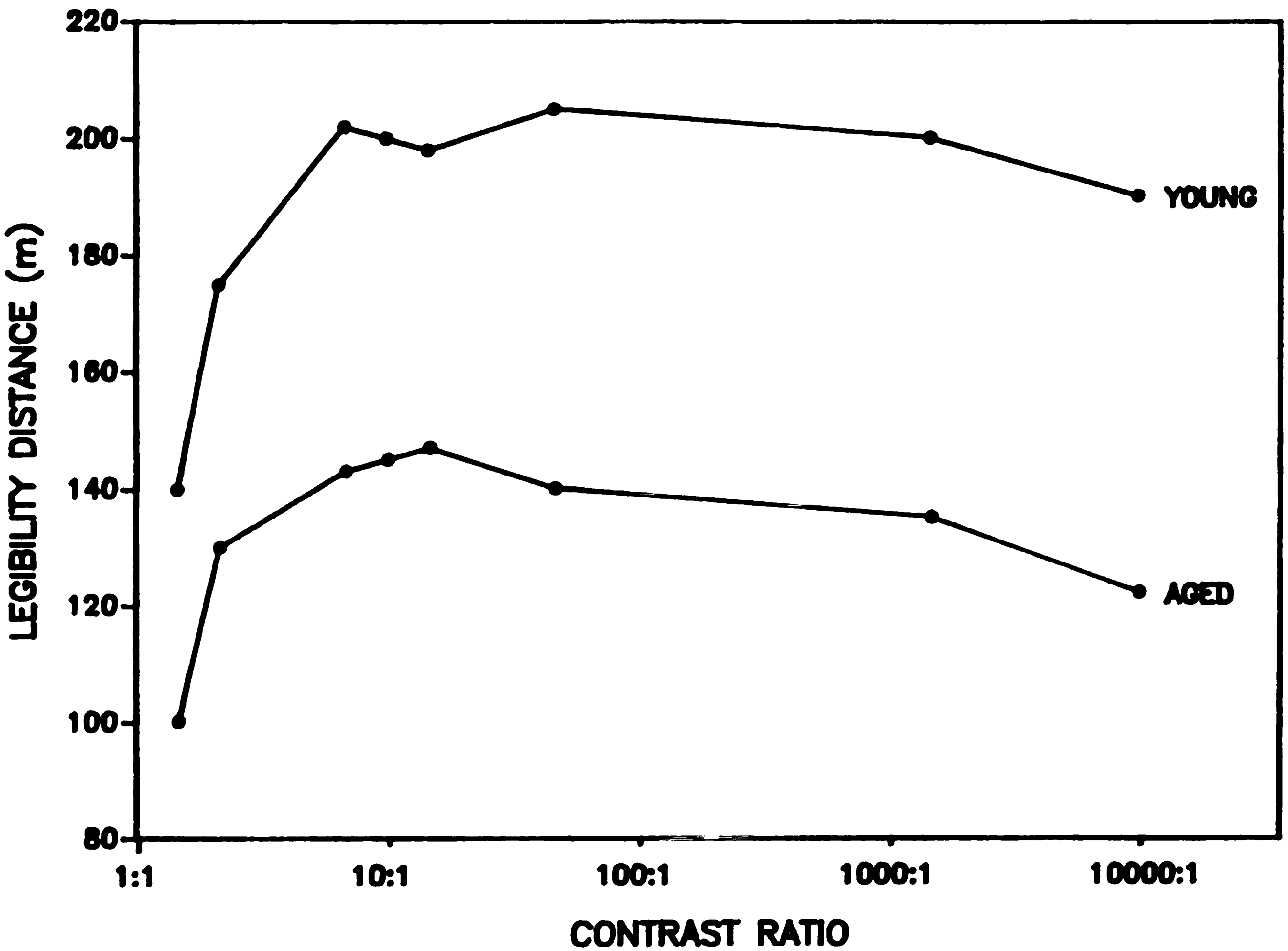

Figure 2.4. Legibility distances as a function of sign contrast ratios and age

experiments with younger drivers. This was also suggested in a study by Allen et al [2] as well as in a workshop for the Mobility and Safety of Older Drivers and Pedestrians [37].

2.5.2. Traffic Signals

As for traffic signs, the purpose of signals is to inform the driver which direction has the assigned right of way.

The recognition of the current color of the lens is of great importance for safe driving. Early detection of the color of the signal is also important. The same problems that were described previously for the detection of the color of traffic signs concerning elderly drivers also exists for signals. Thus, the yellowing of the lens creates a reduced ability to perceive short wave colors. This could be considered more serious for the traffic signals since they are the principal regulators of traffic.

The detection of the color of a traffic signal leads to a particular action one would take in driving an automobile. As indicated previously, the reaction time of an aged driver is higher than that of a younger driver. The increased reaction time combined with the reduced visual abilities of elderly drivers, and particularly color blindness, could create serious problems if the color of the traffic signal is not detected early. There were no studies found indicating a difference between drivers without color blindness and aged drivers in the time in which the color of the lens was perceived. But the differences between the available time for perception and reaction to the signal are reduced for the elderly drivers, as indicated in the preceding discussion.

Traffic signals are usually encountered in urban areas. In most cases, the traffic density is higher and there is a larger amount of information that a driver has to deal with. Driving in an urban setting is the most complex performance of the driving task because continuous adjustments in the speed and position of the vehicle are required in addition to observing and following the various traffic regulations. The information processing time is reduced for aged drivers due to reduced ability of their short term memory to retrieve information. Therefore, the early detection of the color of the traffic signal and its correct recognition are of great importance for safe driving.

The existence of traffic lights in urban areas creates additional problems at night. For example, it is possible that traffic signals are surrounded by colored light from advertisements. The existence of various other light sources results in their interference with traffic lights, particularly when their colors are similar to those of traffic lights. A study by Finch and Howard [7] showed that such interaction between traffic signals and colored light advertisements exists. The study found that the correct color of the signal could be mistaken and sometimes the signals become invisible due to the existence of other light sources.

A study was conducted by Freedman et al. [9] concerning the conspicuity of traffic signals to determine their brightness requirements at night. Both laboratory and field tests showed that the signal brightness had a significant effect on the speed and accuracy of the correct identification of which lens was lit. The study indicated that there are significant differences in speed and accuracy of the reactions during recognition of the correct color between younger and older drivers. The differences between the younger and the older drivers became more significant when the reduction of the brightness was 30 percent or more. This could be considered as additional support of the problem of accurate perception of the correct color of the signal by elderly drivers.

In some cases the complexity of the signal creates additional problems to the understanding of the signal. The existence of special phases for left and/or right turns is the major contributor of additional problems. The existence of additional information that has to be processed and the required distinction between the two signals (for the through and turn traffic), create additional load which will result in the reduced processing ability of the elderly drivers.

2.6. Accident Involvement of Aged Drivers

The increase of the aging population creates an additional concern for traffic safety since an increase of the driving population results in an increase in the miles driven by elderly drivers. There is concern that the aged drivers make up a high risk group. In a study by Moore et al [26] it was found that drivers with ages greater than 65 years are slightly less likely to have an accident than the average driver, while it was noted that the relative accident rates for drivers between 30 and 64 were substantially lower than the average driver. This indicates a decrease in safety for aged (over 65) drivers. From additional information it was found that aged drivers are most likely to be involved in accidents that involve turning movements at intersections.

In another study by the Organization for Economic Co-operation and Development [28] the risks of being in an injury accident were compared between drivers age 25 to 64 to those of drivers age 65 and over. The results showed that the aged were 2.5 to 5 times more likely to be involved in a fatal accident and 1 to 2 times more likely to be involved in an injury accident. In the same study it was found that typical problems related to the traffic safety of the aged drivers include maintaining proper speed, reacting to traffic conditions, reacting to traffic signs and signals, and failing to yield the right of way. It was also shown that aged drivers tended to be at fault in accidents more than younger drivers.

When the number of accidents where the elderly are involved, considered on the base of total elderly population or in comparison to accidents where drivers of other ages are involved, shows that they are not such a high risk group of drivers [3]. However, a national transportation study [49] indicated that the elderly drive fewer miles than other age groups do. Therefore, their accident record viewed in relation to the miles driven appears to be the highest among any age group except teenagers.

Due to the natural aging process elderly become more physically vulnerable and are more likely to be killed in traffic accidents than younger drivers. Koltnow [18] indicated that the number of fatalities for accidents in the United States was reduced by 14 percent during the period 1980 to 1982. However, this reduction was not reflected in the elderly drivers, where males experienced no reduction and females showed a 14 percent increase in fatalities for the same time period. In the same study, it was also noted that elderly account for 7 percent of the total accidents but they account for 12 percent of those killed. An aged driver involved in an accident is 3.5 times more likely to be killed than a younger driver.

2.7. Conclusions from the Literature Review

The driving task is a process of detecting information, interpreting it and reacting to it. The information from traffic control devices is equally important to elderly drivers as to other age groups of drivers. However, the foregoing review indicates that aging impairs the mental and physical factors that are required for safe execution of the driving task. The ability of the eye to clearly distinguish objects is reduced with age. Also, longer time is required for aged eyes to recover from glare as well as to adapt in the dark. Sensory functions also experience a deterioration with age. The perception and recognition of stimuli requires more time than needed for a younger person, due to limited capacity in short term memory. The decision for an action and the reaction time to a stimulus also increases with age.

All these effects of age create problems for the detection and appropriate reaction to intersection traffic controllers. The differences between young and elderly drivers in the time required for the perception of a sign could create major disadvantages to the aged drivers. Illumination levels , legibility of traffic signs, and problems associated with night vision, such as glare from oncoming traffic and illumination of the surrounding area, are other factors that increase the disadvantages that occur from age.

Previous studies showed that problems with early detection of the color of a traffic signal exist for aged drivers and this reduces the reaction time that is available to them. Also the mental load is higher in urban traffic situations where the signals are usually encountered, since a greater amount of information has to be processed. This combined with interference from possible colored light advertisements will create effects such as misinterpretation of the color of the signal and occasionally an inability to perceive the existence of the signal. The complexity of the signal is another factor that can create problems in the early and correct detection of the intended message.

From this, the next step involves the establishment of a methodology to quantify the problems for the elderly drivers in relation to accidents at intersection areas.

3. METHODOLOGY

3.1. Introduction

The general purpose of this study is to explore and define the relationship between accidents that occur at intersection areas and elderly drivers. The specific purpose of this study is to determine if certain aspects of traffic controllers at intersection areas affect the aged driver differently than the non-aged driver in his/hers driving performance. The aspects of the traffic controllers will be viewed in the context of their existence or absence and their characteristics as well as in relation to other parameters of the accident, such as physical and geometric characteristics of the area, time of the accident and so on.

Investigation of the hypotheses will involve testing between the aged and younger drivers concerning the effects of the intersection traffic controllers on accident occurrence. To test the hypotheses derived to examine these questions, an experimental methodology is outlined in this section of the paper.

3.2. Data Base

The accident records for the calendar years 1983 through 1985 were used to perform the analysis of the relationship between aged drivers and accidents. From these records only the ones pertaining to intersection accidents were extracted. To study the relationship of accidents at intersection areas and aged drivers four computer data files were obtained from the Division of Traffic and Safety of the Michigan Department of Transportation (MDOT). These files include the Highway Accident Master File for the three years mentioned previously, the Michigan Dimensional Accident Surveillance (MIDAS) Geometric File, the MIDAS Traffic Volume File, and the Traffic Signal Inventory File.

The Highway Accident Master File contains information about each accident that occurred on a state trunkline, including the accident location (time and place), driving condition, type and severity of the accident, and data regarding the drivers and vehicles involved in the accident. For accidents that involve more than one vehicle the first driver coded is the one determined by the investigating officer to be mostly at fault.

The MIDAS Geometric Segment File contains information about the geometric characteristics of each state trunkline, including the highway laneage, lane width, roadside development, and roadway curvature.

The MIDAS Traffic Volume File contains information about the capacity and average daily traffic. The structure of the two MIDAS files is similar, both of them containing one record per highway segment.

The Traffic Signal Inventory File contains information about the existence of traffic signals and other electrical traffic control devices. This file includes information as to the type of the signal, the number of phases, turn prohibitions, and lens characteristics.

All four files share a common location identification system that indicates the highway district number, the control section number, and the mileage point. By using this information, it was possible to merge the four data files into one, where each accident record was augmented with the appropriate characteristics of the roadway geometry, the volume and the traffic signal data (where appropriate). From each one of the four files only the necessary data was used during the merging in order to reduce the length of each record.

This research, as stated previously, is concentrated only on accidents that occurred at intersection areas. An intersection area includes the intersection plus an area in any direction of its emanating legs that is influenced by the characteristics of the intersection. For this research an intersection influence zone is defined by the MDOT in the MIDAS Geometric Segment File. Therefore, the accident records that will be used here include those that occurred both at intersections and those within the influence zone (150 feet) of the intersection.

3.3. Data Variables

From the four original data files one new condensed data base was created that includes data that are deemed necessary for the exploration of the objective of this research.

The variables that are selected from the Highway Accident Master File are:

- the environmental characteristics at the time of the accident; that is time, date, and conditions of the weather, light, and road surface;

- the characteristics of the drivers and vehicles involved; such as age and sex of driver, degree of injury, contributing circumstances for the accident, and traffic code violation of drivers;
- general characteristics of the accident; such as accident type, number of persons killed and injured, and number of vehicles involved.

From the MIDAS Geometric Segment File the variables selected include:

- the geometric characteristics of the segment; such as number of lanes, lane and shoulder width, degree of curve, and type of intersection;
- the movement characteristics of the intersection; such as signal code, no turn on red and left turn prohibitions, and left turn code.
- general characteristics of the area; such as roadside development, beginning and end of influence zone, and speed limit.

The only variable to be used from the MIDAS Volume File is the Average Daily Traffic (ADT).

From the Traffic Signal Inventory File the variables selected are the type of traffic signal, the number of phases, the left and right turn prohibitions, the lens size of the signal, and the number of signal heads.

These variables from the four data files were considered as the most appropriate since they provide information about the characteristics of the accident presenting a complete description of its occurrence and defining and describing all the aspects of the area where the accident occurred.

3.4. Induced Exposure Method

To determine if a certain age group of drivers has a higher accident risk than others, accident rates are usually obtained. These rates traditionally are based upon the number of miles driven by the specific age group. The use of this method indicates that elderly drivers have a below average safety record [26]. For this research, the calculation of accident rates is not feasible, since accurate data for miles driven per age group does not exist. An alternative way to measure driver safety is to compare the number of accidents per licensed driver. This method is not a very accurate representation of the true driving population, since it is based on the implicit assumption that all licensed drivers have equal driving patterns.

In order to overcome the potential problems of both methods stated above, an alternative method will be utilized in this research. The method for analyzing accident frequency is a variation of the induced exposure method that has been used by others [5,10,11,41]. The variation of the induced exposure method that will be used here is based on the assumption that the accident exposure by any age group of drivers is proportional to the innocent victim involvements in multi vehicle accidents by that age group of drivers [39], where the innocent victim in an accident is defined as the driver not responsible for the accident.

Based on the above definition of the induced exposure method two basic assumptions for this research were established. First, the probability of a driver in a given age group being responsible while involved in an accident is represented by the percentage of accidents in which the drivers of that age group were involved where they were most at fault, as defined in the Highway Accident Master File. These drivers are defined as Driver 1. Second, the probability of a driver in a given age group being exposed in an accident while not responsible is represented by the percentage of accidents in which the drivers of that age group were involved but they were not at fault, therefore they were the innocent victim. These drivers are defined as Driver 2.

Driver 2 will be used here as a measure of the accident exposure. This measure of accident exposure provides a tool to study accident frequency of different age groups of drivers under different driving conditions. A study by McKelvey et al [21] indicates that the use of this measure produces similar results as previous studies where induced exposure methods were utilized.

To obtain a measure similar to accident rates for each age group of drivers a ratio that will indicate the involvement of the drivers of that age group to their respective exposure measure was established. Following the two basic assumptions of this research this ratio was defined as the division of the percentage of accidents of Driver 1 for a given age group by the percentage of accidents of Driver 2 for the same age group. This ratio is called the relative accident involvement ratio and is considered an accurate representation of accident involvement since it is a ratio of the number of accidents for a given age group of drivers, Driver 1, to the exposure measure of the same age group, Driver 2.

This ratio provides an indication of the relative frequency of accident involvement for the various age groups of drivers, and it can be used for comparative purposes. The physical meaning of the relative accident involvement ratio indicates that a value of 1.00 denotes equality between the accident involvement and accident exposure for drivers in a given age group. Similarly, when the ratio is less than 1.00 the driver is less likely to be responsible for the accident, which constitutes under-involvement, and when the ratio is greater than 1.00 the driver is more likely to be responsible for the accident, which constitutes over-involvement. A schematic illustration of the distribution of the relative accident involvement ratio and the involvement concepts are presented in Figure 3.1.

3.5. Driver 1, Driver 2 Validation

Essential to the basic assumption for this research is the interpretation of Driver 1 and Driver 2 from the accident records. The interpretation of the way that drivers involved in a multi vehicle accident are coded in the Highway Accident Master File is that the driver who is most at fault for the accident is coded as Driver 1 while driver at less or no fault is coded as Driver 2. In addition to this distinction between the drivers involved in a multi-vehicle accident in the accident records there is an indication of any hazardous action that either one of the drivers committed, that were deemed by the investigating officer as contributing to the occurrence of the accident.

Since the distinction for the driver at fault is done on the scene of the accident it is possible to introduce a bias in the classification of the driver that is mostly at fault, Driver 1. In order to minimize this bias the use of the hazardous action code from

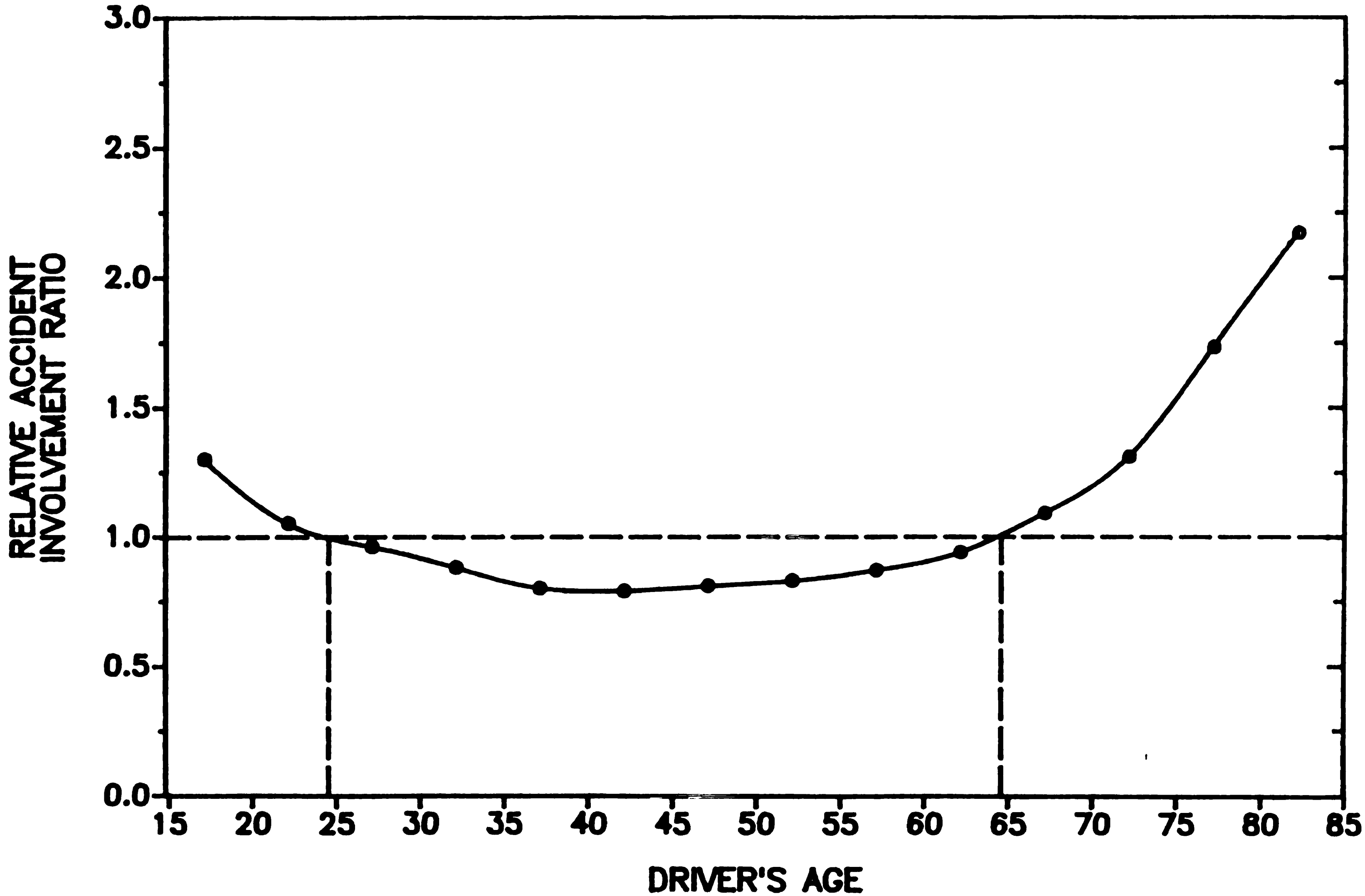

Figure 3.1. Schematic illustration of relative accident involvement ratio

the accident records was used in this study to verify the accuracy for the distinction of the responsible driver. This was based on the belief that if a driver did not contribute to the occurrence of the accident they would not have been cited for committing a hazardous action.

Because of the concern of the existence of a large magnitude error a cross-classification between the coding of Driver 1 and 2 and hazardous action codes was performed. The results of this analysis are presented in Table 3.1, indicating in a matrix form the number of accidents and their percentages where the driver was cited for committing a hazardous action. This table indicates that 76.9 percent of the accidents had the drivers correctly coded while 13.6 percent of them were reversed. Also, for 4.1 percent of the accidents none of the drivers committed a hazardous action contributing to the accident occurrence and for 5.4 percent of them both drivers had committed a hazardous action that contributed to the accident occurrence.

An analysis was performed to determine if there is a problem with the reversed coded drivers and to examine if the errors occurring are randomly distributed with respect to age. A typical example is shown in Figure 3.2 for Driver 1. In this figure, one curve, noted as All, plots the distribution of the driver's age from the original data set, that is the drivers' age is plotted as indicated in the accident record. The second curve, noted as Yes-No, shows the age distribution of the drivers correctly identified based on the hazardous action code. This curve does not include accidents where both or neither of the drivers were at fault or those incorrectly coded. Thus 22.1 percent of the accidents were not used. The third curve, noted as Reversed, shows

Table 3.1. Matrix for violations contributing to multi-vehicle accidents occurrence, Driver 1, Driver 2

		Driver 1 Yes	No	Total
	Yes	8570	21215	29785
		5.47	13.53	19.00
Driver 2	No	120552	6410	126962
		76.91	4.09	81.00
	Total	129122	27625	156747
		82.38	17.62	100.00

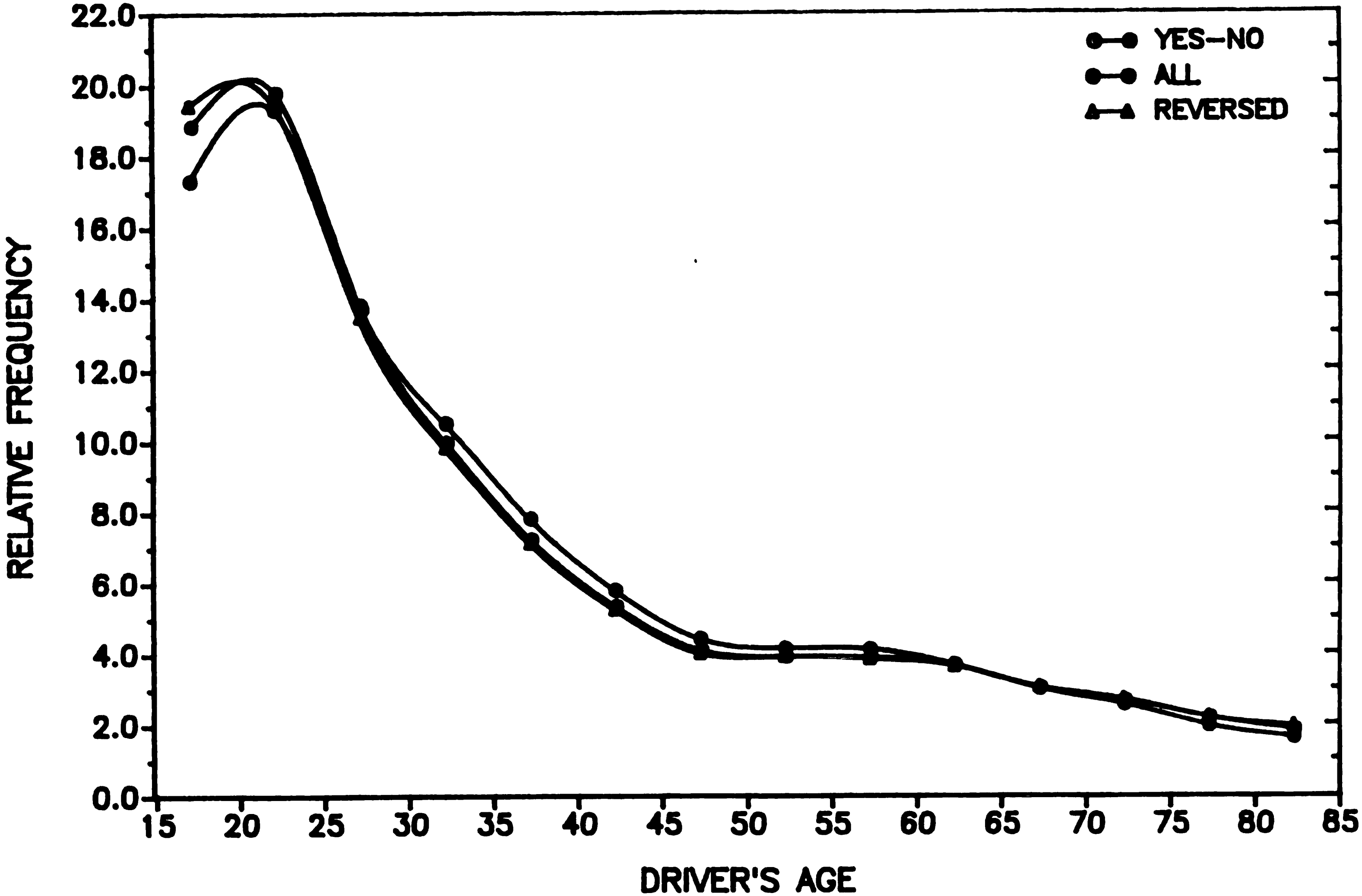

Figure 3.2. Driver 1 age distribution for all intersection accidents, for original and altered data

the age distribution of Driver 1 from the second curve with the addition of the incorrectly coded drivers, that is Driver 1 and 2 were reversed based upon the hazardous action codes. For this final curve 9.6 percent of the accidents were eliminated.

From a visual examination of these three curves it is apparent that they are virtually the same. This is considered an indication that through an examination of the hazardous action codes any bias related to the age of the driver who was responsible for the accident can be eliminated.

There were a total of 156,747 multi-vehicle accidents that occurred at intersection areas between 1983-85. According to Table 3.1, the use of only those accidents where the driver code and the hazardous action code are consistent will result in a sample of 120,552 accidents. If the process outlined previously for reversing the drivers is adopted, the total correct sample size will increase to 141,767 accident records. Even though the size of the sample is increased using either case it was not considered necessary to reverse the incorrectly coded drivers or to exclude them from the data set. This was due to the way that these distributions resemble the original data set as it was shown in Figure 3.2.

3.6. Research Approach

In Figures 3.1 and 3.2 the distribution of the drivers' age was defined in five-year intervals starting from 15 and ending at 85. The two ends of the distribution are actually groups of ages, where in the lower end are included drivers less than 20 years of age and in the upper end drivers age 85 and over. For this research such a fine breakdown of the driver's age was not considered essential since its objective is not to define which particular age group has higher accident involvement rates but to locate the possible problems of elderly drivers.

From previous studies [21,22,23,42] where the use of the relative accident involvement ratio was utilized the distribution of this rate with respect to driver's age follows a U-shaped distribution. In the same studies it was found that young drivers with age less than 25 and older drivers with age higher than 60 show an involvement ratio greater than 1.0. On the other hand, drivers with age between 25 and 60 years showed an involvement ratio of less than 1.0 representing the sag of the curve. This was the case for almost all curves where the distribution of the involvement ratio was plotted against the age of the driver.

To verify these findings with the data to be used in this study the involvement ratios for three age groups were obtained for the total number of accidents. The drivers were grouped as young, (age less than 25 years), middle aged (ages between 25 and 59), and elderly (ages greater than 60 years). The involvement ratios for the three age groups were 1.19, 0.86, and 1.22, respectively, which verified the observations from the previous studies. To further examine the accuracy of these observations the group of elderly drivers was decreased by five years, that is age 55 and over, and new ratios were calculated. The ratio for the middle aged group remained the same, 0.86, while the ratio for the elderly was reduced to 1.12. An additional decrease of 5 years in the elderly group did not affect the middle-aged group but further reduced the elderly one to 1.04. From these observations it was decided to group the drivers in the three original age groups. These findings are further supported with the examination of Figure 3.3 where the distribution of the relative accident involvement ratio for all intersection accidents is presented. This figure indicates that the ratio is increasing for drivers of approximately 60 years of age and crosses the 1.00 line at approximately 64 years.

Due to possible differences among the age groups of elderly it was considered essential to further divide the elderly group into subgroups. Based on the data given in Table 3.2, which was used to draw Figure 3.3, it became apparent that there are differences in the relative accident involvement ratio among the groups of the elderly drivers. Table 3.2 indicates that elderly with age between 60 to 69 years have a ratio of less than 1.00, while an increase is noted for drivers between age 70 to 74, and a greater increase is observed for drivers over 75 years of age. These data indicate that a creation of three different age groups for the elderly is needed in order to accurately reflect the observation from Table 3.2. Therefore, it was decided to create the "young-old" group, which includes drivers with age between 60 to 69, the "middle-old", including drivers with age between 70 to 74, and the "old-old", which includes drivers with age greater than 75 years. The main reason for combining drivers with age greater than 75 years was the small number of accidents and therefore, an insufficient representation if each group was considered alone.

The first step taken for this research was to analyze all variables included in the record and deemed to be related to the

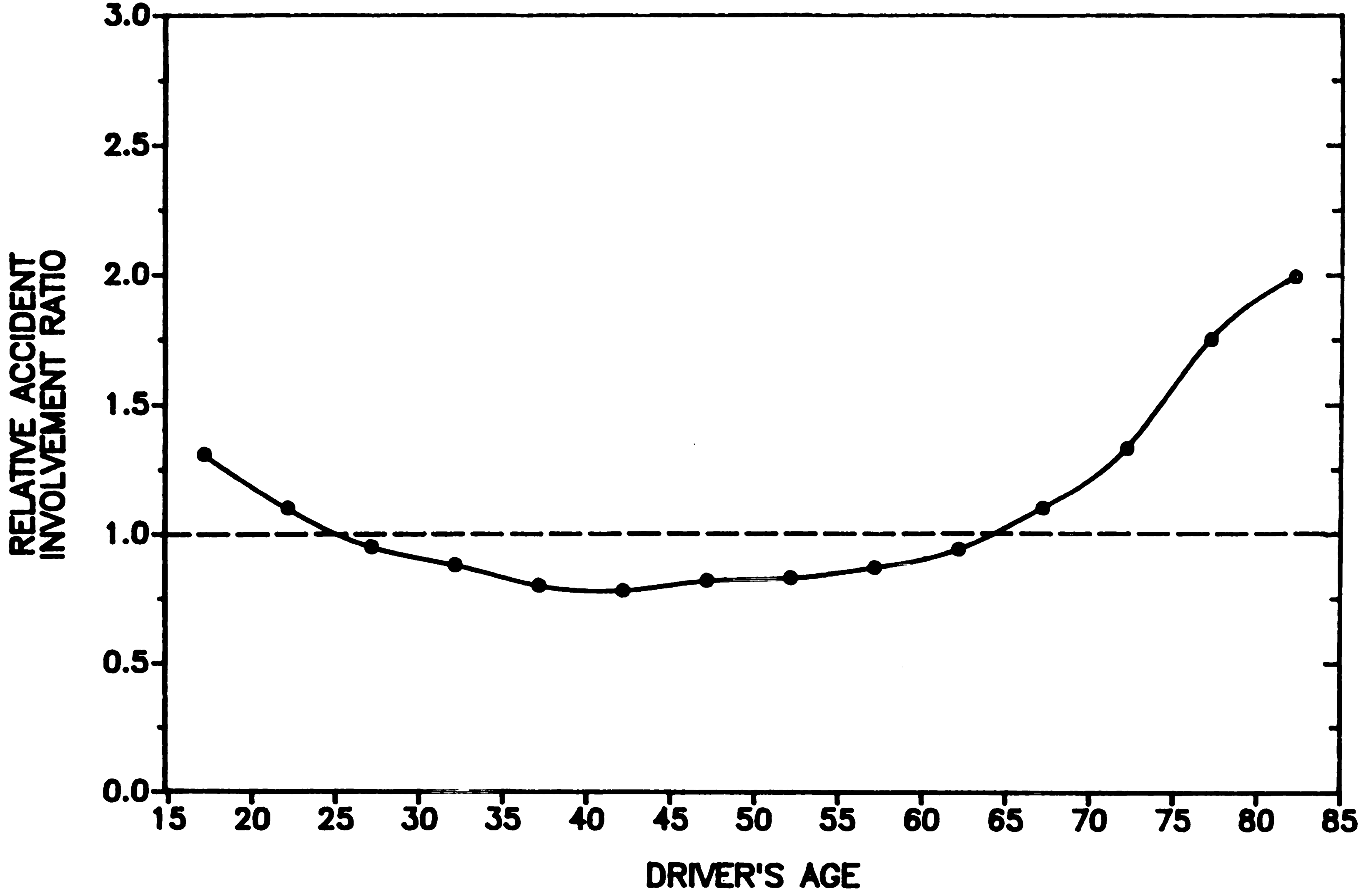

Figure 3.3. Relative accident involvement ratio for intersection accidents, 1983-1985

Table 3.2. Distribution of Driver 1 and Driver 2 age, all multi-vehicle intersection accidents (percentages)

Age Group	Percentages Driver 1	Driver 2	Ratio
Under 20	17.3	13.2	1.31
20-24	19.3	17.6	1.10
25-29	13.8	14.5	0.95
30-34	10.5	12.0	0.88
35-39	7.8	9.8	0.80
40-44	5.8	7.4	0.78
45-49	4.4	5.4	0.81
50-54	4.1	5.0	0.82
55-59	4.1	4.7	0.87
60-64	3.7	3.9	0.95
65-69	3.0	2.7	1.11
70-74	2.5	1.9	1.32
75-79	1.9	1.1	1.73
Over 80	1.6	0.8	2.00
Total	100.0	100.0	

occurrence of an accident. This analysis was performed in two ways. First, the available data was examined to determine which variables seem to affect elderly in a different way than younger drivers and if there is a difference in the levels of exposure and/or involvement between elderly and younger drivers. Second, relative accident involvement ratios were obtained for all variables to be studied for each age group of drivers to determine if a specific value of that variable has any effect on the elderly group of drivers by causing over- or under-involvement. This analysis is called the one way analysis of the data. For example, if the ratio of the elderly drivers is higher for accidents that occurred during night than the one obtained for day accidents and the ratios for the younger groups of drivers are the same for both day and night then it can be concluded that the elderly experience a higher involvement rate during the night than during the day.

The use of the relative accident involvement ratio for comparisons implies the stratification of the accident data into subsets where each one has its own characteristics for the variables to be used. The levels of each variable are defined as follows:

- Driver's age: young, middle-aged, young-old, middle-old, old-old;
- Light condition: day, night;
- Road surface condition: dry, wet, icy;
- Weather condition: clear, rainy, snowy;
- Degree of driver's injury: property damage, possible injury, non-incapacitating injury, incapacitating injury, fatal;
- Driver's sex: male, female;
- Accident severity: fatal, injury, property damage only;

- Laneage code: 1 way, 2 way, divided;
- Lane width: less than 12 ft., 12 ft., more than 12 ft.;
- Shoulder width: curb, 0-4 ft., 4-8 ft., 8-10 ft., 10-12 ft.;
- Road alignment: straight, 0-1 degrees, 1-9 degrees, 10 or more degrees;
- Signal code: stop sign, signal, flasher;
- Roadside development: urban, rural;
- Average daily traffic: 0-9,999 ADT, 10,000-19,999 ADT, 20,000-29,999 ADT, 30,000-39,999 ADT, 40,000 or more ADT;
- Number of signal phases: two, more than two;
- Type of phasing: exclusive left turn, permissive left turn, far/near signal, split phasing, regular;
- Lens size: 8 inch, 12 inch.

After the determination of the variables that have the greatest effect on elderly drivers the next step involved a two way combination of these variables and a new analysis was performed. The rationale for examining the data in this way was to determine if a combination of the individual variables that had an influence on the performance of the elderly had an increased effect on their accident involvement levels. This analysis was also used as the basis for defining potential conditions that could be influenced by the presence or absence of a traffic controller. Finally, this two way analysis was used to obtain the hypotheses to be tested in this study.

It was decided to use this approach to determine the hypotheses to be tested, since the number of variable combinations could produce an enormous number of potential conditions to be tested. Therefore, it was considered more efficient to first determine possible conditions under which elderly drivers seem to experience more problems than younger drivers and then to test the effects of the presence or absence of traffic control under these conditions. This way conditions that do not affect aged drivers differently than younger drivers will not be tested and will be excluded from the final testing procedures.

The comparisons of the relative accident involvement ratios for the one and two way analysis will be conducted based on the absolute values of the ratios. An analysis was performed to determine if the examination of the ratios is a reliable means for drawing conclusions. It is reasonable to assume that during each year drivers do not experience any major changes and that their accident patterns should be the same for each of the years examined. This phenomenon for the data at hand was verified in a study by McKelvey et al [24], indicating no differences in the age distribution of drivers among the three years of data. With this as a given, it is reasonable to assume that the ratios should follow a similar pattern, thus no major differences should be detected in the ratios for each year.

The analysis was performed using the combination of various variables used in pairs. Some typical results are shown in Figure 3.4, where the variables of driver's sex and roadside development are combined. For each age group the ratios for each year were calculated indicating that these ratios do not present any great variations from year to year. Only for drivers with ages between 70 and 74 did the data show a significant fluctuation in the values of the ratios. This fluctuation may be attributed to the small number of accidents in these cells. The same was true for the over 75 drivers, which are not presented in this figure. This analysis verifies the assumption stated

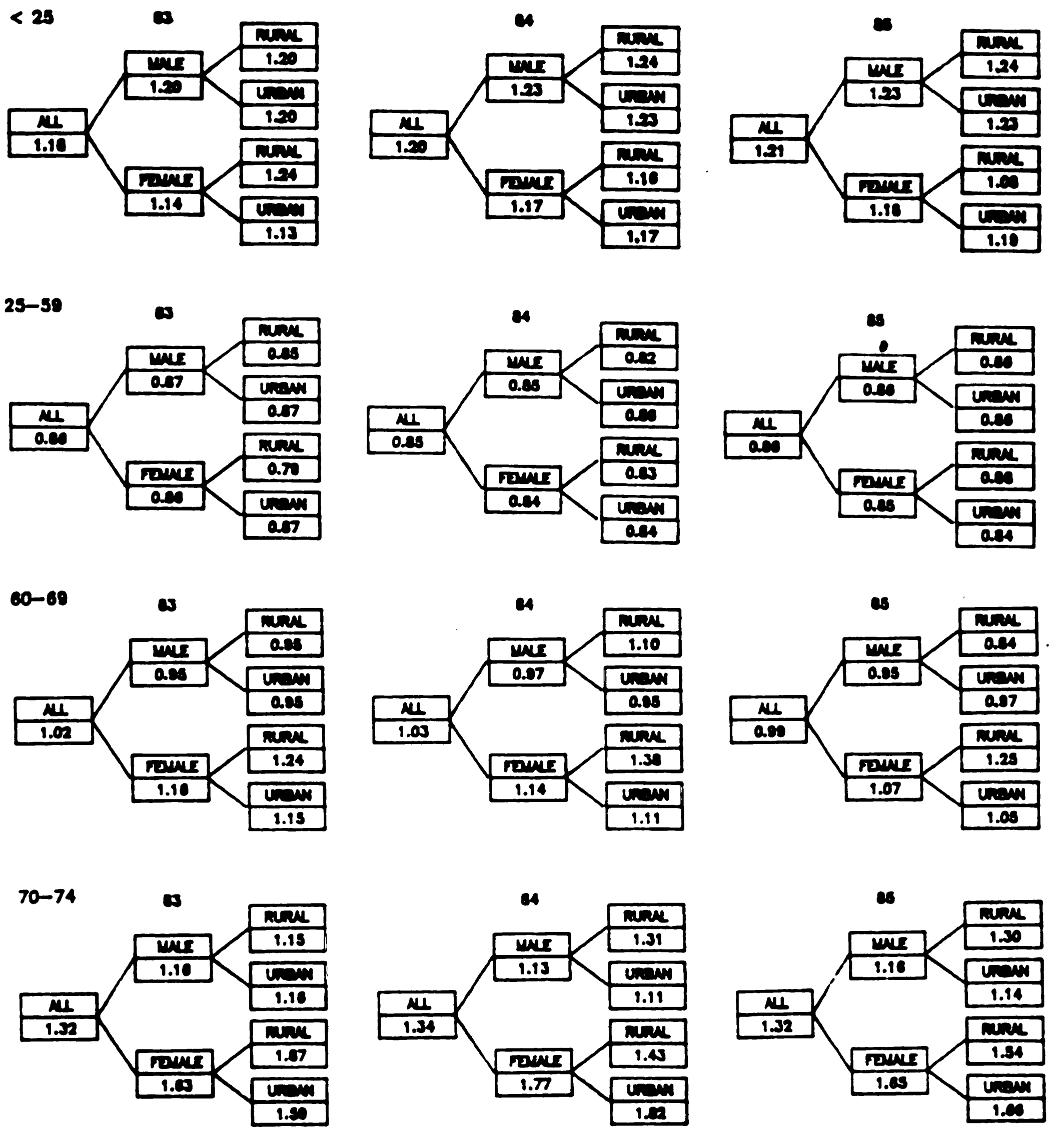

Figure 3.4. Relative accident involvement ratio, age groups
by year of accident, sex, and development

previously and indicates that the ratios follow a pattern that can be considered reasonable and expected.

The addition of a third variable created a significant impact by altering the results of the analysis stated above. At the third level the variations became large and no consistent pattern was detected. This was true not only for the variables presented in Figure 3.4 but for most other variables as well. This was considered as the most important reason for stopping the branching of the data at the second level (two way analysis) since the ratio could follow a path that will not be an accurate descriptor of the way that these variables interact after the split at the second level.

To overcome this it was decided to analyze the data according to the following procedure. First, the data will be analyzed using the one and two way analysis, as stated in the preceding. After the performance of the two way analysis the variables describing the accident conditions, in which elderly indicated a significantly high ratio, will be singled out for further examination. These variables will be examined to determine if the presence or absence of a traffic controller affects these drivers in a different way than younger drivers. In order to test the effects of the intersection traffic control the chi-square test will be applied to test the hypotheses to be put forth after the two way analysis. The chi-square test will compare each group of elderly drivers, who will be the test group, to a group of younger drivers, who will make up the control group. The tests will be performed for driver 1, the driver who caused the accident. Similar tests will be performed for driver 2, the innocent victim of the accident. The performance of tests for driver 2 is needed to determine if the exposure of elderly drivers is the same as the exposure of younger drivers.

One problem that may arise from the use of the chi-square test is the large difference in the number of accidents between elderly and younger drivers. As Table 3.3 indicates middle-aged drivers caused 68,436 accidents, while elderly drivers with ages between 60 and 69 caused 9,049 accidents. If numbers with large differences such as these figures are used in the chi-square test, it is almost sure that the test will reject the null hypothesis every time. To overcome this problem it was decided to sample the middle-aged group of drivers and create three different samples to be used for the tests with each of the elderly groups. Each sample from the middle-aged group will have a size approximately equal to the test group of elderly drivers. Each sample will be selected as an accurate representation of the population of middle-aged drivers.

There were two alternatives for creating the sample from the middle-aged drivers. The first alternative was to divide the middle-aged drivers into smaller age groups, consisting of ten years each, define the average age of the group and obtain the required number of accidents using all the accidents from the drivers with the average age of the group. If the total number of accidents obtained is less than the required one then additional accidents would be obtained including accidents with drivers whose age would be one year more or less than the age of the average driver for each group. The second alternative consists of defining the average age of the driver for all middle age drivers and obtain the required number of accidents including the drivers whose age was equal to the age of the average driver and those

Table 3.3. Distribution of Driver 1 age, all multi-vehicle intersection accidents

Age Group	Accident Number	Percentage
Under 25	50,035	36.8
25-59	68,436	50.4
60-69	9,049	6.7
70-74	3,441	2.5
Over 75	4,852	3.6
Total	135,813	100.0

whose age was N years more or less than the age of the average driver. The number of years (N) is defined by the required number of accidents for each age group of the elderly. The total number of accidents and the relative accident involvement ratio for middle-aged drivers by age are presented in Table 3.4.

For each alternative the samples were obtained matching the number of elderly drivers in each age group. As indicated in Table 3.3 the number of accidents caused by elderly drivers were 9,049 for the 60-69 group, 3,441 for the 70-74 group, and 4,852 for the over 75 group. For each alternative method, a select list of variables were examined to determine if the sample drawn was an accurate representation of the population. These variables include the driver's sex, weather and light conditions, accident and traffic violation types, laneage and development codes, and signal code. The number of accidents within each category of the variables was then compared to the same division from the total population group of middle-aged drivers. The data indicated that the second alternative produces results that are more representative of the true population. The results were compared using the percent split and they are presented in Table 3.5 for the method using the average age.

The sample for comparing the young-old to the middle-aged drivers will consist of drivers with ages between 36 and 40 years and will have a total of 9,852 accidents. The sample to be used for the middle-old will consist of drivers with ages 37 and 38 years with 4,117 accidents. Finally, the old-old drivers will be compared to drivers with ages 37 to 39 years and the total number of accidents for this sample is 5,833. Based on the results presented in Table 3.5 these samples are

Table 3.4. Distribution of middle-aged Driver 1 age and ratio, all multi-vehicle intersection accidents

Driver's Age	Accident Number	Ratio	Driver's Age	Accident Number	Ratio
25	4,198	0.98	43	1,510	0.76
26	4,016	0.98	44	1,369	0.82
27	3,750	0.96	45	1,316	0.82
28	3,483	0.94	46	1,229	0.82
29	3,315	0.89	47	1,173	0.81
30	3,204	0.91	48	1,125	0.80
31	2,894	0.86	49	1,148	0.80
32	2,867	0.88	50	1,118	0.80
33	2,719	0.86	51	1,037	0.82
34	2,513	0.82	52	1,147	0.83
35	2,425	0.81	53	1,147	0.84
36	2,304	0.80	54	1,156	0.83
37	2,156	0.78	55	1,110	0.84
38	1,961	0.80	56	1,077	0.85
39	1,716	0.78	57	1,117	0.88
40	1,715	0.77	58	1,106	0.90
41	1,579	0.76	59	1,110	0.89
42	1,626	0.77			

Table 3.5. Comparisons between the samples drawn from middle-aged drivers and all middle-aged drivers

Variable	Value	All	Group 1	Group 2	Group 3
Sex	Male	64.5	62.6	63.7	63.7
	Female	35.5	37.4	36.3	36.3
Weather	Clear	75.8	75.7	75.8	75.4
	Fog	0.5	0.5	0.6	0.4
	Rain	14.8	14.7	14.9	15.1
	Snow	8.8	9.0	8.8	9.1
Light	Day	78.3	78.6	78.5	78.4
	Night	21.7	21.4	21.5	21.6
Development	Rural	12.0	12.7	12.9	12.7
	Urban	88.0	87.3	87.1	87.3
Accident	Head-on	2.0	1.8	1.7	1.6
	Head-on left turn	9.9	9.9	9.7	10.0
	Right angle	18.2	18.3	17.5	17.7
	Angle turning	9.7	9.9	9.8	9.7
	Angle driveway	3.4	3.4	3.3	3.3
	Rear end	43.2	42.9	43.5	43.4
	Rear end left turn	4.9	5.0	5.2	5.1
	Rear end right turn	3.2	3.3	3.5	3.5
	Rear end driveway	5.5	5.5	5.8	5.7
Violation	None	20.5	22.5	22.1	22.3
	Speeding	3.1	3.1	3.2	3.0
	Driving too slow	0.0	0.0	0.0	0.0
	Failure to yield right-of-way	27.8	27.4	26.9	26.8
	Wrong way	0.2	0.2	0.2	0.1
	Improper lane usage	8.0	8.0	7.7	7.9
	Improper turn	5.5	5.2	5.5	5.1
	Improper backing	2.8	2.8	2.8	2.9
	Following too close	30.0	28.7	29.4	29.7
	Other	2.0	2.1	2.3	2.2
Exposure	Under 25	30.0	30.1	30.6	30.0
	25-59	59.6	59.7	59.1	59.6
	60-69	6.6	6.5	6.3	6.5
	70-74	1.9	1.8	1.9	1.9
	Over 75	1.9	1.9	2.1	2.0
Signal	Non-signalized	50.4	51.3	51.4	51.6
	Signalized	49.6	48.7	48.6	48.4

Table 3.5. (cont'd)

Variable	Value	All	Group 1	Group 2	Group 3
Laneage	2 lane 2 way	17.4	18.4	18.7	18.8
	Other 2 way	49.6	49.7	48.9	49.5
	One way	9.9	9.7	9.8	9.6
	Divided	23.1	22.2	22.5	22.1

considered as good and accurate approximations of the true population. These samples are the ones to be used in the final tests of the hypotheses. The one and two way analysis will be performed using all the data.

Next an examination of the data is presented to indicate observations and define possible patterns for the elderly followed by the one and two way analyses which will determine the relationship of the accident characteristics and will lead to the final formulation of the hypotheses.

4. DATA ANALYSIS

4.1. Introduction

The data used in this research consists of multi-vehicle accidents which occurred during the 1983-1985 period at intersection areas on the Michigan Trunkline System. The first step in this analysis was to examine the data to define variables that might affect the elderly drivers in a different way than younger drivers, to determine if there are discernible patterns of accidents involving elderly drivers, and to indicate possible relationships between accidents and the age of the driver. To complete this task the characteristics of the accidents in an aggregate form were examined and are presented in this chapter.

In analyzing accidents involving elderly drivers it should be mentioned that there is a possibility that aged drivers take certain precautions during driving to compensate for various losses in driving skills that may occur during the aging process. Such measures might include not driving during peak hours, avoiding certain routes, not driving under extreme weather conditions and limiting their driving only to daytime hours. An attempt will be undertaken to identify patterns which indicate that there is a potential compensation factor for the aged drivers.

4.2. Highway Statistics

4.2.1. Total Number of Accidents

For the 1983-1985 period the total number of multi-vehicle accidents that occurred at intersection areas on the Michigan trunkline system was 148,134. Table 4.1 shows the distribution of the accident involvement between the driver at fault, the innocent victim and the number of licensed drivers for each age group. Table 4.2 shows the various accident percentages and ratios for each age group. This table indicates that the young-old were cited as driver at fault in 6.7 percent of the accidents and as innocent victim in 6.6 percent of the accidents producing a relative accident involvement ratio of 1.01. Similarly, the middle-old were cited as the driver at fault in 2.5 percent of the accidents and as the innocent victim in 1.9 percent of the accidents with a relative accident involvement ratio of 1.32, while the old-old were defined as driver at fault in 3.6 percent of the accidents and as the victim in 1.9 percent producing a ratio of 1.89. The ratio of middle-old and old-old is significantly higher than that of middle-aged drivers. The ratio of old-old drivers is more than two times larger than the ratio of the middle-aged drivers, who have a relative accident involvement ratio of 0.86, and 57.5 percent higher than that for the young drivers with a relative accident involvement ratio of 1.20.

Table 4.2 also presents the ratio of accidents to licensed drivers, derived as the ratio of the percentage of driver at fault over the percentage of licensed drivers for a given age group. These data

Table 4.1. Total number of intersection accidents and licensed drivers in State of Michigan, 1983-1985

Age Group	Driver at fault	Driver not at fault	Licenses (Thousands)
Under 25	50,035	45,571	3,786
25-59	68,436	87,157	11,677
60-69	9,049	9,768	1,991
70-74	3,441	2,836	620
Over 75	4,852	2,802	563
Total	135,813	148,134	18,636

Table 4.2. Percentages of intersection accidents and licensed drivers in State of Michigan, 1983- 1985

Age	Driver at fault		Licenses	Rel. Acc.	Acc/Lic
Group	Yes	No		Inv. Rat.	Ratio
Under 25	36.8	30.8	20.3	1.20	1.81
25-59	50.4	58.8	62.7	0.86	0.80
60-69	6.7	6.6	10.7	1.01	0.62
70-74	2.5	1.9	3.3	1.32	0.76
Over 75	3.6	1.9	3.0	1.89	1.18
Total	100.0	100.0	100.0		

indicate that there is a reduction in the accident involvement with an increase in the driver's age. However, this metric will not be used in this study, since the number of miles driven in different age groups is not the same and thus a different exposure for each age group exists.

The relative accident involvement ratio indicates that the elderly drivers, and particularly middle-old and old-old experience an overinvolvement in accidents and, therefore, there is a need to identify potential factors relating either to the driver or the environment that affect the safety of these drivers.

4.2.2. Hour of Accident Occurrence

The percent distribution of accidents tabulated by the time period of the accident occurrence is presented in Tables 4.3 and 4.4.

Approximately 3.8 percent of the accidents which occurred during the time period between midnight and 7:00 A.M. involved an elderly driver. This time period was heavily dominated by accidents involving drivers with ages less than 60. This may well be considered as an indication that elderly drivers tend to drive less in the early morning hours. Similarly, a small number of accidents, 6.8 percent, involved elderly drivers during the time period between 7:00 P.M. and midnight. This could be considered an attempt to compensate for their visibility limitations during nighttime driving conditions by driving less during these hours.

The time periods that are considered peak hours, 7:00 A.M. to 10:00 A.M. and 4:00 P.M. to 7:00 P.M., show an increased involvement for both groups of elderly drivers. The young-old driver was cited as

Table 4.3. Accident involvement distribution for hour of occurrence, driver at fault (percentages)

Age Group	Hour of occurrence 00-07	07-10	10-16	16-19	19-24
Under 25	43.5	31.8	32.8	37.9	46.6
25-59	52.7	56.4	49.8	50.5	46.6
60-69	2.8	6.7	8.5	6.2	4.2
70-74	0.5	2.1	3.6	2.4	1.2
Over 75	0.5	3.0	5.3	3.1	1.4
Total	100.0	100.0	100.0	100.0	100.0

Table 4.4. Accident involvement distribution for hour of occurrence, driver not at fault (percentages)

Age Group	Hour of occurrence 00-07	07-10	10-16	16-19	19-24
Under 25	38.0	25.0	27.3	30.5	40.4
25-59	58.2	64.4	58.7	60.3	53.8
60-69	3.0	6.8	8.4	6.1	4.2
70-74	0.5	1.9	2.7	1.6	1.0
Over 75	0.3	1.9	2.9	1.5	0.7
Total	100.0	100.0	100.0	100.0	100.0

the driver at fault for 6.7 percent of the accidents occurring during the morning peak and for 6.2 percent for those occurring during the afternoon peak period. Both these numbers are higher than those found in the early morning and late night periods. However, these numbers are still smaller than the percentage of accidents caused by young-old drivers during the off-peak period of 10:00 A.M. to 4:00 P.M., which was 8.5 percent. A similar pattern was detected for the middle-old and old-old drivers, but the difference between the peak periods and the off-peak was 71 percent for middle-old and 77 percent for old-old drivers. These numbers could be considered as an indication of the precautions that elderly drivers take in order to avoid high risk driving conditions. Also trips occurring during these periods are mostly work related and these figures reflect that a smaller percentage of elderly drivers are working.

4.2.3. Weather Condition

The percent distribution of the accidents for each age group by weather condition is given in Tables 4.5 and 4.6 for both the driver at fault and the innocent victim. Table 4.5 shows that young-old drivers have the lowest accident percentage for snowy weather, 5.3 percent, which represents a 30 percent reduction compared to the percentage of accidents that these drivers caused under clear weather conditions, 6.9 percent. Even though the percentage for foggy weather is low as well, little validity was given to these data since the total number of accidents under this weather condition is less than 0.6 percent.

A similar pattern was detected for both middle-old and old-old

Table 4.5. Accident involvement distribution for weather conditions, driver at fault (percentages)

Age Group	Weather conditions Clear	Fog	Rain	Snow
Under 25	36.5	37.4	38.3	37.7
25-59	50.0	51.4	50.4	53.9
60-69	6.9	5.8	6.0	5.3
70-74	2.7	2.0	2.2	1.4
Over 75	3.9	3.4	3.0	1.8
Total	100.0	100.0	100.0	100.0

Table 4.6. Accident involvement distribution for weather conditions, driver not at fault (percentages)

Age Group	Weather conditions Clear	Fog	Rain	Snow
Under 25	31.0	33.2	30.5	29.1
25-59	58.3	57.9	59.7	62.9
60-69	6.7	6.0	6.6	5.6
70-74	2.0	1.7	1.6	1.3
Over 75	2.0	1.2	1.6	1.2
Total	100.0	100.0	100.0	100.0

drivers. The accident percentage for the middle-old under snowy weather was 1.4 percent, representing a 48 percent decrease from the clear weather condition, while for old-old drivers the percentage for accidents caused by them in snowy weather is 1.8 percent indicating a 54 percent decrease from clear weather accidents. It should also be noted that the percentage of accidents under rainy weather was also smaller than those for clear weather, but this was a smaller reduction. For accidents under rainy weather the young-old drivers show a 15 percent reduction, the middle-old a 19 percent decrease, and the old-old a 28 percent reduction when they are compared to clear weather accidents.

An analogous pattern was detected for the innocent victim to that of the driver at fault but with smaller differences between percentages for clear weather and other weather conditions, as can be noted from Table 4.6. Both Tables 4.5 and 4.6 might indicate that elderly drivers attempt to compensate for bad weather conditions either by driving more cautiously or not driving at all.

4.2.4. Light Condition

The distribution of the accident frequency percentages for day and night are presented in Tables 4.7 and 4.8 for the driver at fault and the innocent victim, respectively. For accidents that occurred during the day, 7.5 percent were caused by young-old drivers while during night only 3.8 percent of the accidents were caused by drivers in the same age group. The night accidents represent a 49 percent reduction from day accidents. The decrease is significantly higher for the other

Table 4.7. Accident involvement distribution for light conditions, driver at fault (percentages)

Age Group	Light Conditions Day	Night		Light Conditions Day	Night	Total
Under 25	34.4	45.2		72.6	27.4	100
25-59	50.8	49.1		78.3	21.7	100
60-69	7.5	3.8		87.3	12.7	100
70-74	3.0	1.0		91.3	8.7	100
Over 75	4.3	1.0		93.8	6.2	100
Total	100.0	100.0	Avg	77.7	22.3	100

Table 4.8. Accident involvement distribution for light conditions, driver not at fault (percentages)

Age Group	Light Conditions Day	Night		Light Conditions Day	Night	Total
Under 25	28.2	39.1		70.3	29.7	100
25-59	59.7	56.0		77.8	22.2	100
60-69	7.5	3.7		86.9	13.1	100
70-74	2.3	0.8		90.4	9.6	100
Over 75	2.3	0.5		94.0	6.0	100
Total	100.0	100.0	Avg	76.6	23.4	100

two elderly groups of drivers, being 67 percent for the middle-old and 77 percent for the old-old.

The results from these data coincide with those noted previously for the hour of accident occurrence (section 4.2.2). Thus, it seems to indicate that elderly drivers drive less during the night. This observation can be noted from Table 4.8 since this table denotes the driving frequency of the population of drivers. This table indicates reductions in the accident involvement of the innocent victim from day to night for both age groups of elderly drivers. These reductions were similar to those observed for the driver at fault in Table 4.7.

Table 4.8 shows that 23.4 percent of the total number of accidents occurred at night. Under the assumption that the innocent victim represents the driving frequency for each age group, this table also shows that the proportion of accidents between those occurring during day and those occurring at night for the elderly driver is significantly different than that for the other age groups. For accidents in which the 60-69 group was the innocent victim only 13.1 percent of those occurred during night, for the 70-74 group this portion was 9.6 percent, and for the over 75 group this percentage is only 6.0 percent. These data could be used to further validate the early findings that the elderly drive less or more cautiously during the night.

4.2.5. Road Surface Condition

The percentages of the accident frequencies for the driver at fault tabulated by age group for various conditions of the road surface are given in Table 4.9, while in Table 4.10 the same data for the innocent victim is presented. This table shows that the young-old driver has the lowest accident percentage for roads covered with snow or ice, 5.4 percent. The percentage of accidents on snow or ice covered roads represents a 24 percent reduction from accidents on dry roads for this age group.

This pattern was similar for the middle-old and old-old drivers. The accident percentage for snow covered roads was 1.6 percent for middle-old drivers, representing a 43 percent decrease from the accidents on dry roads, while the same portion was 1.8 percent for the old-old indicating a 56 percent reduction. Also, the percentage of accidents on wet roads was also reduced when compared to accidents on dry roads, being 17 percent lower for middle-old and 22 percent for old-old. The young-old drivers showed a similar pattern for wet roads but only had a 13 percent reduction compared to the percentage for accidents on dry roads.

A similar pattern was detected for the innocent victim to that observed for the driver at fault for all groups of elderly drivers but with smaller differences between the percentages for clear weather and other weather conditions, as can be noted from Table 4.10. These results are in agreement with those previously noted for the weather conditions. Thus, one might conclude that elderly drivers attempt to compensate for higher risk road conditions such as wet and snow or ice covered roads either by driving more cautiously or not driving at all.

Table 4.9. Accident involvement distribution for road surface conditions, driver at fault (percentages)

Age Group	Road Surface Condition Dry	Wet	Snow & Ice
Under 25	36.6	37.1	37.4
25-59	49.4	51.3	53.7
60-69	7.1	6.2	5.4
70-74	2.8	2.3	1.6
Over 75	4.1	3.2	1.8
Total	100.0	100.0	100.0

Table 4.10. Accident involvement distribution for road surface conditions, driver not at fault (percentages)

Age Group	Road Surface Condition Dry	Wet	Snow & Ice
Under 25	31.3	30.0	29.5
25-59	57.8	59.9	62.3
60-69	6.8	6.6	5.5
70-74	2.0	1.8	1.4
Over 75	2.1	1.6	1.3
Total	100.0	100.0	100.0

4.2.6. Specific Types of Accidents

Table 4.11 presents a list of the types of accidents which were considered in this analysis. Among all the accident types caused by young-old drivers the highest frequency was noted for rear end accidents followed by right angle, head on while turning left, and angle while turning. This order is observed for drivers at fault while for the innocent victim the rear end accidents were followed by right angle, angle while turning, and head on while turning left, as indicated in Tables 4.12 and 4.13, respectively. If one were to define the order of accident types for the average driver (i.e. total number of accidents) it would resemble the order of accident types for the 60-69 group. This might be considered an indication that these drivers do not experience any different problems than the average driver, since this is the same order for the accident types as noted in Tables 4.12 and 4.13. The only difference between young-old drivers and younger ones is the manner in which the number of accidents are distributed among the accident types, where a higher percentage is noted for younger drivers only for rear end accidents.

An examination of Table 4.14, which presents the percentages by age group for each accident type for the driver at fault, produces a different order to the types of accidents for the young-old. The order indicates the rear end while turning left accident is the one with the highest percentage followed by the right angle, head-on while turning left, and angle while turning. In both analyses, that is, using either the percentages by accident type (Table 4.14) or the percentages by age group (Table 4.12), one comes to the same conclusion. All of the above

Table 4.11. Specific accident types

HO: Head on
RA: Right angle
RE: Rear end
AT: Angle while turning
SSA: Sideswipe, same direction
RELT: Rear end while turning left
RERT: Rear end while turning right
SSO: Sideswipe, opposite direction
HOLT: Head on while turning left

Table 4.12. Accident involvement distribution for specific accident types, driver at fault (percentages)

Age Group	HO	RA	RE	AT	Accident Type SSA	RELT	RERT	SSO	HOLT	Total
Under 25	2.2	19.4	47.8	11.0	0.7	4.9	2.8	0.3	10.8	100
25-59	2.2	19.7	46.9	10.5	0.8	5.3	3.5	0.3	10.7	100
60-69	1.8	25.6	34.7	13.2	0.9	6.8	3.2	0.3	13.6	100
70-74	1.5	28.9	28.5	15.3	0.9	6.9	2.9	0.1	15.0	100
Over 75	1.1	29.0	25.9	16.7	0.8	6.1	2.5	0.4	17.6	100
Avg	2.1	20.6	45.2	11.2	0.8	5.3	3.2	0.3	11.3	100

Table 4.13. Accident involvement distribution for specific accident types, driver not at fault (percentages)

Age Group	HO	RA	RE	AT	Accident Type SSA	RELT	RERT	SSO	HOLT	Total
Under 25	1.9	19.0	44.8	11.6	0.9	5.6	3.0	0.3	12.8	100
25-59	2.2	19.7	47.3	10.7	1.0	5.2	3.4	0.4	10.1	100
60-69	2.1	23.5	44.4	11.7	1.1	4.9	2.9	0.3	9.2	100
70-74	2.1	24.9	40.2	11.7	1.0	4.8	3.5	0.3	11.3	100
Over 75	2.0	28.1	33.3	14.0	1.0	5.5	3.5	0.2	12.3	100
Avg	2.1	20.0	45.9	11.1	1.0	5.3	3.2	0.3	10.9	100

Table 4.14. Accident involvement distribution for specific accident types, driver at fault (percentages)

Age Group	Accident Type HO	RA	RE	AT	SSA	RELT	RERT	SSO	HOLT
Under 25	38.7	35.4	39.6	36.8	34.5	34.8	33.4	37.5	35.9
25-59	52.1	48.0	51.8	46.9	52.1	49.6	54.9	52.0	47.4
60-69	5.7	8.2	5.1	7.7	7.2	8.3	6.6	5.7	8.0
70-74	1.8	3.5	1.5	3.3	2.8	3.2	2.3	0.9	3.3
Over 75	1.8	5.0	2.0	5.3	3.4	4.1	2.8	4.0	5.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.15. Accident involvement distribution for specific accident types, driver not at fault (percentages)

Age Group	Accident Type HO	RA	RE	AT	SSA	RELT	RERT	SSO	HOLT
Under 25	27.0	28.1	28.9	31.0	27.3	31.6	27.2	28.3	34.7
25-59	62.9	59.1	61.7	57.7	61.5	58.7	62.8	62.2	55.6
60-69	6.5	7.8	6.4	7.0	7.3	6.1	6.0	6.3	5.6
70-74	1.9	2.4	1.7	2.0	1.9	1.7	2.1	1.9	2.0
Over 75	1.7	2.5	1.3	2.3	1.9	1.9	1.9	1.2	2.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

types of accidents involve a turning movement, which might be an indication of the susceptibility of the young-old driver to properly handle turning movements.

Similar patterns were detected for the other two groups of elderly drivers regarding the rank of the accident types for the percentages by age group (Tables 4.12 and 4.13). However, both groups of middle-old and old-old drivers seem to have greater differences from the average driver indicating that they possibly experience more difficulties than the average driver causing accidents such as right angle, head on while turning left, and angle while turning.

For middle-old drivers at fault the leading accident type is right angle followed by angle while turning and head on while turning left, while for old-old drivers at fault the leading type of accident is the head on while turning left followed by right angle and angle while turning (Table 4.14). Once again, in both types of analyses, percentages by accident type or by age group, middle-old and old-old drivers experience more problems with turning movements than any other type of driving maneuver. It should be noted that both these age groups of drivers experienced the highest percentage among all age groups for accidents that involved a left turn movement. For accidents such as head on while turning left and angle while turning left, the higher percentage for these drivers might be attributable to misjudgement of traffic gaps. On the other hand, for accidents such as rear end while turning left, the higher percentage might be explained by failing to keep a safe distance from the leading vehicle or improper lane use. However, not leaving sufficient distance between vehicles might be an indication of diminished perception-reaction time for older drivers.

4.2.7. Sex of Driver

From the total number of accidents in which a driver was cited as the one at fault, males comprise 64.3 percent of the total, as shown in Table 4.16. For the remaining 35.7 percent of the accidents, a female driver was cited as the driver causing the accident. Both the young-old and the average driver share a similar distribution between male (64.5 percent) and female (35.5 percent) drivers. This indicates that where gender is concerned the young-old driver had no additional problems compared to the average driver. The same was also noted for the old-old drivers. On the other hand, the middle-old drivers showed a considerable shift towards female drivers which accounted for 40.1 percent of the accidents for this age group. When Table 4.17, which presents the percentage of the accident distribution for the innocent victim, is considered, there is a considerable shift from male to female drivers. The distribution by sex of driver for all elderly drivers is approximately 67 percent for males and 33 percent for females. The differences between the split for the driver at fault and innocent victim for elderly indicates that female drivers in these age groups have a higher tendency to cause accidents than males in the same age groups.

The observations made above are strengthened by examining the percentages of accidents by sex in Table 4.16. The young-old drivers indicate a very small reduction from male to female drivers and the old-old show a small increase from male to female. However, the

Table 4.16. Accident involvement distribution for driver's sex, driver at fault (percentages)

Age Group	Driver's Sex Male	Driver's Sex Female		Driver's Sex Male	Driver's Sex Female	Total
Under 25	36.9	36.7		64.4	35.6	100
25-59	50.5	50.1		64.5	35.5	100
60-69	6.7	6.6		64.5	35.5	100
70-74	2.4	2.8		59.9	40.1	100
Over 75	3.5	3.6		63.5	36.5	100
Total	100.0	100.0	Avg	64.3	35.7	100

Table 4.17. Accident involvement distribution for driver's sex, driver not at fault (percentages)

Age Group	Driver's Sex Male	Driver's Sex Female		Driver's Sex Male	Driver's Sex Female	Total
Under 25	30.2	31.6		61.4	38.6	100
25-59	58.7	59.1		62.3	37.7	100
60-69	7.0	5.9		66.3	33.7	100
70-74	2.0	1.7		66.8	33.2	100
Over 75	2.0	1.6		67.4	32.6	100
Total	100.0	100.0	Avg	62.5	37.5	100

middle-old drivers indicate an increase of approximately 15 percent from male to female drivers. Taking into consideration the corresponding percentages of the innocent victim from Table 4.17, middle-old female drivers are involved as innocent victims in approximately 15 percent fewer accidents than male drivers. These tables indicate the possible existence of a problem for elderly female drivers.

4.2.8. Driver Injury

The percentages of the accident frequencies tabulated by the severity of the injury sustained by the driver causing an accident are given in Table 4.18, while Table 4.19 shows the same data for the driver not causing the accident.

Among the fatalities that occurred in all multi-vehicle accidents at intersections there were more elderly drivers, 32.0 percent, that died than young drivers, 19.3 percent, when they were cited as the driver at fault. When both driver at fault and the innocent victim are combined and an accidents per licensed driver ratio is obtained, the elderly drivers show an increased tendency to be involved in a fatal accident. Table 4.20 indicates that the average fatality rate is 0.020 accidents per thousand licensed drivers, while the young-old drivers show a 0.022 rate, the middle-old a 0.029 rate, and the old-old a 0.089 rate. The ratio for the middle-old driver indicates a 45 percent increase from the average driver, while the old-old indicate an increase of 345 percent. This rate clearly indicates that there is a significantly greater chance for an elderly driver to be killed in an

Table 4.18. Accident involvement distribution for driver's injury, driver at fault (percentages)

Age Group	Driver's Injury Fatal	Incap	Non Inc	Possible	None
Under 25	19.3	34.9	39.3	34.4	37.0
25-59	48.7	50.0	46.8	53.2	50.3
60-69	10.7	6.6	6.4	6.6	6.7
70-74	5.3	3.6	2.5	2.6	2.5
Over 75	16.0	4.9	4.9	3.2	3.5
Total	100.0	100.0	100.0	100.0	100.0

Table 4.19. Accident involvement distribution for driver's injury, driver not at fault (percentages)

Age Group	Driver's Injury Fatal	Incap	Non Inc	Possible	None
Under 25	27.3	36.4	40.1	27.3	30.6
25-59	45.0	51.8	50.7	62.7	59.0
60-69	12.1	6.5	5.5	7.1	6.6
70-74	4.3	2.1	1.8	1.6	2.0
Over 75	11.3	3.2	1.9	1.3	1.9
Total	100.0	100.0	100.0	100.0	100.0

Table 4.20. Comparison of fatality rates for age groups, total and driver at fault (Driver 1)

Age Group	Licenses	Fatal Accidents Total	Fatal Accidents Driver 1	Acc/Lic Ratio Total	Acc/Lic Ratio Driver 1
Under 25	3786	92	29	0.024	0.008
25-59	11677	177	73	0.015	0.006
60-69	1991	44	16	0.022	0.008
70-74	620	18	8	0.029	0.013
Over 75	563	50	24	0.089	0.043
Total	18636	281	150	0.020	0.008

accident than any other age group. This increase is even higher when only the driver at fault is considered for the calculation of the fatality rate. In this case the middle-old experience a 63 percent increase while the old-old drivers sustained a 438 percent increase, having a rate of 0.043 fatalities per thousand licensed drivers compared to the average rate of 0.008. Thus, the data indicates that elderly drivers not only tend to be involved more in an accident that caused a fatality to the driver but they also tend to cause more of these accidents.

For the remaining levels of injury severity to the driver, the elderly were found to be comparable to the average driver.

4.2.9. Driver Intention

Table 4.21 presents a list of the driver intentions that were examined.

The intention of the driver at fault for the young-old driver followed a pattern similar to that of the average driver as noted in Table 4.22, where the percentages of the accident frequencies by driver's age group tabulated by driver intention are given for the driver at fault. In most cases, the average driver intended to continue movement forward when involved in an accident. This was followed by an intention to turn left, to turn right, and to change lanes. This was the order for the young-old driver at fault, with the exception that there were higher percentages for these drivers than the average driver for intentions to either turn right or left. This deviation from the average driver indicates again the problem that

Table 4.21. Driver's intention

STR:	Go straight
PASS:	To pass
LN CH:	Lane change
RT:	Right turn
LT:	Left turn
UT:	U-turn
STA:	Starting up
LV P:	Leaving parking
BACK:	Backing
STOP:	Stopped
AV VH:	Avoid vehicle

Table 4.22. Accident involvement distribution for driver's intention, driver at fault (percentages)

Age Group	Driver's Intention STR	PASS	LN CH	RT	LT	UT	STA	LV P	BACK	STOP	Total
Under 25	62.2	1.6	5.1	5.8	18.4	0.2	1.3	0.5	2.1	2.7	100
25-59	58.9	1.7	4.9	6.3	18.2	0.4	1.3	0.7	2.7	4.8	100
60-69	51.5	1.4	5.8	7.8	23.9	0.6	1.4	1.2	2.5	3.8	100
70-74	47.2	1.2	5.6	8.8	28.6	0.8	1.7	1.4	2.2	2.5	100
Over 75	45.2	1.2	5.8	9.1	30.4	0.6	2.1	1.6	2.5	1.4	100
Avg	58.8	1.6	5.1	6.4	19.4	0.4	1.4	0.7	2.5	3.8	100

Table 4.23. Accident involvement distribution for driver's intention, driver not at fault (percentages)

Age Group	Driver's Intention STR	PASS	LN CH	RT	LT	UT	STA	LV P	BACK	STOP	Total
Under 25	61.2	1.5	1.3	4.2	11.9	0.1	0.4	0.2	0.5	18.7	100
25-59	57.4	1.0	0.9	4.5	10.7	0.1	0.3	0.2	0.5	24.4	100
60-69	57.3	0.9	1.2	5.0	11.9	0.1	0.2	0.4	0.6	22.3	100
70-74	56.4	1.3	1.4	6.0	13.1	0.1	0.5	0.5	0.9	19.6	100
Over 75	56.8	1.6	1.8	6.9	16.7	0.3	0.8	0.5	1.0	13.5	100
Avg	58.5	1.2	1.1	4.5	11.3	0.1	0.3	0.2	0.5	22.2	100

elderly drivers have with turning maneuvers. The total number of accidents for the combined intentions to turn accounted for almost one third, 32.1 percent, of the total number of accidents for this age group.

The same pattern relative to the leading types of intention was noted for the other two groups of elderly drivers. The deviation for turning movement intention was significantly higher than that noted for the young-old driver compared to the average driver and the combined total of right, left, and U-turn intention exceeded one-third of the total number of accidents, being 38.0 percent for middle-old drivers and 39.8 percent for the old-old ones. It should be noted that the middle-old driver indicated a twice as large tendency to cause an accident when the intention was to complete a U-turn than the average driver.

A closer comparison between middle-aged and middle-old and old-old drivers based on Table 4.22 was performed for all the intentions in which a turning movement was attempted. This comparison indicates that middle-old drivers experience a 55 percent increase in the percentages compared to the middle-aged drivers, while the old-old driver experience a 60 percent increase for the same comparison. The intentions involving a turning movement for middle-aged drivers accounted only for 24.7 percent of their total accidents compared to the 38.0 and 39.8 percent for middle-old and old-old, respectively.

4.2.10. Driver Violations

The driver violations that are coded in the accident record are given in Table 4.24. The percentages of the accident frequencies by age group tabulated by the driver's violation are given in Tables 4.25 and 4.26 for the driver at fault and the innocent victim, respectively.

The young-old driver at fault has the same chance as the average driver to be cited for a violation while the other two age groups of elderly have significantly higher chance of being cited for a violation. Table 4.25 indicates that the middle-old drivers have a 26.7 percent higher chance than the average driver to be cited for a violation, while the old-old have a significantly higher chance than the average driver (91.8 percent compared to 82.9 percent). The same was noted for the elderly even in the case of the innocent victim. Thus, young-old drivers have the same chance to be cited as the average driver, middle-old drivers show a small increase (8 percent) in their chances, and old-old drivers have a 28.2 percent higher chance to be cited for a violation than the average driver.

Table 4.25 also indicates that for all elderly drivers the leading violation type is failure to yield the right of way followed by the violations of following too close, improper lane use, and improper turn. The violation types of failure to yield the right of way and following too close can be attributed to failure to accurately estimate available gaps reducing the available time and distance for reaction while the violation types of improper turns and improper lane use can be attributed to failure to properly handle turning maneuvers.

The same table indicates that the only difference among the groups

Table 4.24. Driver's violation

NONE:	No violation
SPD:	Speeding
SLW:	Driving too slow
ROW:	Failed to yield right-of-way
WRGW:	Driving the wrong way
LN:	Improper lane usage
TRN:	Improper turn
BCK:	Improper backing
CLS:	Following too close
OTH:	Other or unknown violation

Table 4.25. Accident involvement distribution for driver's violation, driver at fault (percentages)

Age Group	NONE	SPD	SLW	ROW	WRGW	LN	TRN	BCK	CLS	OTH	Total
					Driver's Violation						
Under 25	13.5	4.0	0.0	30.5	0.1	7.7	4.7	2.1	35.7	1.7	100
25-59	20.5	3.1	0.0	27.8	0.2	8.0	5.5	2.8	30.0	2.0	100
60-69	17.0	1.8	0.0	39.6	0.2	9.4	7.5	2.6	20.3	1.5	100
70-74	13.5	1.2	0.0	46.4	0.2	9.5	8.7	2.3	17.0	1.3	100
Over 75	8.1	1.4	0.0	52.0	0.3	9.9	8.9	2.8	15.3	1.2	100
Avg	17.1	3.2	0.0	30.9	0.2	8.1	5.6	2.5	30.6	1.8	100

Table 4.26. Accident involvement distribution for driver's violation, driver not at fault (percentages)

Age Group	NONE	SPD	SLW	ROW	WRGW	LN	TRN	BCK	CLS	OTH	Total
					Driver's Violation						
Under 25	76.8	1.0	0.0	8.9	0.1	2.2	1.4	0.4	7.8	1.3	100
25-59	85.4	0.6	0.0	5.0	0.0	1.7	1.2	0.4	4.7	1.0	100
60-69	81.6	0.4	0.0	8.4	0.0	2.2	1.9	0.4	4.3	0.8	100
70-74	75.2	0.4	0.0	12.4	0.0	2.7	2.5	0.8	4.9	1.2	100
Over 75	63.9	0.5	0.1	21.4	0.1	3.8	3.7	0.3	5.3	0.8	100
Avg	81.9	0.7	0.0	6.9	0.1	2.0	1.4	0.4	5.7	1.1	100

of elderly drivers is the magnitude of each violation type. The problem of handling turning movements is higher for the middle-old and old-old driver than not only the young-old but all other age groups. These drivers indicate approximately a 56 percent increase from the average driver. The violation of failure to yield the right-of-way was more significant for the elderly than any other violation type, accounting for 40 percent or more of their accidents. For middle-old this violation accounted for 46.4 percent of their total number of accidents. This is a 50 percent increase from the average driver. For old-old drivers this violation accounted for 52.0 percent of the accidents showing a 68 percent increase from the average driver. On the other hand, all elderly drivers experienced a reduction in violations for following too close when compared to the average driver. The young-old driver showed a 33 percent reduction, the middle-old indicated a 44 percent decrease, and the old-old experienced a 50 percent reduction. This reduction may indicate an attempt to compensate for their diminishing abilities by attempting to allow more space for perception and reaction.

4.2.11. Contributing Circumstances

The contributing circumstances that are coded in the accident record are given in Table 4.27. The data indicated that for most accidents there were no contributing circumstances for the occurrence of the accident. The data were tabulated again using only the accidents in which circumstances were deemed to have contributed to its occurrence and the results are given in Tables 4.28 and 4.29 for the

Table 4.27. Contributing circumstances

DUIL: Driving under the influence
RCK: Reckless driving
ILL: Ill or fatigued driver
LIC: License restrictions
VIS: Visual obstruction
EQU: Failure of equipment
SKID: Skidding

Table 4.28. Accident involvement distribution for contributing circumstance, driver at fault (percentages)

Age Group	Contributing Circumstance DUIL	RCK	ILL	LI	VIS	EQU	SKID	Total
Under 25	17.9	9.9	8.2	0.1	15.0	12.7	36.2	100
25-59	32.1	6.4	6.3	0.1	14.0	9.1	32.0	100
60-69	30.8	4.3	6.2	0.3	23.9	6.2	28.3	100
70-74	17.8	5.9	7.9	0.0	31.6	5.3	31.6	100
Over 75	8.2	9.7	10.3	1.0	35.9	4.6	30.3	100
Avg	25.8	7.8	7.1	0.1	15.4	10.3	33.5	100

Table 4.29. Accident involvement distribution for contributing circumstance, driver not at fault (percentages)

Age Group	Contributing Circumstance DUIL	RCK	ILL	LI	VIS	EQU	SKID	Total
Under 25	12.7	17.1	3.7	0.2	18.0	10.0	38.4	100
25-59	21.6	9.5	3.2	0.2	19.5	7.6	38.5	100
60-69	16.8	12.7	6.4	0.0	21.4	4.0	38.7	100
70-74	14.3	14.3	1.8	0.0	35.7	7.1	26.8	100
Over 75	3.2	44.4	1.6	0.0	25.4	7.9	17.5	100
Avg	17.4	13.3	3.5	0.2	19.4	8.4	37.9	100

driver at fault and the innocent victim, respectively.

The young old driver showed a pattern similar to that for the average driver. Only two differences were noted between the young-old and the average driver. The first one is noted for visual obstructions, in which the average driver had 15.4 percent of the accidents with this circumstance, while the young-old were affected by visual obstructions for 23.9 percent of their accidents, showing a 55.2 percent increase when compared to the average driver. This increase might be attributed to the aging process and the reductions that occur in the visual or physical mobility characteristics of the elderly. The second difference is encountered for accidents where driving under the influence of intoxicating substances is present. The young-old drivers showed a 19.4 percent increase compared to the average driver.

The pattern noted for middle-old and old-old drivers indicated a reduction from driving under the influence of alcohol and an increase in visual obstruction contributions. For both these age groups visual obstructions are the major contributing circumstance when such circumstances are present. The increase for middle-old is 105.2 percent from the average driver and for the old-old is 133.1 percent. Also for the old-old drivers an increase of 45.1 percent was noted compared to the average driver when illness contributed to the accident occurrence.

The combination of the increases for these contributing circumstances for elderly drivers, and in particular for old-old ones, indicates that a relationship exists between physical limitations of the elderly and their contribution to accidents. The increased presence of the above contributing circumstances in the occurrence of the accidents show that the elderly have a higher tendency to cause accidents due to mental and physical distractions that may occur due to the natural aging process.

The data based on the contributing circumstances indicated that old-old drivers face certain limitations in driving safely when compared to the average driver. However, the old-old driver causes fewer accidents driving under the influence than the average driver. Table 4.28 shows that the second leading contributing circumstance for the average driver is driving under the influence which contributed for more than 25 percent of the accidents with contributing circumstances. The old-old drivers caused only 8.2 percent of their accidents driving under the influence which represents a 68.2 percent reduction from the average driver.

4.2.12. Visual Obstructions

The visual obstructions contributing to accident occurrence are identified in Table 4.30. The data showed that for most accidents there were no visual obstructions that contributed to the occurrence of the accident. Tables 4.31 and 4.32 present the percent distribution only for those accidents in which a visual obstruction was deemed to have contributed to the occurrence of the accident for the driver at fault and the innocent victim, respectively.

Table 4.31 shows that the young-old driver experiences a pattern similar to that of the average driver. The only difference noted is for physical obstructions outside the vehicle, which represents an eight percent increase compared to the average driver. For the young-old innocent victim an increase was noted for glare and a decrease for

Table 4.30. Visual obstructions

IN VEH: Within the vehicle
PHYS: Physical obstruction
WEATH: Weather related visual obstruction
GLARE: Glare due to headlights of oncoming traffic or sunlight

Table 4.31. Accident involvement distribution for visual obstruction, driver at fault (percentages)

Age		Visual Obstruction				
Group	IN VEH	PHYS	WEATH	GLARE	OTH	Total
Under 25	12.4	72.8	5.6	7.7	1.5	100
25-59	11.3	70.4	7.9	8.8	1.7	100
60-69	7.9	77.6	4.6	9.9	0.0	100
70-74	9.8	72.5	2.0	13.7	2.0	100
Over 75	8.3	66.7	5.6	19.4	0.0	100
Avg	11.3	71.8	6.5	8.9	1.4	100

Table 4.32. Accident involvement distribution for visual obstruction, driver not at fault (percentages)

Age		Visual Obstruction				
Group	IN VEH	PHYS	WEATH	GLARE	OTH	Total
Under 25	6.6	78.9	9.3	3.1	2.1	100
25-59	6.6	74.3	13.9	2.8	2.4	100
60-69	2.2	75.6	6.7	11.1	4.4	100
70-74	0.0	95.0	0.0	5.0	0.0	100
Over 75	5.9	76.5	11.8	5.9	0.0	100
Avg	6.2	76.6	11.4	3.5	2.3	100

weather related visual obstructions. These drivers experience a 217 percent increase from the average driver due to glare and a 41 percent reduction due to weather visual obstructions.

The other two groups of elderly drivers experienced a pattern similar to that of the young-old driver but they showed a higher increase for visual obstructions due to glare when cited as the driver at fault. The increase was 54 percent for the middle-old and 118 percent for the old-old when compared to the average driver at fault. This indicates that elderly drivers are affected by glare to a greater degree than any other age group. The greater impact of glare for the old-old driver may be attributable to reduced visual acuity, to diseases of the eye occurring during aging, or to a need for longer time for recovery from glare sources than the average driver.

The middle-old and old-old innocent victim showed a pattern similar to that described earlier for the young-old driver. These drivers showed similar differences compared to the average innocent victim when compared to the differences earlier noted for the young-old driver. The middle-old showed a 42 percent increase in accidents with glare related visual obstructions, while there were no accidents with visual obstructions related to weather. The old-old driver showed a 67 percent increase in accidents in which glare was present and no difference in accidents with weather related visual obstructions. These data indicate that glare, when present, may not only contribute to more accidents for the at fault driver but also may contribute to a reduction in the ability to react properly and avoid accidents when not at fault.

The data also indicates that elderly drivers showed a reduction for weather related visual obstructions when compared to the average driver. These data might indicate that elderly drivers avoid high risk weather conditions by reducing traveling under such conditions.

4.2.13. Accident Severity

The accident severity represents the overall severity of the accident as opposed to the injury sustained by the driver as presented earlier. Tables 4.33 and 4.34 present the percent distribution of the accident frequencies for the driver at fault and the innocent victim, respectively.

A comparison between the young-old driver at fault and the average driver produced no differences as shown in Table 4.33. The same table reveals a significant difference between the average driver and the other two groups of elderly drivers at fault for fatal accidents. The middle-old driver caused 67 percent more fatal accidents than the average driver rate and the old-old driver caused 133 percent more than the average driver rate.

Table 4.34 shows similar patterns as those observed in Table 4.33 for the elderly innocent victim when compared to the average innocent victim. The young-old innocent victim showed a pattern in accident severity similar to that experienced by the average innocent victim. On the other hand, the middle-old innocent victim experienced a 50 percent increase, while the old-old one sustained a 233 percent increase in fatal accident involvement rate than the average innocent victim. The combination of the data from Tables 4.33 and 4.34 indicate that middle-old and old-old drivers not only tend to cause more fatal

Table 4.33. Accident involvement distribution for severity of accident, driver at fault (percentages)

Age Group	Accident Severity Fatal	Injury	PDO		Accident Severity Fatal	Injury	PDO	Total
Under 25	31.8	36.6	37.0		0.3	32.6	67.1	100
25-59	50.5	50.8	50.2		0.3	33.1	66.5	100
60-69	6.5	6.6	6.7		0.3	32.3	67.3	100
70-74	3.7	2.5	2.5		0.5	32.6	66.9	100
Over 75	7.4	3.5	3.6		0.7	31.8	67.5	100
Total	100.0	100.0	100.0	Avg	0.3	32.8	66.8	100

Table 4.34. Accident involvement distribution forseverity of accident, driver not at fault (percentages)

Age Group	Accident Severity Fatal	Injury	PDO		Accident Severity Fatal	Injury	PDO	Total
Under 25	27.3	31.1	30.6		0.3	32.7	67.0	100
25-59	53.9	58.5	59.0		0.3	32.2	67.5	100
60-69	9.2	6.7	6.5		0.5	32.9	66.7	100
70-74	3.6	1.7	2.0		0.6	29.5	69.9	100
Over 75	6.1	1.9	1.9		1.0	31.8	67.2	100
Total	100.0	100.0	100.0	Avg	0.3	32.3	67.3	100

accidents but also tend to be involved in more of these accidents.

4.2.14. Roadside Development

The distributions of the accident frequency percentages for urban and rural development are presented in Tables 4.35 and 4.36 for the driver at fault and the innocent victim, respectively. The young-old driver indicates a similar pattern to the one noted for the average driver and almost an equal involvement in causing an accident and being the victim of the accident for both rural and urban intersection areas. However, the other two groups of elderly drivers show some deviations from the pattern noted for the young-old driver.

The middle-old driver showed a small increase, 15 percent, for causing accidents in rural areas compared to the average driver. The middle-old driver at fault showed a 38 percent increase from the innocent victim for rural areas and a 31 percent increase for urban ones. These increases were higher for the old-old driver. These figures indicate that the old-old driver caused 23 percent more accidents than the average driver in rural areas. This group of drivers also showed a 110 percent increase from the innocent victim for accidents occurring in rural areas and an 84 percent increase for urban areas.

The results from these data indicate that elderly drivers experience more problems than the average driver for rural areas. This problem may be attributed to the fact that rural intersections are more likely to have higher speeds and less likely to be controlled by a traffic controller. Moreover, Table 4.36, which denotes the driving

Table 4.35. Accident involvement distribution for roadside development, driver at fault (percentages)

Age Group	Development Rural	Development Urban		Development Rural	Development Urban	Total
Under 25	35.9	37.0		11.8	88.2	100
25-59	50.0	50.4		12.0	88.0	100
60-69	6.8	6.6		12.4	87.6	100
70-74	2.9	2.5		13.9	86.1	100
Over 75	4.4	3.5		14.9	85.1	100
Total	100.0	100.0	Avg	12.1	87.9	100

Table 4.36. Accident involvement distribution for roadside development, driver not at fault (percentages)

Age Group	Development Rural	Development Urban		Development Rural	Development Urban	Total
Under 25	29.9	30.9		11.1	88.9	100
25-59	59.5	58.8		11.6	88.4	100
60-69	6.5	6.6		11.2	88.8	100
70-74	2.1	1.9		12.7	87.3	100
Over 75	2.1	1.9		12.4	87.6	100
Total	100.0	100.0	Avg	11.4	88.6	100

frequency of the population of drivers, indicates that there are no differences between the exposure levels of elderly drivers under the two types of roadside development. Therefore, the increase that elderly drivers experience could be solely attributed to deficiencies due to their age.

4.2.15. Average Daily Traffic (ADT)

The percentages of the accident frequencies for the driver at fault tabulated by age group for the various levels of ADT are given in Table 4.37. This table shows that the young-old driver has a pattern similar to the one observed for the average driver. The data indicates that this is the case for both the driver at fault and the innocent victim, as shown in Table 4.38.

This pattern was slightly different for the middle-old driver while higher differences were detected for the old-old driver. The middle-old driver showed a 23 percent increase compared to the average driver for accidents on roads with less than 10,000 ADT and a 25 percent decrease for roads with ADT between 30,000 and 40,000. The old-old driver indicated higher differences from the average driver in roads with the same volumes. These drivers experienced a 42 percent increase for roads with less than 10,000 ADT and a 26 percent decrease for roads with ADT over 30,000. For both middle-old and old-old drivers the only significant difference compared to the average innocent victim was noted for roads with less than 10,000 ADT. The middle-old innocent victim showed a 21 percent increase from the average driver and the old-old a 32 percent increase.

Table 4.37. Accident involvement distribution for Average Daily Traffic, driver at fault (percentages)

Age Group	ADT (Thousands) 0-10	10-20	20-30	30-40	Over 40	Total
Under 25	16.5	30.5	18.2	16.6	18.3	100
25-59	16.2	29.2	18.3	16.5	19.8	100
60-69	18.7	31.1	17.7	14.1	18.5	100
70-74	20.6	33.9	17.3	12.1	16.1	100
Over 75	23.8	33.9	16.4	11.9	14.0	100
Avg	16.8	30.1	18.2	16.1	18.9	100

Table 4.38. Accident involvement distribution for Average Daily Traffic, driver not at fault (percentages)

Age Group	ADT (Thousands) 0-10	10-20	20-30	30-40	Over 40	Total
Under 25	16.1	29.7	18.9	16.3	19.0	100
25-59	15.6	29.0	18.8	16.7	19.9	100
60-69	17.1	29.3	18.1	14.8	20.6	100
70-74	19.4	29.8	18.0	14.3	18.6	100
Over 75	21.1	32.1	16.8	12.2	17.7	100
Avg	16.0	29.3	18.8	16.3	19.6	100

For both the driver at fault and the innocent victim elderly drivers indicated the same pattern. They experience an increase in accident involvement for roads with low volumes and a decrease in accident involvement for roads with higher volume. This may indicate that elderly drivers tend to compensate for their limitations and reduced driving abilities by avoiding high volume roads and concentrating their driving on roads with light volumes.

4.2.16. Traffic Control

The distribution of the accident frequency percentages by the intersection traffic control are presented in Tables 4.39 and 4.40 for the driver at fault and the innocent victim, respectively. For accidents that occurred in either signalized or non-signalized intersections young-old drivers caused a similar percentage, 6.4 and 6.8 percent respectively. However, for accidents occurring at intersections with a flasher control young-old drivers were at fault 8.8 percent of the time, indicating approximately a 30 percent increase. A similar pattern was noted for these drivers as the innocent victim in Table 4.40. The young-old driver showed a similar pattern to the average driver but a 34 percent increase was noted for the accidents at flasher controlled intersections, which accounted only for 4.3 percent of their total number.

An analogous pattern was noted for the other two groups of elderly drivers. The middle-old drivers showed an increase similar to the one noted for the young-old driver, while the old-old showed higher increases. These drivers showed a 56 percent increase between

Table 4.39. Accident involvement distribution for traffic control type, driver at fault (percentages)

Age Group	Control Type None	Flasher	Signal		Control Type None	Flasher	Signal	Total
Under 25	37.3	33.4	36.6		48.9	2.9	48.1	100
25-59	49.3	48.1	51.6		47.3	3.1	49.6	100
60-69	6.8	8.8	6.4		49.4	4.3	46.3	100
70-74	2.7	3.7	2.3		51.3	4.7	44.0	100
Over 75	3.9	6.1	3.1		53.1	5.5	41.4	100
Total	100.0	100.0	100.0	Avg	48.4	3.2	48.4	100

Table 4.40. Accident involvement distribution for traffic control type, driver not at fault (percentages)

Age Group	Control Type None	Flasher	Signal		Control Type None	Flasher	Signal	Total
Under 25	31.7	29.9	29.9		49.2	3.0	47.8	100
25-59	57.8	58.0	59.9		46.9	3.0	50.0	100
60-69	6.5	7.3	6.6		47.1	3.4	49.5	100
70-74	1.9	2.3	1.9		47.7	3.8	48.5	100
Over 75	2.0	2.4	1.7		50.9	4.0	45.1	100
Total	100.0	100.0	100.0	Avg	47.7	3.1	49.2	100

accidents occurring at non-signalized and flasher controlled intersections and a 97 percent increase between accidents at signalized and flasher controlled intersections. Also, these drivers showed a 72 percent increase compared to the average driver for accidents at flasher controlled intersections.

The data in Tables 4.39 and 4.40 indicates that the elderly have a similar involvement rate between accidents at signalized and non-signalized intersections, while they experience more problems at intersections that are controlled by a flasher. This was the case for both the driver at fault and the innocent victim and this phenomenon had a higher presence for the old-old drivers.

4.3. Summary and Conclusions

The existing data indicate that elderly drivers experience an over involvement in accidents, and certain factors affect these drivers to a greater degree than other drivers. The data indicate that elderly drivers tend to cause more accidents under certain conditions or circumstances. On the other hand, the data for the innocent victim indicates that there is also an attempt or tendency by these drives to compensate for diminishing driving ability.

In most cases, the young-old driver compared to the average driver does not seem to exhibit any significantly different ratios. These drivers have an overall relative accident involvement ratio of 1.01 which is 17 percent higher than that of the middle-aged driver but 16 percent lower than that of the younger driver. These drivers seem to have problems mainly in handling turns, especially left turns, and in causing rear end and right angle accidents. These drivers are cited for violations such as failing to yield right of way, following too close, and improper lane changes. Glare and visual obstructions seem to affect these drivers more than the average driver.

Both middle-old and old-old drivers experience problems similar to those of the young-old driver, but to a greater degree. The main problem these drivers experience when causing accidents is proper handling of left turns. These drivers frequently cause accidents which involve a turn and have a greater chance to be cited for a violation than the average driver. These drivers tend to cause more fatal accidents, and to be involved in fatal accidents as innocent victims, especially old-old drivers. Glare and visual obstructions have greater impact on the old-old driver in both causing an accident and being involved as an innocent victim in an accident. Also, middle-old and old-old female drivers tend to cause disproportionally more accidents than their male counterparts.

Though elderly drivers experience the problems discussed above, they tend to compensate for diminishing driving ability due to aging. The data for the innocent victim indicate that these drivers tend to not drive as much at night as during the day, and these drivers avoid driving during peak hours. These drivers showed a reduced involvement in accidents during bad weather and wet/icy pavement conditions. They also showed a reduced accident involvement as innocent victims in accidents associated with violation for following too close, which may indicate an attempt to compensate for diminishing driving ability by allowing more space for perception and reaction.

Thus, the data indicate that the elderly driver is not only causing more accidents but under certain conditions is more involved in these accidents as an innocent victim than the average driver. The next step involves the analysis of the data using the relative accident involvement ratios to determine the relationship between the variables affecting the occurrence of the accident and the age of the driver.

5. ANALYSIS OF RELATIVE ACCIDENT INVOLVEMENT RATIOS

5.1. Introduction

After the analysis of the data presented in the preceding chapter, the same data was used to calculate the relative accident involvement ratios. For each variable in the data set the percentage of the total accidents by age group were calculated for both the driver at fault and the innocent victim (driver not at fault) for all values of the variable. Then, the relative accident involvement ratio was calculated as the ratio of the percentage of accidents of the driver at fault for a given age group by the percentage of accidents of the driver not at fault for the same age group.

Using these ratios, comparisons were performed to determine the effect of the value of a variable on the elderly driver and to define a potential relationship between age of driver and accident involvement. The data was first analyzed using each variable alone and thus the one way relationship between age of driver and accident characteristics was established. Based on these results, for specific values of the variables which indicated a possible influence on the accident pattern, a similar analysis was performed. This step determined the two way analysis of the data. The results of these analyses (one way and two way) are presented in this chapter.

5.2. One Way Analysis

For the whole data set the relative accident involvement ratios were defined for each age group. These ratios may be considered as the ratio for any age group across all variables. The comparisons performed for each value of every variable were based on comparing the ratio of the value for a given age group with the value of the same age group from the whole data set. Thus, the relative accident involvement ratio for a given age group is compared to the ratio of the average driver of the same group to determine the effects that the variable has on this age group.

No relative accident involvement ratios were obtained for the variables of violation types, contributing circumstances and visual obstructions contributing to the accident occurrence, and driver's intention. This was due to the fact that these variables are very dependant upon the driver and no meaningful results can be derived by comparing these ratios to the average values.

The results of the one-way analysis for these variables related to the geometry, road conditions, and traffic control devices are described in the following sections.

5.2.1. Type of Traffic Signal Control

The data showed that all three groups of elderly drivers showed a reduced ratio for accidents occurring at semi-actuated traffic signals. Among these groups the old-old drivers showed the highest reduction. Also the old-old drivers showed a reduced ratio for accidents occurring at fully actuated traffic signals. The small number of accidents may have contributed to these results, since most of the accidents occurred at fixed time signals.

5.2.2. Number of Traffic Signal Phases

All three groups of elderly drivers showed a reduced ratio for accidents occurring at traffic signals with 4 or more phases.

5.2.3. Traffic Signal Phase Control

The data indicated that there is no apparent interaction between driver's age and phase control for the young-old driver. The middle-old drivers showed a reduction for accidents occurring at areas with traffic signals with lagging left turn, exclusive left turn, and split phasing. The old-old group showed an increased ratio for accidents occurring at areas with traffic signals with far/near phase control while a reduced ratio was noted for those which occurred at signals with exclusive left turn phase control.

5.2.4. Size of Lens of Traffic Signal

The data indicated that only the old-old driver showed a decreased ratio for accidents occurring at areas with traffic signals with 8 inch lens size as opposed to the 12 inch lens.

5.2.5. Signal Code

The data showed that all three groups of elderly drivers experienced an increase for accidents occurring at intersections controlled by flashers. The middle-old and old-old drivers also showed an increase for accidents occurring at signalized intersections. For accidents occurring at non-signalized intersections the ratios of the elderly were approximately the same as their respective ratios of the average driver.

5.2.6. Weather Conditions

The data indicated that in general there is no specific pattern emerging from the weather conditions for any of the elderly age groups. The only difference was observed for accidents occurring under snowy weather, where the middle-old and old-old drivers experience a reduction in their ratios.

5.2.7. Light Conditions

The data indicated that there is no difference between day and night conditions for the young-old and middle-old drivers. However, the old-old drivers experience an increase for accidents occurring at night. This is consistent with the findings in section 5.2.2.

5.2.8. Road Surface Conditions

The data showed that there is no difference in the accident pattern for any road condition for the young-old driver. On the other hand, both middle-old and old-old drivers experience a reduction in the snowy or icy road conditions. The old-old group experiences the greatest reduction.

5.2.9. Accident Type

The young-old drivers showed a reduction in the relative accident involvement ratio for rear end accidents and an increase for rear end while turning left and head on while turning left. The middle-old driver showed an increase for angle while turning, rear end while turning left, and head on turning left accidents. The same group of drivers showed a reduction in rear end and head on accidents. The old-old drivers indicated a reduction in head on accidents and an increase for right angle, angle while turning, rear end while turning left, and head on while turning left accidents.

5.2.10. Driver's Sex

The data showed that there was a very small increase in the ratio of the young-old female drivers. On the other hand, both middle-old and old-old drivers showed a reduction for male drivers, while female drivers indicated a ratio almost twice as high as the average driver.

5.2.11. Laneage

The data indicated that young-old drivers experienced an increase for accidents that occurred on 1 way and divided roads. The middle-old and old-old drivers showed an increase for accidents occurring on multi-lane 2 way, on 1 way, and divided roads.

5.2.12. Road Alignment

The data showed that all three groups of elderly drivers experienced an increase in their ratios for accidents occurring on roads with 1 to 9 degrees of curvature. The young-old driver also showed an increase for accidents on roads with 0 to 1 degrees of curvature while the middle-old driver experienced a reduction for accidents on similar roads.

5.2.13. Intersection Type

The young-old drivers showed an increased ratio for accidents occurring at crossover intersections. The middle-old driver experienced an increase for accidents occurring at offset intersections and a decrease for accidents at crossovers. Finally, the old-old driver showed a decrease for accidents occurring at crossover and wye intersections and an increase for those occurring at offset type intersections.

5.2.14. Number of Auxiliary Right Lanes

The data for the young-old drivers showed no interaction between age and number of auxiliary lanes in the right side. However, both the middle-old and old-old drivers showed an increased ratio for accidents occurring on roads with 1 auxiliary right lane and a decreased ratio for accidents occurred on roads with 2 auxiliary right lanes.

5.2.15. Number of Auxiliary Left Lanes

The young-old drivers showed no interaction between age and accidents occurring on roads with auxiliary lanes in the left side. On the other hand, both the middle-old and old-old drivers showed a decreased ratio for accidents occurring on roads with 1 auxiliary left lane. The old-old drivers showed an increased ratio for accidents occurring on roads with 2 auxiliary left lanes.

5.2.16. Average Daily Traffic

The data indicated that for the young-old drivers no interaction exists between age of driver and average daily traffic. The middle-old drivers experienced an increase for accidents occurring on roads with 10,000-20,000 ADT and a reduction for accidents on roads with 30,000-40,000 and more than 40,000 ADT. The old-old drivers showed an increased ratio for accidents on roads with less than 10,000 ADT and a reduced one for roads with more than 40,000 ADT.

5.2.17. Results

The results from the one way analysis of the data are presented tabulated by group of elderly drivers in Table 5.1. The X mark under each group denotes differences between the ratio of the variable and the ratio of the average driver for that group of elderly drivers indicating an increase, while an O mark indicates a decrease between the ratio of the variable and the average driver.

5.3. Two Way Analysis

The values of the variables that were studied in the two way analysis were only those that showed some variation from the overall accident ratio, as they were defined in the one way analysis. Each value of a variable that entered the analysis was combined with all the values of the remaining variables, regardless of the results from their one way analysis. The inclusion of all variables was considered essential in order to avoid masking of a potential problem due to data aggregation. That is, a possibility exists for a variable to not indicate a difference when considered alone but when combined with another variable the presence of a problem can be indicated.

The relative increase or decrease of the ratio for any age group of drivers is based on the comparison of this ratio with the ratio obtained from the one way analysis of the data. For example, from the variable "light conditions" it was determined that the value of night is the one to be studied according to the results from the one way

Table 5.1. Summary of results from the one way analysis for elderly drivers

Variable	Young-old	Middle-old	Old-old
Weather condition			
Clear			
Rainy			
Snowy		O	O
Light conditions			
Day			
Night			X
Road surface conditions			
Dry			
Wet			
Snowy/icy		O	O
Accident type			
Head on		O	O
Head on, left turn	X	X	X
Rear end	O	O	
Rear end, left turn	X		X
Rear end, right turn			
Right angle			X
Angle turning		X	X
Driver's sex			
Male			
Female	X	X	X
Laneage			
2 lane 2 way			
Multi-lane 2 way		X	X
1 way	X	X	X
Divided	X	X	X
Alignment			
Straight			
0-1 degrees	X	O	
1-9 degrees	X	X	X
10+ degrees			
Intersection type			
Cross	X	O	O
Tee			
Offset		X	X
Wye			O

Table 5.1. (cont'd)

Variable	Young-old	Middle-old	Old-old
Auxiliary right lanes			
0			
1		X	X
2		O	O
Auxiliary left lanes			
0			
1		O	O
2		X	X
Average daily traffic			
0- 9,999			X
10,000-19,999		X	
20,000-29,999		O	
30,000-39,999		O	
40,000 +			O
Number of phases			
2			
3			
4+	O	O	O
Phase control			
Leading left turn			
Lagging left turn		O	
Split phasing		O	
Exclusive left turn		O	O
Far/near signal			X
Signal lens size			
8 inch			X
12 inch			
Traffic control			
Signal		X	X
Flasher	X	X	X
None			

analysis. A second division of the data involves the variable "driver's sex." The ratios of the male drivers at night and female drivers at night were compared to the ratio of night accidents to determine any possible relationships between age of driver and the combination of driver's sex and light conditions. An additional comparison was also performed between the ratios of male drivers at night and female drivers at night. The results of the two way analysis are presented in the following subsections.

5.3.1. Signal Code: Flasher

The young-old driver data showed an increased ratio for accidents on divided roads, at night, and involving female drivers.

The data for middle-aged drivers indicated an increased ratio for head on while turning left accidents, for accidents involving females, for accidents on divided roads, at cross type intersections, and at night.

The old-old driver showed an increased ratio for rear end accidents, for accidents on 2 lane 2 way roads, on roads with 1 to 9 degrees of curvature, at tee type intersections, and at night.

5.3.2. Signal Code: Traffic Signal

The data for the young-old driver showed an increased ratio for head on accidents while turning left, rear end accidents while turning left, and for accidents involving female drivers.

The middle-old driver showed an increased ratio for accidents involving female drivers and at offset type intersections.

The data for the old-old driver showed an increased ratio for head on and rear end accidents while turning left, for accidents involving female drivers, and under snowy weather.

5.3.3. Type of Traffic Signal Control

Most of the accidents were concentrated in one value of the variables which resulted in duplication of the average ratios, thus producing no meaningful comparisons.

5.3.4. Number of Phases: 2

For the young-old driver the data showed an increased ratio for head on accidents while turning left and for rear end accidents while turning left.

For the middle-old driver the data showed an increased ratio for head on and rear end accidents while turning left, for accidents at offset type intersections, on divided roads, and under snowy weather. For the same drivers the data indicated a decreased ratio for accidents at night.

For the old-old driver the data showed an increased ratio for rear end accidents while turning left, for accidents involving female drivers, at tee or offset type intersections, and under snowy weather.

5.3.5. Number of Phases: More than 2

For the young-old drivers the data showed an increased ratio for accidents with female drivers, under snowy weather, on multi-lane 2 way and 1 way roads.

The data for the middle-old drivers showed an increased ratio for angle while turning, rear end while turning left, and head on while turning left accidents, for accidents with female drivers, at cross type intersections, at signalized intersections with exclusive left turn phase signals, and on multi-lane 2 way roads.

The data for the old-old driver indicated an increased ratio for head on accidents while turning left, right angle and rear end while turning left accidents, for accidents with female driver involvement, at signalized intersections with exclusive left turn phase signals, and at night.

5.3.6. Traffic Signal Phase Control: Exclusive Left Turn Phase

The young-old driver showed an increased ratio for head on while turning left and right angle accidents and for accidents on roads with icy pavement.

The data for the middle-old driver showed an increase in the ratio of accidents involving female drivers and at signalized intersections with 3 phase signals. The same age group also experienced a reduction for accidents at night.

The old-old drivers experienced an increased ratio for accidents at signalized intersections with 3 phase signals.

5.3.7. Traffic Signal Lens Size: 8 inches

The young-old driver experienced an increase in the ratio of head on accidents while turning left and of accidents at signalized intersections with 4 or more phase signals.

The middle-old drivers showed an increased ratio for accidents at signalized intersections with 3 phase signals and on divided roads. These drivers also showed reduced ratios for accidents at night.

The data for the old-old drivers showed increased ratios for head on accidents while turning left and for accidents at night.

5.3.8. Traffic Signal Lens Size: 12 inches

The young-old drivers showed an increased ratio only for head on accidents while turning left.

The middle-old drivers showed an increased ratio for right angle and head on while turning left accidents, and for accidents at signalized intersections with 2 phase signals. These drivers also showed reduced ratio for accidents at night.

The data for the old-old driver showed an increased ratio for head on while turning left accidents, for accidents at signalized intersections with 4 or more phase signals, and at night.

5.3.9. Weather: Snow

The data for the young-old drivers showed an increase compared to the average driver for accidents occurring at intersections controlled by flashers, at signalized intersections with 4 or more phases, and for head on accidents while turning left.

The middle-old driver showed an increased ratio compared to the average driver for right angle accidents, angle while turning accidents, head on while turning left accidents, and rear end accidents, female driver involvement, wet pavement, at intersections controlled by flashers, on roads with 1 to 9 degrees of curvature, and on 1 way roads.

The data for the old-old driver showed that snowy weather conditions have a greater effect in their accident patterns than the effect noted for the other two groups of elderly drivers. These drivers showed an increase from the average driver for right angle accidents, head on accidents while turning left, female driver involvement, on 1 way roads, at intersections controlled by either a signal or a flasher, at signalized intersections with a 2 phase signal, on roads with wet pavement, during night, and at cross type intersections.

5.3.10. Light Conditions: Night

The young-old drivers experienced an increase for night accidents, for head on accidents while turning left, for accidents on 1 way segments, and at intersections controlled by flashers.

The data for middle-old drivers showed an increased ratio for angle while turning accidents, head on accidents while turning left, female driver involvement, for accidents on 2 lane 2 way or multi-lane 2 way or divided roads, in rural areas, and at intersections controlled by a flasher. The same drivers showed a decrease for accidents on roads with snowy and wet pavement and under snow weather conditions.

As for the snowy weather conditions, night affected the old-old driver more than the other two groups of elderly drivers. These drivers showed an increase from the average driver for angle accidents while turning, head on accidents while turning left, rear end accidents while turning left, female driver involvement, for accidents on roads with dry pavement, on 2 lane 2 way or multi-lane 2 way roads, at intersections controlled by a flasher, at signalized intersections with a 12 inch signal lens, and under snowy weather.

5.3.11. Accident Type: Head On

The only remarkable variation from the average driver for the young-old driver was an increase in female driver involvement.

However, the middle-old driver in addition to the increase in female driver involvement indicated an increase for accidents at signalized intersections with 2 phases.

The old-old driver showed an increase from the average driver for accidents at signalized intersections, on roads with wet pavement, and at night. These drivers showed a reduced ratio for accidents occurring on roads with icy pavement.

5.3.12.Accident Type: Head On while Turning Left

For head on accidents while turning left the young-old driver showed an increase for accidents at signalized intersections with 2 phases and for accidents involving a female driver.

The middle-old drivers had an increased ratio for female driver involvement, for accidents on multi-lane 2 way roads, on roads with 1 to 9 degrees of curvature, at intersections controlled by a flasher, at tee type intersections, and on wet roads.

A larger variation was noted for the old-old driver than the other two groups of elderly drivers. These drivers showed an increase in female driver involvement, for accidents on 2 lane 2 way and multi-lane 2 way roads, at non signalized intersections, at signalized intersections with 3 phase signals, under snowy weather, and at night.

5.3.13. Accident Type: Right Angle

For right angle accidents the young-old driver showed an increase for accidents on divided roads and for accidents involving a female driver. This driver group also showed a decrease for accidents on roads with icy pavement.

The middle-old driver showed an increased ratio for female driver involvement, for accidents on 2 lane 2 way and divided roads, at non signalized intersections, at wye type intersections, and at wye or tee type intersections. The same drivers showed a decrease for accidents on roads with icy pavement and at night.

An increase was noted for the old-old driver in female driver involvement, for accidents on 2 lane 2 way, 1 way, and divided roads, at wye type intersections, at signalized intersections with 4 or more phase signals, and on roads with icy pavement. These drivers showed a reduced ratio for accidents at night.

5.3.14. Accident Type: Angle while Turning

For angle accidents while turning the young-old driver showed an increase for accidents on divided roads and at night.

An increased ratio was noted for the middle-old drivers for female driver involvement, for accidents on multi-lane 2 way and divided roads, at signalized intersections with 3 phase signals, on roads with dry pavement, and at night. These drivers showed a decrease for accidents on roads with icy pavement.

The old-old driver showed an increase for female driver involvement, for accidents on multi-lane 2 way, 1 way, and divided roads, at signalized intersections with 3 or 4 or more phase signals, on roads with dry pavement, and at night. The same drivers showed a reduced ratio for accidents under snowy weather.

5.3.15. Accident Type: Rear End

The rear end accident data for the young-old driver showed an increase for accidents on 1 way and divided roads, and at night.

The middle-old group showed an increased ratio for female driver involvement, on divided roads, at signalized intersections with 4 or more phase signals, on roads with dry pavement, and at night.

The ratios that showed an increase for the old-old driver include female driver involvement, accidents on multi-lane 2 way and 1 way roads, at intersections controlled by a flasher, at signalized intersections with 2 or 4 or more phase signals, on roads with dry pavement, and at night.

5.3.16. Accident Type: Rear End while Turning Left

The data for the young-old driver showed an increase for accidents involving a female driver, for accidents on 1 way roads, at signalized intersections, and at signalized intersections with 2 phase signals. The same drivers experienced a reduction in their ratio for accidents occurring under snowy weather.

The middle-old driver showed an increased ratio for female driver involvement, for accidents on 1 way roads, on roads with 1 to 9 degrees of curvature, at signalized intersections, at intersections controlled by a flasher, at cross type intersections, at signalized intersections with 2 or 3 phase signals, and on roads with icy pavement. The data also indicated that these drivers experienced a reduction for accidents under snowy weather and at night.

The data for the old-old driver showed an increase for female driver involvement, for accidents on multi-lane 2 way and 1 way roads, at signalized intersections, at signalized intersections with 2 or 3 phase signals, on wet roads, at tee type intersections, and at night. These drivers showed a reduced ratio for accidents under snowy weather.

5.3.17. Accident Type: Rear End while Turning Right

The data for the middle-old drivers showed an increased ratio for female driver involvement, for accidents on 2 lane 2 way and multi-lane 2 way roads, at non signalized intersections, at tee type intersections, and on roads with either wet or icy pavement.

The old-old driver showed an increase for female driver involvement, for accidents on multi-lane 2 way roads, at signalized intersections, at cross type intersections, and on roads with dry pavement. The data for the old-old driver showed a reduction in the ratios for accidents at night.

5.3.18. Driver's Sex: Female

The data for the young-old female drivers showed an increased ratio for head on accidents, for accidents occurring on 1 way roads, at intersections controlled by a flasher, and on roads with dry pavement.

The middle-old female driver showed an increased ratio for head on accidents, for accidents on multi-lane 2 way and divided roads, on roads with 10 or more degrees of curvature, at intersections controlled by a flasher, at offset, wye or tee type intersections, and at signalized intersections with 3 phase signals. The same drivers showed a reduced rate for accidents under snowy weather and at night.

The old-old female driver experienced an increased ratio for head on accidents, for accidents on multi-lane 2 way, 1 way, and divided roads, at cross or offset type intersections,on roads with either wet or icy pavement, and at night.

5.3.19. Laneage: 2 Lane 2 Way Roads

The young-old driver showed an increased ratio for accidents at intersections controlled by a flasher, on roads with wet pavement, and at night.

The middle-old drivers showed an increased ratio for accidents at night, for angle while turning and rear end while turning right accidents, and for accidents that involved female drivers. The data also indicated an improvement in the ratio of signalized intersection when 3 phase signals exist over the existence of 2 phase signals.

For the old-old driver the data showed that they experienced an increased ratio for head on and right angle accidents, at intersections controlled by a flasher, at offset type intersections, and at night.

5.3.20. Laneage: Multi-lane 2 Way Roads

For the multi-lane 2 way roads the young-old driver showed an increased ratio for accidents at intersections controlled by a flasher, and at signalized intersections with 4 or more phase signals.

The middle-old driver showed an increased ratio for female driver involvement, head on accidents while turning left, for accidents at offset or wye type intersections, at signalized intersections with 4 or more phase signals, and at night. The same data showed a decreased ratio for accidents under snowy weather.

The old-old drivers showed an increased ratio for head on, head on while turning left, rear end while turning right, and rear end while turning left accidents, for female driver involvement, for accidents at offset type intersections, at signalized intersections with 3 phase signals, and at night. The same data indicated a reduced ratio for accidents under snowy weather.

5.3.21. Laneage: 1 Way Roads

For the young-old driver the data showed an increased ratio for rear end accidents, for accidents involving female drivers, at tee type intersections, at signalized intersections with 3 phase signals, and at night.

The data for the middle-old driver showed an increased ratio for accidents involving female drivers, at non signalized intersections, and under snowy weather.

The old-old driver showed an increased ratio for rear end and right angle accidents, for accidents involving female drivers, at non signalized intersections, on roads with dry pavement, under snowy weather, and at night.

5.3.22. Laneage: Divided Roads

The young-old driver experienced an increased ratio for right angle accidents and for accidents at non signalized intersections. The same drivers experienced a decreased ratio for accidents at tee type intersections.

The middle-old drivers showed an increase in the ratios of rear end and right angle accidents, accidents involving a female driver, accidents at intersections controlled by a flasher, at signalized intersections with 2 phase signals and 8 inch signal lens, and at night.

The old-old driver experienced an increased ratio for right angle accidents, accidents involving a female driver, at non signalized intersections, and at intersections controlled by flasher. These drivers also experienced a reduced ratio for accidents under snowy weather and at night.

5.3.23. Roadside Development: Rural

The young-old driver showed an increased ratio for accidents that involved female drivers, for head on accidents while turning left, for accidents on multi-lane 2 way roads, on roads with 10 or more degrees of curvature, and at cross type intersections.

The data for the middle-old driver indicated an increased ratio for rear end accidents, for accidents involving female drivers, for accidents on multi-lane 2 way or divided roads, on roads with 10 or more degrees of curvature, at wye type intersections, on roads with icy pavement, under snowy weather, and at night.

For the old-old driver the data showed an increased ratio for right angle, rear end, and head on accidents while turning left, for accidents on 2 lane 2 way or divided roads, on roads with 0 to 1 degrees of curvature, and on roads with wet pavement. For the same drivers the data showed a decreased ratio for accidents under snowy weather.

5.3.24. Results

Table 5.2. presents an explanation of the abbreviated variables used in Tables 5.3, 5.4, and 5.5 which present tabulated the results of the two way analysis for the variables discussed for each one of the

Table 5.2. Description of abbreviated variables in Tables 5.3 through 5.5

Abbreviation	Description
SN	Snowy weather conditions
NI	Night conditions
HO	Head on accidents
HL	Head on while turning left accidents
RA	Right angle accidents
AT	Angle while turning accidents
RE	Rear end accidents
RL	Rear end while turning left accidents
RR	Rear end while turning right accidents
FE	Female drivers
22	2 lane 2 way roads
M2	Multi-lane 2 way roads
1W	1 way roads
DI	Divided roads
RU	Rural areas
FL	Flasher controlled intersection
SI	Signalized intersections
2P	2 phase signal
2+	More than 2 phase signal
EX	Exclusive left turn signal control
8	8 inch signal lens
12	12 inch signal lens

Table 5.3. Summary of results from the two-way analysis for young-old drivers

Variable	SN	NI	HO	HL	RA	AT	RE	RL	RR	FE	22	M2	1W	DI	RU	FL	SI	2P	2+	EX	8	12
Snowy weather																			X			
Night						X	X				X		X			X						
Dry roads										X												
Wet roads											X											
Snowy/icy roads																				X		
Head on										X											X	
Head on, left turn	X	X													X		X	X		X		X
Rear end													X									
Rear end, left turn																	X	X				
Rear end, right turn																						
Right angle														X						X		
Angle turning																						
Females			X	X	X			X					X		X	X	X		X			
2 lane 2 way roads																						
Multi-lane 2 way rds															X				X			
1 way roads		X					X	X		X									X			
Divided roads					X	X	X									X						
Rural							X	X		X		X										
Right curves																						
Left curves							X		X													

Table 5.3. (cont'd)

Variable	SN	NI	HO	HL	RA	AT	RE	RL	RR	FE	22	M2	1W	DI	RU	FL	SI	2P	2+	EX	8	12
Straight roads																						
0-1 degrees curvature																						
1-9 degrees curvature																						
10+ degrees curvature															X							
Cross intersections															X							
Tee intersections													X									
Offset intersections																						
Wye intersections																						
2 phases			X					X														
3 phases													X									
4 or more phases	X											X									X	
Exclusive left turn																						
8 inch signal lens																						
12 inch signal lens																						
Signal								X														
Flasher	X	X								X	X	X										
None														X								

Table 5.4. Summary of results from the two-way analysis for middle-old drivers

Variable	SN	NI	HO	HL	RA	AT	RE	RL	RR	FE	22	M2	1W	DI	RU	FL	SI	2P	2+	EX	8	12
Snowy weather													X		X			X				
Night						X	X				X	X		X	X	X						
Dry roads						X	X															
Wet roads	X			X					X													
Snowy/icy roads								X	X						X							
Head on										X								X	X			
Head on, left turn	X	X										X				X						X
Rear end	X													X	X							
Rear end, left turn																			X			
Rear end, right turn											X											
Right angle	X													X								X
Angle turning	X	X									X								X			
Females	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X		
2 lane 2 way roads		X			X				X													
Multi-lane 2 way rds		X		X		X			X	X					X				X			
1 way roads	X							X														
Divided roads		X			X	X	X			X					X	X		X			X	
Rural	X	X				X	X		X	X		X										
Right curves					X																	
Left curves				X																		

Table 5.4. (cont'd)

Variable	SN	NI	HO	HL	RA	AT	RE	RL	RR	FE	22	M2	1W	DI	RU	FL	SI	2P	2+	EX	8	12
Straight roads																						
0-1 degrees curvature																						
1-9 degrees curvature	X			X				X														
10+ degrees curvature										X					X							
Cross intersections								X								X			X			
Tee intersections				X	X				X	X												
Offset intersections										X		X					X	X				
Wye intersections					X					X		X										
2 phases			X					X						X								X
3 phases						X		X		X										X	X	
4 or more phases							X					X										
Exclusive left turn																			X			
8 inch signal lens														X								
12 inch signal lens																						
Signal								X														
Flasher	X	X		X				X		X				X								
None					X				X				X									

Table 5.5. Summary of results from the two-way analysis for old-old drivers

Variable	Variable																					
	SN	NI	HO	HL	RA	AT	RE	RL	RR	FE	22	M2	1W	DI	RU	FL	SI	2P	2+	EX	8	12
Snowy weather		X		X									X				X	X				
Night	X		X	X		X	X	X		X	X	X	X			X			X		X	X
Dry roads		X				X	X		X				X									
Wet roads	X		X					X		X					X							
Snowy/icy roads					X					X												
Head on										X	X	X					X					
Head on, left turn	X	X										X			X				X		X	X
Rear end													X		X	X						
Rear end, left turn		X										X					X	X	X			
Rear end, right turn												X										
Right angle	X										X		X	X	X				X			
Angle turning		X																				
Females	X	X		X	X	X	X	X	X			X	X	X			X	X	X			
2 lane 2 way roads		X		X	X										X	X						
Multi-lane 2 way rds		X		X		X	X	X	X	X												
1 way roads	X				X	X	X	X		X												
Divided roads					X	X				X					X							
Rural			X	X	X		X				X			X								
Right curves							X		X													
Left curves		X		X	X		X		X													

Table 5.5. (cont'd)

Variable	SN	NI	HO	HL	RA	AT	RE	RL	RR	FE	22	M2	1W	DI	RU	FL	SI	2P	2+	EX	8	12
Straight roads																						
0-1 degrees curvature															X							
1-9 degrees curvature																X						
10+ degrees curvature																						
Cross intersections	X								X	X												
Tee intersections								X								X		X				
Offset intersections										X	X	X						X				
Wye intersections					X																	
2 phases	X						X	X														
3 phases				X		X		X				X								X		
4 or more phases					X	X	X															X
Exclusive left turn																			X			
8 inch signal lens																						
12 inch signal lens		X																				
Signal	X		X					X	X													
Flasher	X	X					X				X			X								
None				X					X				X	X								

groups of elderly drivers. An X mark is used to denote the variables for which an increased difference was detected between the variables of the average driver (given by columns) and the combined effect of the two variables (columns and rows combined).

5.4. Combination of Variables

The last step in the ratio analysis explores the impact of a combination of a number of adverse variables on the performance of the driver. This postulates that for a given set of adverse characteristics the presence or absence of an additional adverse characteristic will not affect the performance of the elderly driver.

To determine if such a condition exists, it was decided to combine the variables for which the relative accident involvement ratio of the old-old and middle-old drivers had the highest differences. The ratios that were used were obtained from the one way analysis. From this analysis it was concluded that with decreasing order the worst variables were the driver's sex, the road surface condition, the roadside development, the light conditions, and the intersection traffic control device. The highest difference was noted between male and female drivers (0.41) and the smallest between signalized and non-signalized intersections (0.18) for old-old drivers. Similar results were noted for the middle-old drivers (0.43 for the driver's sex and 0.22 for the traffic control device).

Only five variables were considered for this analysis since the use of additional variables would produce cells with a very small number of observations. The use of five variables creates at the final level 240 possible cells, with a number of these cells containing no entries.

It was hypothesized that the addition of one variable at a time will continuously increase the differences among the ratios for the new cells. In the event that the driver's performance is not altered by the presence of additional adverse accident characteristics these ratios should became stable after a given division of the data. Thus, at the point where such a phenomenon is noted it could be concluded that the driver's performance has reached a maximum level of poor performance.

The data at hand did not indicate that such a condition exists, at least for the variables tested. From the one way analysis it was concluded that these five conditions each had a significant result on the accident patterns of the elderly drivers. Therefore, it was assumed that a combination of these variables could intensify the effects on the accident patterns. The relative accident involvement ratios followed the hypothesized continuously increasing difference for every new division for all three groups of elderly drivers.

The data split for each level of these variables and the ratios for each successive level are presented in Figures 5.1 through 5.3 for each group of elderly drivers. The cells that lay on the path with the maximum splits for every level are outlined with a double perimeter.

5.5. Conclusions of the Ratio Analysis

The ratio analysis was used to determine the relationships between the driver's age and the characteristics of the accident. The one way

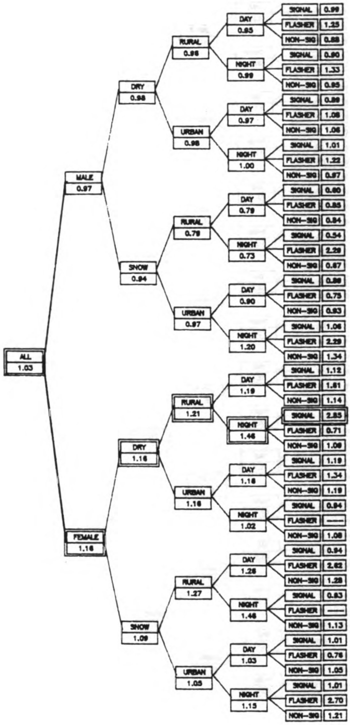

Figure 5.1. Effect on the relative accident involvement ratio from combination of variables, young-old

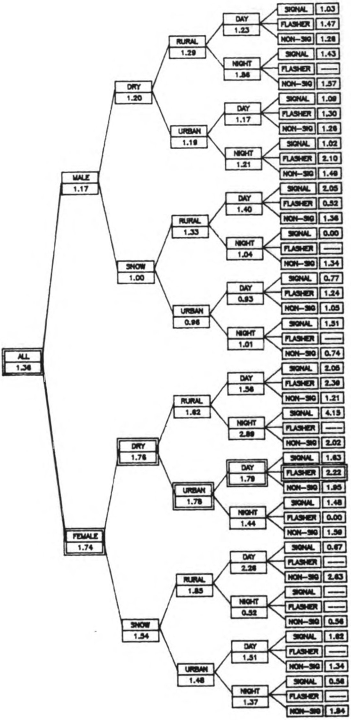

Figure 5.2. Effect on the relative accident involvement ratio from combination of variables, middle-old

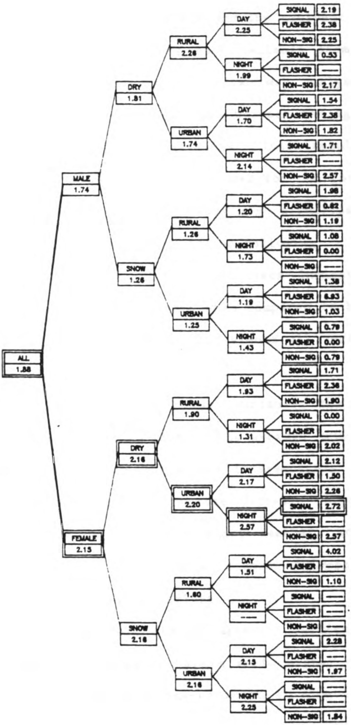

Figure 5.3. Effect on the relative accident involvement ratio from combination of variables, old-old

analysis of the data was applied to determine the first level interactions between the driver's age and the accident characteristics and to determine which values of each variable seem to create the greatest effect on the drivers. The two way analysis was used to determine the second level interactions between the age of the driver and the combined effect of two variables. These results were given a higher significance since they will be used for the formulation of the final hypotheses of this research. The most significant results from the two way analysis are presented in the following.

The two way classification of the data indicated that female drivers tend to have a higher ratio when compared to both the average driver and their male counterparts for almost all variables that were analyzed in this step.

The data indicated that for most variables the elderly drivers produced a smaller ratio than that of the average driver at signalized intersections while at non signalized intersections their ratio was higher than the ratio of the average driver. Also under certain conditions, such as driving under snowy weather, at night, and at intersections controlled by flashers, elderly drivers showed a ratio higher than that of the average driver.

The data indicated that elderly drivers, particularly middle-old and old-old, almost universally have a ratio higher than that of the average driver for head on accidents while turning left. A similar pattern was also noted for accidents where a turning movement was involved or intended. The types of accidents where the elderly drivers seem to have more problems may indicate a difficulty in handling turns. This may be attributed to their failure to either yield the right of way or to correctly estimate the available gaps and the speed of oncoming traffic.

Usually, for accidents occurring at night, elderly have a higher ratio than the average driver. On the other hand, the analysis of the hour of accident occurrence indicated that elderly either have a very small or a very big ratio for early morning or late night accidents. A closer examination of the data from the innocent victim (considered to be the exposure metric) indicated a small number of accidents in both time periods for elderly drivers. This may be considered as an indication of an attempt by elderly drivers to compensate for possible physical deficiencies, such as reduced visual abilities. Also the early morning traffic is usually dominated by drivers whose purpose is to commute to work. The majority of elderly drivers do not belong to the working class, since most are retired and thus they are less likely to be driving during this time of the day.

A similar pattern for the elderly drivers was noted for the weather and road surface conditions. Elderly drivers seem to have an increased ratio over that of the average driver for snowy weather conditions and for driving on roads with either snowy or icy pavements. However, the examination of the data from the innocent victim indicated a reduced number of accidents under these conditions, which can be translated into a form of compensation for their reduced driving abilities.

The above analysis indicates that elderly drivers tend to exercise some compensation regarding the decrease in their driving abilities. It can be postulated that these drivers tend to drive less during night and avoid bad weather conditions. On the other hand, the results also indicate that they cause accidents during these conditions at a higher rate than the average driver. These drivers also seem to have a bigger problem dealing with turns, and particularly left turns. It is possible that a combination of confusion and need to make instant decisions may be the worst enemy that elderly drivers have to battle. Based on these results, hypotheses will be formulated for testing the data and examining the relationship between the driver's age and the intersection traffic control under various conditions.

6. HYPOTHESES

6.1. Introduction

In the preceding chapter a set of variables was defined that were deemed to have contributed to the accident occurrence or to have affected the probability of aged drivers being over represented in accident involvement. After the one-way analysis a number of variables was determined as having a potential effect on the accident involvement of the elderly drivers. Based on the results of this analysis each variable that indicated a difference from the average driver was paired with all the variables examined. In this manner the two way analysis of the data was performed to determine the synergistic effect among these variables.

Based on the relationships determined by the two way analysis, certain hypotheses were formulated to allow for the exploration and definition of the effects of traffic control on the accident patterns of aged drivers at intersections.

6.2. Formulation of Hypotheses

The results from the two way analysis indicated a potential relationship between accident patterns and elderly female drivers involved in accidents under snowy weather. This was noted due to a higher relative accident involvement ratio for female drivers in snowy weather conditions than that observed for the average driver or for male drivers in snowy weather. This observation leads to the formulation of the hypothesis:

There is no difference in the pattern of accidents between signalized and non-signalized intersections for female drivers under snowy weather conditions. (1)*

In addition to this hypothesis, regardless of the outcome of the test, two additional hypotheses will be tested to determine if the presence or absence of intersection traffic control has an effect on the accident patterns of the elderly female drivers under snowy weather. These two hypotheses are:

There is no difference between the pattern of accidents at non-signalized intersections for female drivers under snowy eather conditions versus all other weather conditions. (1.a)

There is no difference among the pattern of accidents for the various signal characteristics for female drivers under snowy weather conditions. (1.b)

The two way analysis also repeatedly indicated a higher relative accident involvement ratio for female drivers for accidents occurring at night than that observed for either the average driver or male drivers. Based on this observation the following hypothesis was formulated:

There is no difference in the pattern of accidents between signalized and non-signalized intersections for female

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* The numbers at the end of each statement denote a numbering order

drivers at night. (2)

A similar second set of hypotheses, as the ones defined previously, were defined to test in further detail the effects of the intersection traffic control on the accident pattern of elderly female drivers at night. These hypotheses are:

There is no difference between the pattern of accidents at non-signalized intersections for female drivers at night and at day. (2.a)

There is no difference among the pattern of accidents for the various signal characteristics for female drivers at night. (2.b)

The results from the two way analysis also indicated that elderly female drivers experience a higher ratio for accidents occurring at signalized intersections than male drivers, while male drivers have a higher ratio for accidents occurring at intersections controlled by a flasher. In general, the data also showed that female drivers have a higher accident ratio than their male counterparts for the majority of the variables tested in the two way analysis. Since the difference between the sexes and the effects of the absence or presence of intersection traffic control were noted in the previous analysis only the second set of hypotheses was formulated to test the relationship between these variables:

There is no difference among the pattern of accidents for the various signal characteristics for male drivers. (3.a)

There is no difference among the pattern of accidents for the various signal characteristics for female drivers. (3.b)

The analysis of the data showed that female drivers experience a higher accident involvement for accidents occurring on multi-lane two way roads (such as 4 and 5 lane roads) than the one noted for either male drivers or the average driver. This observation leads to the hypothesis:

There is no difference in the pattern of accidents between signalized and non-signalized intersections for female drivers on multi-lane two way roads. (4)

The same second set of hypotheses will be tested to determine the effects of the intersection traffic control on the elderly female drivers. Thus, these hypotheses are:

There is no difference between the pattern of accidents at non-signalized intersections for female drivers on multi-lane two way roads and all other types of roads. (4.a)

There is no difference among the pattern of accidents for the various signal characteristics for female drivers on multi-lane two way roads. (4.b)

The two way analysis indicated a higher relative accident involvement ratio for elderly drivers for accidents occurring in rural areas at night. Also from the same analysis a higher ratio was obtained for aged drivers involved in accidents occurring in rural areas under snowy weather conditions than under clear weather. Since the absence of differences between signalized and non-signalized intersections in rural areas was demonstrated in the preceding only the second set of hypotheses was formulated. The hypotheses based on these two observations and their combination are:

There is no difference between the pattern of accidents at rural non-signalized intersections at night versus during the

day. (5.a)

There is no difference among the pattern of accidents for the various signal characteristics at rural signalized intersections at night. (5.b)

There is no difference between the pattern of accidents at rural non-signalized intersections under snowy weather conditions versus all other weather conditions. (5.c)

There is no difference among the pattern of accidents for the various signal characteristics at rural signalized intersections under snowy weather. (5.d)

There is no difference among the pattern of accidents for the various signal characteristics at rural signalized intersections at night and under snowy weather conditions. (5.e)

There is no difference between the pattern of accidents occurring on rural non-signalized intersections at night and under snowy weather than either during the day or under other weather conditions. (5.f)

The last two hypotheses (5.e and 5.f) are used to define the potential effects of the combination of these environmental conditions on accidents occurring in rural areas. It was postulated that the combination of these two conditions will produce higher adverse effects on the accident ratio of the elderly since each variable alone resulted to an increased ratio.

The two way analysis also indicated that elderly drivers experience a higher ratio than the average driver for accidents occurring at night on multi-lane two way roads (4 and 5 lanes). The same analysis also showed a relationship between signalized intersections and multi-lane two way roads by producing a higher accident ratio for elderly drivers than the ratio observed for the average driver. The set of hypotheses based on these observations is:

There is no difference in the pattern of accidents between signalized and non-signalized intersections on multi-lane two way roads at night. (6.a)

There is no difference between the pattern of accidents at non-signalized intersections on multi-lane two way roads at night than on two lane roads at night. (6.b)

There is no difference among the pattern of accidents for the various signal characteristics on multi-lane two way roads at night. (6.c)

There is no difference among the pattern of accidents for the various signal characteristics at signalized intersections on multi-lane two way roads. (6.d)

The two way analysis of the data also indicated a relationship between accidents occurring on non-signalized intersections and one way roads by producing a higher accident ratio for elderly drivers under these conditions than the ratio observed for the average elderly driver. A similar relationship was detected for divided roads as well. Based on these observations the following hypotheses were formulated:

There is no difference between the pattern of accidents at non-signalized intersections on one way roads compared to two way roads. (7.a)

There is no difference between the pattern of accidents at non-signalized intersections on divided roads compared to

non-divided roads. (7.b)

Since the objective of this research is to define the effects of the intersection traffic control on accident patterns of elderly drivers it was decided to include another hypothesis regarding the presence or absence of a traffic controller at intersections. This was deemed necessary in order to determine if elderly drivers experience more problems or are affected in a greater degree when any traffic controller is present. This hypothesis is formulated as follows:

There is no difference in the pattern of accidents of elderly drivers between a non-signalized or a signalized or a flasher controlled intersection. (8)

6.3. Data for Testing the Hypotheses

To test the hypotheses stated above the type of the accident and the violations committed by the driver at fault will be examined. In addition to these two characteristics of the accident, the exposure rates will be tested to determine if the exposure levels of the elderly drivers are different than those of the other drivers.

The hypotheses can be grouped in two major sets; those that test the differences between accident patterns at signalized and non-signalized intersections for specific conditions and those that test the aspects of the intersection traffic control for specific conditions at either signalized or non-signalized intersections.

The accident type will be used to define possible errors in the reaction and decision process of the elderly drivers. For example, higher accident rates for rear end accidents may indicate a reduced ability to exercise the appropriate reaction. Similarly, a higher rate for right angle accidents, and in general for accidents that involve a turning maneuver, may indicate a misjudgement of the available gaps (thus a reduced ability to make the appropriate decision).

The violation committed by the driver at fault will provide more information regarding the possible deficiencies of elderly drivers. For example, if the predominant violation type for accidents occurring at non-signalized intersections is failure to yield the right of way, then this could be attributed to an incorrect estimation of the available gap. In a similar manner, a higher rate of improper turn or improper lane usage violations for accidents that involve a turning movement may indicate a lower ability for aged drivers to properly handle this type of maneuver. These errors may include driving on a turn only designated lane (either right or left turn only lane) or attempting the completion of a turn from an improper lane. Both of these errors could be attributed to a delayed reaction or identification of the signs that designate the use of each lane indicating a reduced ability of elderly drivers.

A driver being at an intersection has three choices, that is to go straight or turn left or turn right. For the right turn movement the driver has to observe only one stream of traffic and has to wait for one acceptable gap to complete his movement and merge with the traffic. On the other hand, for the completion of a left turn or for crossing the intersection to proceed straight, the driver has to observe both traffic streams and define an acceptable gap for both streams at the same time. It is apparent that for these conditions a greater load is placed on the driver and a decision has to be made not only accurately but in a short time as well. If elderly drivers experience a deficiency in their decision process and a prolonged reaction time then this phenomenon should be reflected in their violations and accident patterns. Therefore, if the proportion of elderly drivers causing head on while turning left or right angle accidents is higher than the proportion of other accidents it can be postulated that the greater mental load has a certain affect in their judgement and can affect their decision process. Similarly, the failure to yield the right of way will indicate a similar condition.

A combination of the these variables, type of accident and driver violation, will be used to test the hypotheses set forth. For example, to determine if the aged drivers show a reduced reaction time at non-signalized intersections, rear end accidents will be examined in combination with the violation of the driver at fault. If the driver at fault was the one who rear ended the other vehicle then this could be attributed to a delayed reaction. On the other hand, if the driver was the victim of the rear end collision, this may indicate that there was an instantaneous change in the intention of the driver. This change may indicate an erratic action attributable to delayed reaction to a traffic situation (having to turn at a cross road, to change lane and so on). Other appropriate combinations of these variables will be performed when that is deemed necessary.

Finally, the tests for the exposure levels will be used to verify the basic assumption of this research. This assumption states that the innocent victim is a random choice of the driving population and this distribution should not be affected by age. The tests will indicate if this assumption holds. For those conditions where the null hypothesis is not accepted it could be concluded that the elderly are either under exposed or over exposed. An under exposure to certain driving conditions will indicate a possible recognition by the elderly of their reduced abilities and an attempt by them to minimize the driving risks by driving as little as possible. However, an over exposure will indicate significant problems for elderly when driving under the conditions tested.

In the following the results of the tests of the hypotheses stated here are presented.

7. RESULTS FROM THE TESTS OF HYPOTHESES

7.1. Introduction

Based on the hypotheses defined in the preceding chapter, the hypotheses were tested using the chi-square test. The tests were performed comparing each group of elderly drivers to the corresponding group of middle-aged drivers, as they were previously defined in the methodology of this paper. The elderly drivers were the test group while the middle aged ones were considered as the control group. The 95 percent level of significance was used as the basis for the rejection or acceptance of the hypothesis.

In addition to testing the general hypotheses, as previously defined, three other parameters of the accidents were considered. These were the driver exposure (the age distribution of the innocent victim or Driver 2), the type of violation committed by the driver at fault (Driver 1) which contributed to the accident occurrence, and the accident type. Due to the small number of accidents for most cases it was considered necessary to aggregate the accident types in three major groups, that is head on, rear end, and angle accidents. The hypotheses for these three parameters were in the same format as the general one.

When the hypothesis involves the various characteristics of the signals, three different characteristics are tested. These characteristics are the number of phases, the type of control, and the left turn type of controller. For the type of control each of the three parameters were tested. The set of hypotheses for the left turn type of controller is limited only to the major hypothesis, since the small number of accidents does not allow testing of the additional parameters. Also, for the number of phases in most cases the hypothesis was limited to testing accidents which occurred at signalized intersections with 2 phase signals versus those which occurred at intersections with signals with more than 2 phases.

For those hypotheses where the general one was not rejected for any age group of elderly drivers, the testing was limited to the general one and the secondary one of the exposure testing. It was decided that no meaningful conclusions could be drawn from the secondary hypotheses whenever the general one was accepted.

7.2. Hypotheses

In the following the results from the tests for each hypothesis are discussed. For every group of hypotheses a figure illustrates the branching of the tests and also indicates when the general hypothesis is rejected. For hypotheses that have been rejected a double outline of the corresponding cell indicates this rejection.

7.2.1. Hypothesis 1

There is no difference in the pattern of accidents between signalized and non-signalized intersections for female drivers under snowy weather conditions.

The results of the test indicated that this hypothesis cannot be rejected for the young-old and middle-old drivers, but it was rejected for the old-old. The chi-square value was high for old-old drivers at both signalized and non-signalized intersections. The results of this test indicate that old-old female drivers experience a greater problem at signalized intersections under snowy weather conditions than at non-signalized intersections (Figures 7.1 and 7.2).

The tests for the exposure, violation type, and accident type did not produce any additional insight. The only set that was rejected was the test for violation types at non-signalized intersections where young-old drivers seem to have a greater number of violations such as driving too slow and failing to yield the right of way compared to the middle-aged drivers.

7.2.2. Hypothesis 1.a

There is no difference between the pattern of accidents at non-signalized intersections for female drivers under snowy weather conditions versus all other weather conditions.

The results of the tests showed that this hypothesis was rejected for all three groups of elderly drivers. For all groups snow was the major contributor to the rejection of the hypothesis. The results showed that elderly female drivers experience a problem with snowy weather conditions (Figures 7.1 and 7.2).

The exposure tests resulted in the acceptance of the hypotheses. The tests for the violation type resulted in the acceptance of the

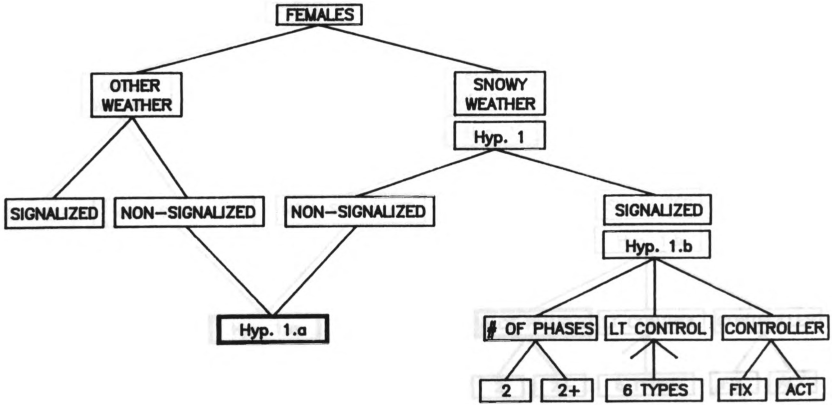

Figure 7.1. Results of testing hypotheses 1, 1.a, and 1.b for young-old and middle-old drivers

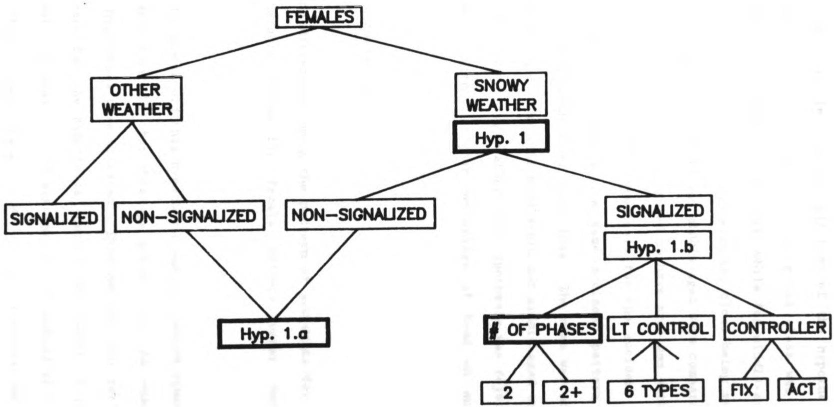

Figure 7.2. Results of testing hypotheses 1, 1.a, and 1.b for old-old drivers

hypothesis for the young-old, were inconclusive (few accidents) for the middle-old, but resulted in the rejection of the hypothesis for the old-old. For the latter group, following too close was the leading violation for snowy weather conditions, while for middle-aged speeding was the major contributor with following too close being second. When the violation types for old-old and middle-aged were compared for snowy weather conditions, the elderly seemed to have problems with failing to yield the right of way. The hypothesis for the accident type showed that all three groups follow the same accident pattern when snowy weather is compared with other conditions. The same was noted for the middle-aged drivers. When the middle-old and middle-aged were compared for accidents under snowy weather, the hypothesis was rejected showing the middle-old with a higher percentage of head on and rear end accidents.

7.2.3. Hypothesis 1.b

There is no difference among the pattern of accidents for the various signal characteristics for female drivers under snowy weather conditions.

For the middle-old this hypothesis was not tested since there were very few accidents (12) for this age group. For the young-old group all three hypotheses were accepted. This was the case for the old-old group, except for the hypothesis testing the number of phases. The results indicated that old-old drivers have a problem at intersections with more than 2 phase signals. This result supports the findings of hypothesis 1, and indicates that old-old female drivers have a problem at signalized intersections with more than 2 phase signals under snowy weather (Figures 7.1 and 7.2).

The tests for exposure, violation type, and accident type led either to the acceptance of the hypothesis or were inconclusive, due to the small number of accidents.

7.2.4. Hypothesis 2

There is no difference in the pattern of accidents between signalized and non-signalized intersections for female drivers at night.

The tests for this hypothesis led to its acceptance for all three groups of elderly female drivers. Thus, these tests indicate that elderly female drivers do not experience different problems during night between signalized and non-signalized intersections (Figure 7.3).

The tests for exposure between young-old and middle-aged showed that both age groups have a similar pattern of accidents at signalized intersections but a different pattern at non-signalized intersections, where there is reduced exposure of elderly drivers at night. The tests for the middle-old were inconclusive due to the small number of accidents, and the tests for the old-old led to the acceptance of the hypotheses.

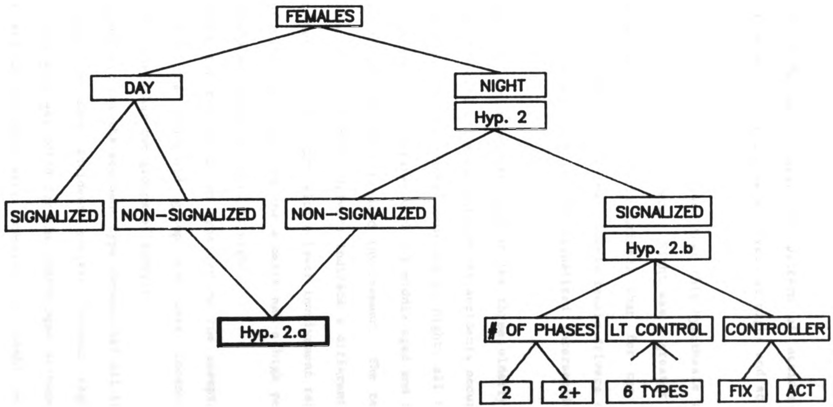

Figure 7.3. Results of testing hypotheses 2, 2.a, and 2.b for all elderly drivers

7.2.5. Hypothesis 2.a

There is no difference between the pattern of accidents at non-signalized intersections for female drivers at night and at day.

The results of the tests showed that this hypothesis was rejected for all three groups of old drivers. Night was a greater contributor for all three groups of elderly drivers than for the middle-aged drivers. The results indicate that elderly female drivers experience a particular problem at night at non-signalized intersections (Figure 7.3).

The exposure tests between each of the three elderly groups and the middle-aged showed a similar pattern for accidents occurring during the day. However, for accidents occurring at night, all three groups showed a difference when compared with the middle-aged and in all cases the elderly drivers showed a reduced involvement. The tests between night and day for the elderly drivers indicate a different pattern of exposure between day and night, with a lower involvement rate at night. In spite of this lower exposure the elderly had a high percentage of their accidents as driver at fault at night.

The tests for the violation type led to the acceptance of the hypothesis for the young-old group and were inconclusive (few accidents) for the other two groups of elderly.

The hypothesis for the accident type showed that all three elderly groups follow the same accident pattern between night and day accidents. The same was noted for the middle-aged drivers. When the middle-old and middle-aged were compared for night accidents the hypothesis was rejected showing the middle-old with a higher percentage of head on accidents. Also, all three groups of elderly showed a different pattern than the middle-aged for day accidents.

7.2.6. Hypothesis 2.b

There is no difference among the pattern of accidents for the various signal characteristics for female drivers at night.

For all three groups all the hypotheses were not rejected, indicating that elderly female drivers do not face any additional problems at night due to signal characteristics (Figure 7.3).

7.2.7. Hypothesis 3.a

There is no difference among the pattern of accidents for the various signal characteristics for male drivers.

The set of the three hypotheses was not rejected for the young-old and old-old drivers. For the middle-old the hypotheses for the number of phases and the left turn controller were rejected. The major contributor to the rejection of the phases hypothesis was the middle-old drivers at 4 phase signals, while for the left turn controller it was the middle-old driver accidents occurring at signals with exclusive left turn control and split phasing. Both hypotheses tend to support each other and both indicate a problem for middle-old male drivers to properly handle multi-phase signals (Figures 7.4, 7.5, and 7.6).

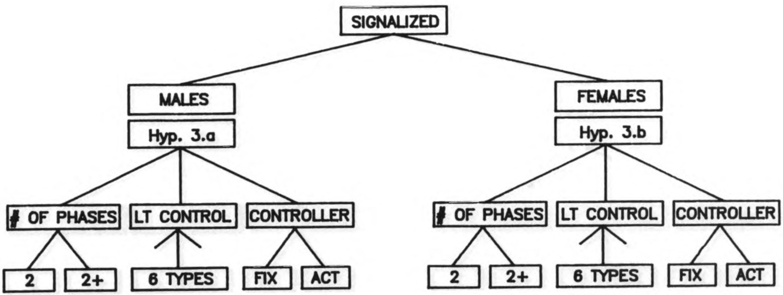

Figure 7.4. Results of testing hypotheses 3.a and 3.b for young-old drivers

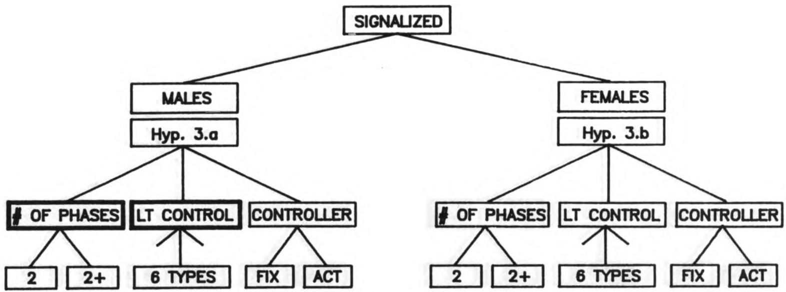

Figure 7.5. Results of testing hypotheses 3.a and 3.b for middle-old drivers

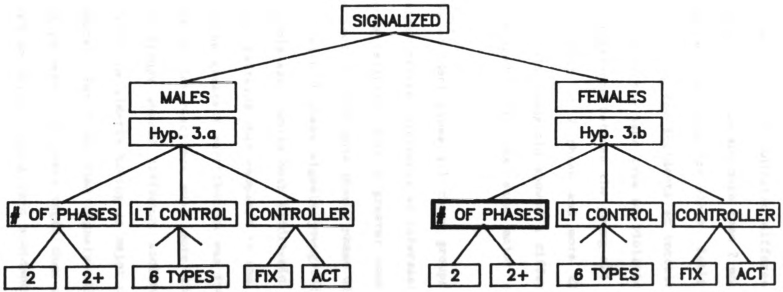

Figure 7.6. Results of testing hypotheses 3.a and 3.b for old-old drivers

The tests for the exposure led to the acceptance of the hypotheses, indicating similar exposure rates for every condition. The tests for violations for the young-old indicated differences between violations at intersections with 2 phase and more than 2 phase signals, with a greater contribution of following too close, failing to yield right of way, and improper turning for accidents at intersections with more than 2 phase signals. Also the same type of violations were the major contributor to the difference between the young-old and middle-aged drivers for accidents both at 2 phase and more than 2 phase signals. For fixed time signals young-old showed a different pattern of violations than middle-aged, with the same major contributors attributed to young-old.

In the tests for the accident types all three groups of elderly drivers indicated differences between accidents at intersections with 2 phase and more than 2 phase signals, with a greater contribution of head on accidents at intersections with more than 2 phase signals. For accidents at intersections with 2 phase signals young-old showed no differences compared to middle-aged, while both middle-old and old-old indicated different accident patterns when compared to the middle-aged drivers. For both groups the greatest contribution was from rear end accidents. For accidents at intersections with more than 2 phase signals all three elderly groups showed different accident patterns compared to middle-aged, with the elderly having as major contributors angle and rear end accidents. For fixed time signals all groups of elderly showed a different pattern in accident types than middle-aged, with the rear end and head on while turning left accidents being the major contributors attributed to elderly drivers.

Both violation types and accident types seem to follow a consistent pattern when tested for the various aspects of signals. In almost all cases, elderly male drivers seem to face problems at multi-phase signals leading to violations of following too close and failing to yield the right of way, and corresponding accident types, such as head on and rear end. The results of these tests may indicate that male elderly drivers have problems with turning maneuvers in complex traffic situations.

7.2.8. Hypothesis 3.b

There is no difference among the pattern of accidents for the various signal characteristics for female drivers.

The set of the three hypotheses was not rejected for the young-old and middle-old drivers. For the old-old, only the hypothesis for the number of phases was rejected. The major contributor to the rejection of the phases hypothesis was the old-old drivers at more than 2 phase signals. The rejection of this hypothesis may indicate a problem for old-old female drivers to properly handle multi-phase signals (Figures 7.4, 7.5, and 7.6).

The tests for the exposure led to the acceptance of the hypotheses, indicating similar exposure rates for every condition. The tests for the violation for the young-old led to the acceptance of the hypotheses for the violation types. For the middle-old and old-old differences between violations at intersections with 2 and more than 2 phase signals were detected, with a greater contribution of violations of following too close and failing to yield the right of way for accidents at intersections with more than 2 phase signals. The same type of violations were the major contributors from the elderly groups for the rejection of the tests between young-old and middle-aged drivers for accidents at both 2 and more than 2 phase signals. For fixed time signals all three elderly groups showed a different pattern in violations than middle-aged, with major contributions from following too close and failing to yield the right of way attributed to elderly drivers.

From the tests for the accident types all three groups of elderly drivers indicated differences between accidents at intersections with 2 and more than 2 phase signals, with a greater contribution of head on while turning left accidents at intersections with more than 2 phase signals. For accidents occurring at intersections with 2 phase signals all three elderly groups showed differences in the accident patterns compared to middle-aged, with the greatest contribution from rear end and head on while turning left accidents attributed to elderly drivers. For accidents at intersections with more than 2 phase signals all three elderly groups again showed a different accident pattern compared to middle-aged, with the young-old and old-old elderly having as major contributors right angle and rear end accidents, with the middle-old having only the rear end accidents as a contributor.

For fixed time signals all groups of elderly showed a different pattern in accident types than middle-aged, with the rear end and head on while turning left accidents being the major contributors attributed to elderly drivers.

A similar conclusion as for hypothesis 3.a was reached for female elderly drivers. In almost all cases, elderly female drivers seem to face problems at multi-phase signals leading to accidents such as head on while turning left and right angle and corresponding violations such as following too close, improper turn, and failing to yield the right of way. The results of these tests may indicate that female elderly drivers have problems with turning maneuvers in complex traffic situations and resemble their male counterparts in this aspect of traffic performance.

7.2.9. Hypothesis 4

There is no difference in the pattern of accidents between signalized and non-signalized intersections for female drivers on multi-lane two way roads.

The hypothesis was not rejected for the young-old and old-old drivers while it was rejected for the middle-old drivers, with the major contributor being the over involvement of the elderly at non-signalized intersections (Figures 7.7, 7.8, and 7.9).

The tests for exposure between elderly and middle-aged drivers showed that both age groups have a similar pattern for accidents occurring at signalized and non-signalized intersections.

The tests for the violation types indicated that all three elderly groups have a similar pattern for accidents occurring at signalized and non-signalized intersections. For accidents either at non-signalized or signalized intersections the old-old have a different pattern of violations than the middle-aged, with the major contributions from the

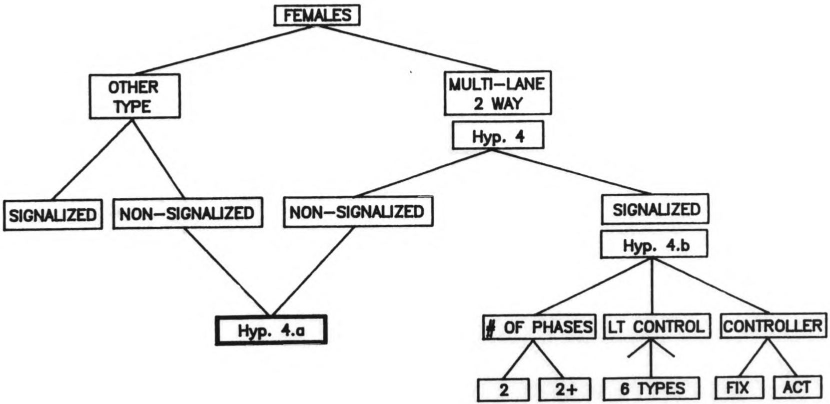

Figure 7.7. Results of testing hypotheses 4, 4.a, and 4.b for young-old drivers

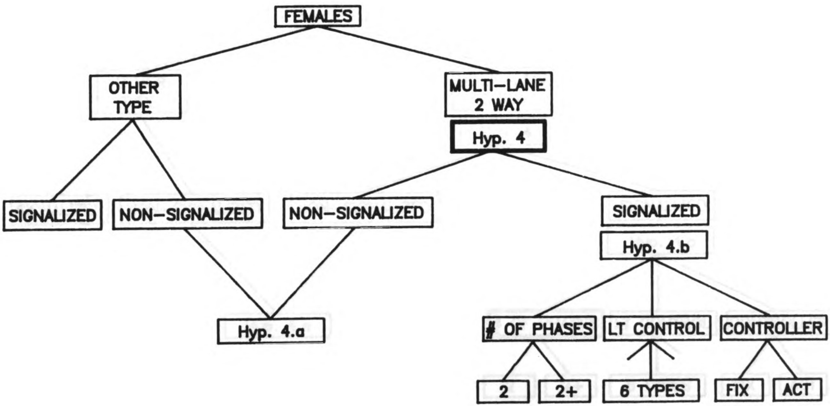

Figure 7.8. Results of testing hypotheses 4, 4.a, and 4.b for middle-old drivers

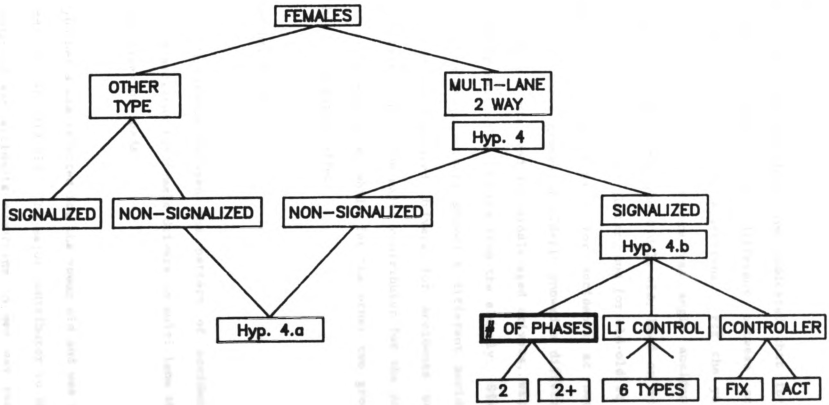

Figure 7.9. Results of testing hypotheses 4, 4.a, and 4.b for old-old drivers

elderly violations being following too close and failing to yield the right of way.

The tests for the accident type indicated that for all three elderly groups the pattern was different between accidents at signalized and non-signalized intersections. For the young-old the major contributor to this difference was angle accidents at non-signalized intersections. For the middle-old, head on at signalized intersections was the major contributor, and for old-old it was head on at non-signalized intersections. For accidents at non-signalized intersections all three groups of elderly showed a different accident pattern than the one observed for middle-aged drivers, with the major contributor being rear end accidents from the elderly. Similarly, all three groups of elderly drivers showed a different accident pattern than that of the middle-aged drivers for accidents occurring at signalized intersections. The major contributor for the young-old was head on and angle accidents, while for the other two groups head on accidents had the greatest effect.

7.2.10. Hypothesis 4.a

There is no difference between the pattern of accidents at non-signalized intersections for female drivers on multi-lane two way roads and all other types of roads.

The hypothesis was rejected for the young-old and was not rejected for the middle-old and old-old. The major contributor to the rejection for the young-old was accidents occurring on one way roads (Figures

7.7, 7.8, and 7.9).

The tests for exposure between elderly and middle-aged drivers showed that both age groups have a similar pattern for accidents occurring on any type of roads.

The tests for the violation types indicated that all three elderly groups do not have a similar pattern for accidents occurring on multi-lane two way roads and other types of roads. The major contributor for all three age groups was the violation of improper lane usage for one way roads and for the old-old the same violation for two lane two way roads was considered an additional major contributor. Similarly, the middle-aged drivers showed a different pattern between multi-lane two way roads and other types, but with the major contributor being violations such as improper turn and following too close for one way roads. For multi-lane two way roads all three groups of elderly showed a different pattern than the middle-aged with the elderly indicating a higher involvement for almost all types of violation.

The tests for the accident type indicated that for all three elderly groups the pattern was different between accidents on multi-lane two way roads and other types of roads. For the young-old and middle-old the major contributor was head on accidents on divided roadways followed by rear end accidents on one way roads, while for the old-old right angle and head on while turning left on multi-lane two way roads were the greatest contributors. A similar pattern was detected for the middle-aged drivers but with leading contributors being head on, rear end while turning left, and right angle accidents on multi-lane two way roads.

7.2.11. Hypothesis 4.b

There is no difference among the pattern of accidents for the various signal characteristics for female drivers on multi-lane two way roads.

The set of the three hypotheses was not rejected for the young-old and middle-old drivers. For the old-old the hypothesis for the number of phases was rejected. The major contributor for the rejection was the old-old drivers at signalized intersections with more than 2 phase signals. The rejection of this hypothesis indicates a problem for old-old female drivers to properly handle multi-phase signals (Figures 7.7, 7.8, and 7.9).

The tests for the exposure led to the acceptance of the hypotheses, indicating similar exposure rates for every condition.

The tests for the violation for all three elderly groups indicated no difference in the violation patterns between accidents occurring at signals with either 2 or more than 2 phases. For accidents occurring either at 2 or more than 2 phase signals all three elderly groups showed a different pattern than the middle-aged drivers. The major contributors to the rejection of the hypotheses for the young-old were the violations of following too close and failing to yield the right of way, for the middle-old the violations of following too close and improper lane use, and for the old-old the violation of failing to yield the right of way.

For fixed time signals all three elderly showed a different pattern in violations than middle-aged, with major contributors being following too close and failing to yield the right of way attributed to elderly drivers.

From the tests for the accident types all three groups of elderly drivers followed similar accident patterns at intersections with 2 and more than 2 phase signals. For accidents occurring at intersections with 2 phase signals the young-old and old-old showed differences in the accident patterns compared to middle-aged, with greater contributions of rear end for the young-old and head on accidents for the old-old. For accidents at intersections with more than 2 phase signals the young-old and middle-old showed different accident patterns compared to middle-aged, with the young-old having as a major contributor rear end accidents and the middle-old having angle and rear end accidents as contributors. For fixed time signals young-old and old-old showed a different pattern in accident types than middle-aged, with the rear end and head on while turning left accidents being the major contributors attributed to elderly drivers for both groups.

The overall pattern indicates a tendency of female drivers to be involved mainly in rear end accidents at signalized intersections when they drive on multi-lane two way roads. In almost all cases, elderly female drivers seem to face problems at multi-phase signals leading to accidents such as rear end and head on and their corresponding violations such as following too close, improper turn, and failing to yield the right of way. The results of these tests may indicate that female elderly drivers have problems with turning maneuvers in complex traffic situations (combination of multi-lane two way roads and multi-phase signals) and fail to react properly and timely in these traffic conditions.

7.2.12. Hypothesis 5.a

There is no difference between the pattern of accidents at rural non-signalized intersections at night versus during the day.

The results of the tests showed that this hypothesis was rejected for all three groups of old drivers. Night was a greater contributor for all three groups of elderly drivers than for the middle-aged drivers, but the way that the data was split may have led to this rejection. Most of the accidents occurred during the day (almost 85 percent) and the large difference between the numbers of day and night accidents may have led to this conclusion. The results indicate that elderly drivers experience a particular problem at night at rural non-signalized intersections (Figure 7.10).

The exposure tests showed a similar pattern for accidents occurring under any condition. The tests for the violation type showed similar patterns for violations between day and night accidents for the young-old group and were inconclusive (few accidents) for the other two groups of elderly.

The test between young-old and middle aged for violations at night resulted in the rejection of the hypothesis indicating that young-old seemed to have problems with failing to yield the right of way and following too close. The hypothesis for the accident type was tested only for the young-old drivers and showed similar accident patterns between accidents occurring at night and during the day. When the young-old and middle-aged were compared for night accidents the hypothesis was not rejected showing a similar accident pattern.

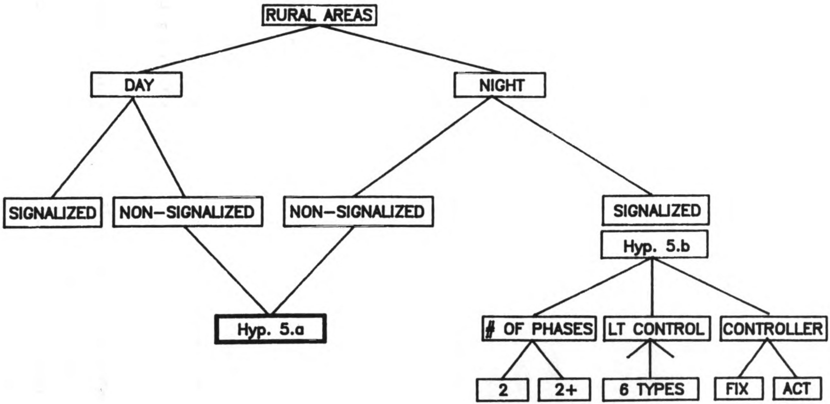

Figure 7.10. Results of testing hypotheses 5.a and 5.b for all elderly drivers

However, the same comparison for accidents occurring during the day resulted in the rejection of the hypothesis indicating that young-old have a higher percentage of rear end accidents.

7.2.13. Hypothesis 5.b

There is no difference among the pattern of accidents for the various signal characteristics at rural signalized intersections at night.

The set of hypotheses was only tested for the young-old since the other two groups had very few accidents. All three hypotheses regarding the traffic signal characteristics were not rejected for the young-old drivers, indicating no additional problems for the elderly from driving in rural areas at night. At this point it has to be mentioned that the small number of accidents may have an influence in the results of this test (Figure 7.10).

7.2.14. Hypothesis 5.c

There is no difference between the pattern of accidents at rural non-signalized intersections under snowy weather conditions versus all other weather conditions.

The results of the tests showed that this hypothesis was not rejected for the young-old but was rejected for the other two groups of elderly drivers. For both middle-old and old-old drivers the reason for rejecting the hypothesis was higher accident involvement under snowy weather. For the test of the old-old versus the middle-aged drivers, snow was a major contributor for both groups but old-old had the higher value. The results showed that elderly drivers experience a problem with snowy weather conditions in rural areas (Figures 7.11 and 7.12).

The exposure tests resulted in the acceptance of the hypotheses. The tests for the violation type resulted in the acceptance of the hypothesis for the young-old and were inconclusive (few accidents) for the middle-old and old-old. The only test performed for the comparison between elderly and middle-aged drivers under snowy weather was for the young-old. The test indicated that young-old drivers seemed to have problems with failing to yield the right of way.

The hypotheses for the accident type were tested only for the young-old and showed that these drivers follow the same accident pattern when snowy weather is compared with other conditions. The same was noted for the middle-aged drivers. When the young-old and middle-aged were compared for accidents under snowy weather the hypothesis was rejected showing the young-old with a higher percentage of right angle accidents.

7.2.15. Hypothesis 5.d

There is no difference among the pattern of accidents for the various signal characteristics at rural signalized intersections under snowy weather.

The data set included very few accidents for all three groups of

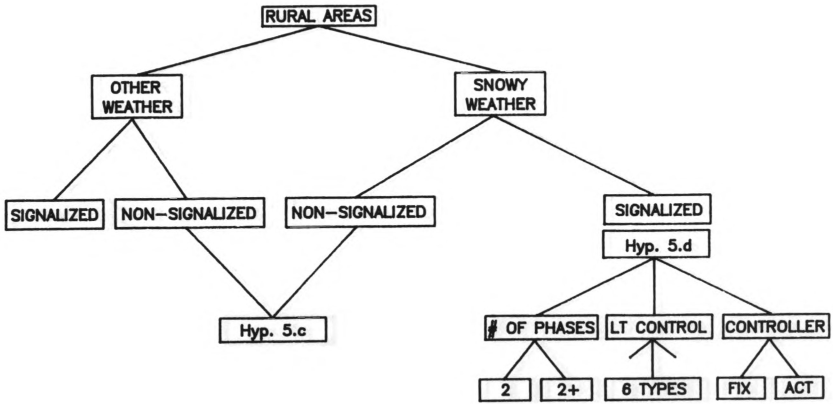

Figure 7.11. Results of testing hypotheses 5.c and 5.d for young-old drivers

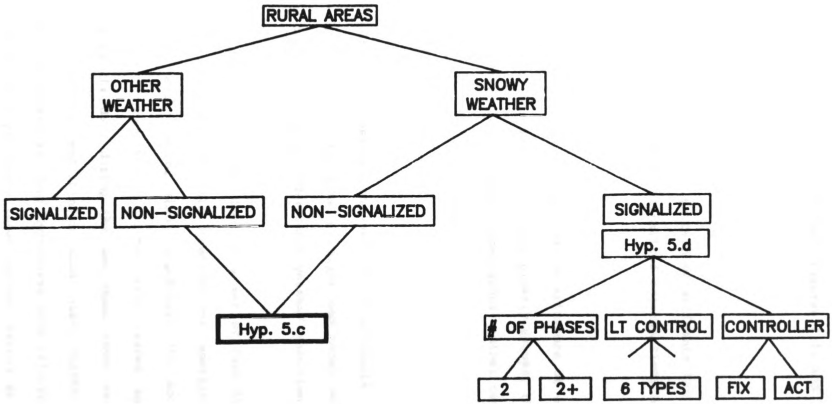

Figure 7.12. Results of testing hypotheses 5.c and 5.d for middle-old and old-old drivers

elderly drivers (only a total of 3 accidents for middle-old and old-old groups) and thus no tests were performed (Figures 7.11 and 7.12).

7.2.16. Hypothesis 5.e

There is no difference among the pattern of accidents for the various signal characteristics at rural signalized intersections at night and under snowy weather.

This hypothesis was not tested due to existence of a very small number of accidents, for any of the three elderly groups, that occurred at signalized intersections at night under snowy weather conditions.

7.2.17. Hypothesis 5.f

There is no difference between the pattern of accidents occurring on rural non-signalized intersections at night and under snowy weather than either during the day or under other weather conditions.

This hypothesis was broken down to a set of four hypotheses in order to test all the possible combinations emerging from its statement. For each one of these hypotheses the accidents that occurred at night under snowy weather were tested against those occurring during the day, during the day under snowy weather, under other weather conditions, and at night under other weather conditions. For the young-old drivers all four hypotheses were rejected except the one for accidents at night under snowy weather versus at night under other weather conditions. For the other three hypotheses that were rejected, the major contributor was the night accidents under snow caused by the young-old (Figures 7.13 and 7.15).

A similar pattern was detected for the middle-old, but this time the hypothesis for testing accidents at night and day both under snowy weather was also not rejected. Again the night accidents under snow caused by the middle-old was the major contributor (Figures 7.14 and 7.15).

The old-old showed the same pattern as the middle-old, but it has to be mentioned that the rejection of the two hypotheses was possibly forced by the way the data was split, 18 accidents for snowy night conditions and 984 for day (Figures 7.14 and 7.15).

The results from these hypotheses indicate that elderly drivers have a problem dealing with driving at night in snowy weather conditions, since they experience a higher rate of accidents than under other combinations of weather conditions and time of day.

The second set of hypotheses did not reveal any additional information, since the tests either led to the acceptance of the hypothesis or were not performed due to the small number of accidents.

7.2.18. Hypothesis 6.a

There is no difference in the pattern of accidents between signalized and non-signalized intersections on multi-lane two way roads at night.

This hypothesis was not rejected for any of the three groups of elderly drivers, indicating that the aged do not face additional

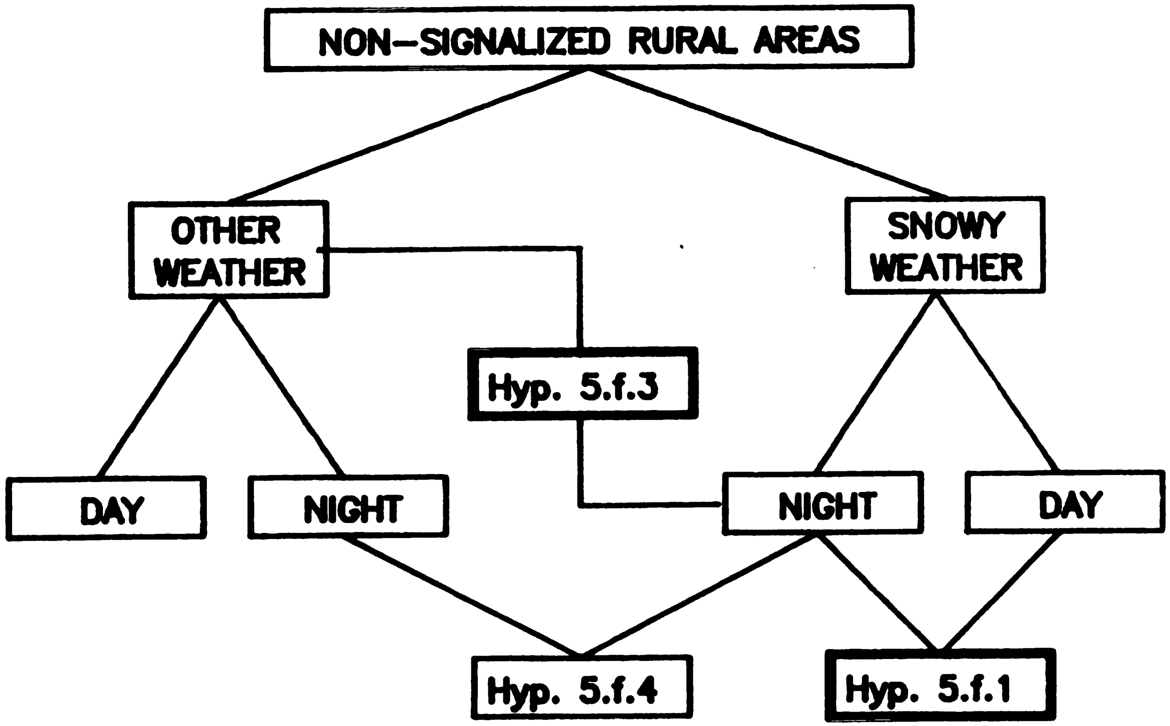

Figure 7.13. Results of testing hypotheses 5.f.1, 5.f.3, and 5.f.4 for young-old drivers

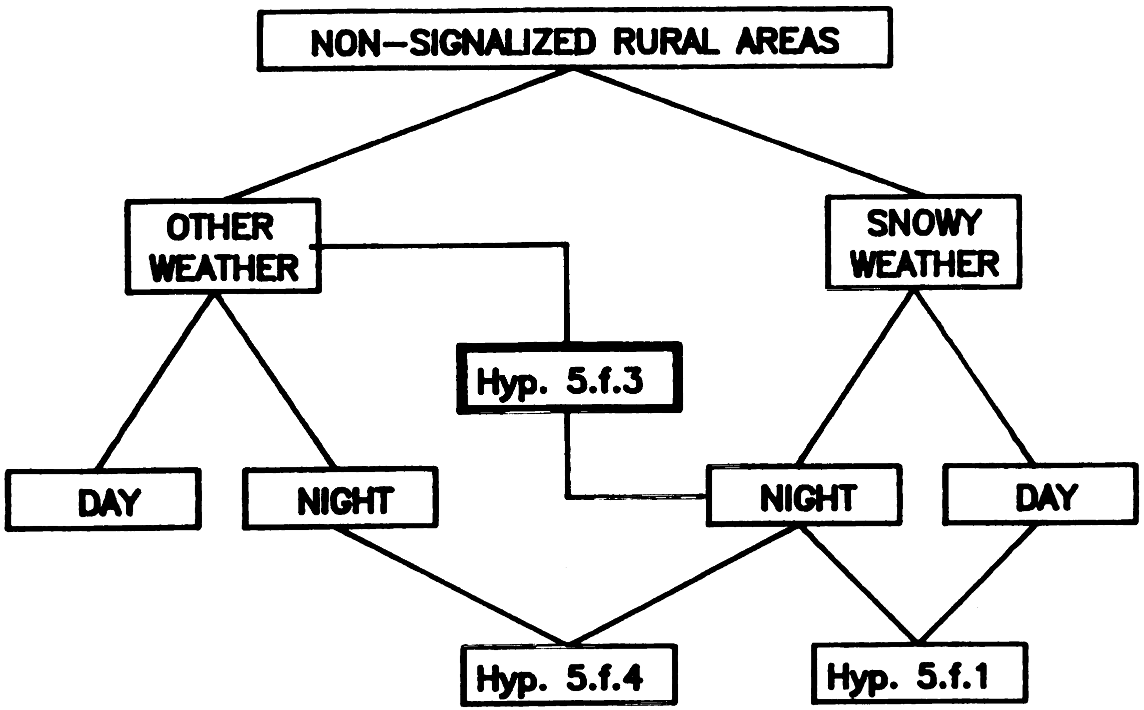

Figure 7.14. Results of testing hypotheses 5.f.1, 5.f.3, and 5.f.4 for middle-old and old-old drivers

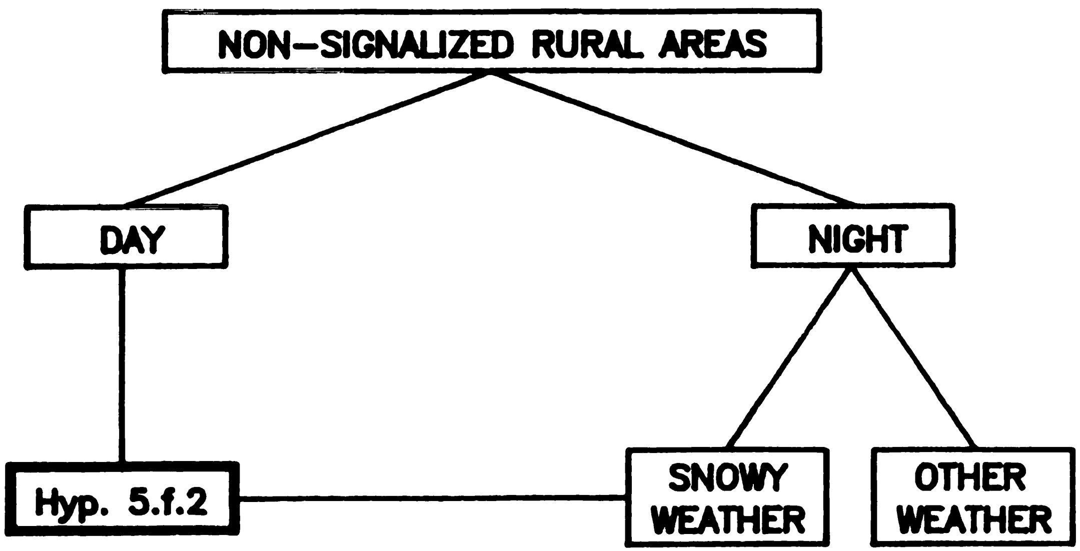

Figure 7.15. Results of testing hypothesis 5.f.2 for all elderly drivers

problems at either signalized or non-signalized intersections at night on multi-lane two way roads (Figure 7.16).

7.2.19. Hypothesis 6.b

There is no difference between the pattern of accidents at non-signalized intersections on multi-lane two way roads at night than on two lane roads at night.

This hypothesis was not rejected for any of the three groups of elderly drivers indicating that there is no difference in the accident patterns between multi-lane and two lane two way roads at night for the elderly drivers (Figure 7.16).

7.2.20. Hypothesis 6.c

There is no difference among the pattern of accidents for the various signal characteristics on multi-lane two way roads at night.

The tests for the set of these hypotheses led to their acceptance for all aspects of the traffic signals indicating that elderly drivers do not face any additional problems at signalized intersections on multi-lane two way roads at night (Figure 7.16).

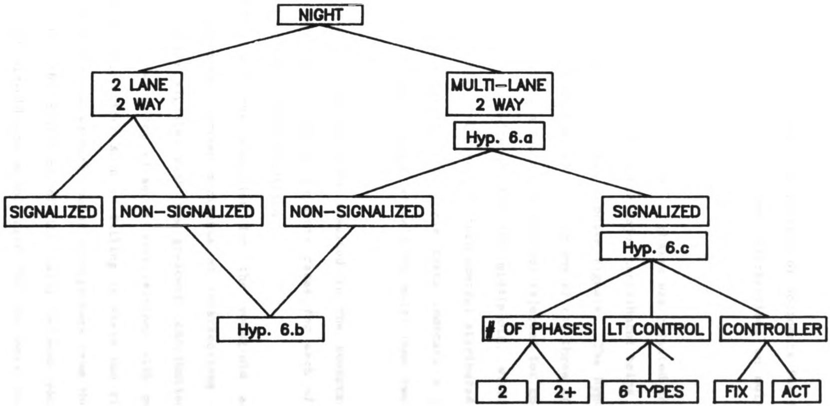

Figure 7.16. Results of testing hypotheses 6.a, 6.b, and 6.c for all elderly drivers

7.2.21. **Hypothesis 6.d**

There is no difference among the pattern of accidents for the various signal characteristics at signalized intersections on multi-lane two way roads.

The hypotheses for the number of phases was rejected for all three groups of elderly drivers, with the major contributor being the elderly at intersections with more than 2 phase signals. The hypothesis for the controller type was not rejected for any of the three groups, while the one for the left turn controller was not rejected for the young-old and old-old but was rejected for the middle-old, with the major contributor being the exclusive left turn control attributed to middle-old. The overall results from these tests indicate a problem for elderly drivers at multi-phase signals on multi-lane two way roads (Figures 7.17, and 7.18).

The tests for the exposure resulted in the acceptance of the hypotheses, indicating similar exposure rates for each of the three groups of elderly for every condition.

The tests for the violation for the young-old and old-old indicated differences between accidents at intersections with 2 and more than 2 phase signals, with the greatest contribution from the violation of following too close at intersections with more than 2 phase signals. Violations such as failing to yield the right of way and following too close were the major contributors from the young-old and old-old for the rejection of the tests between young-old and middle-aged and old-old and middle-aged for the more than 2 phase

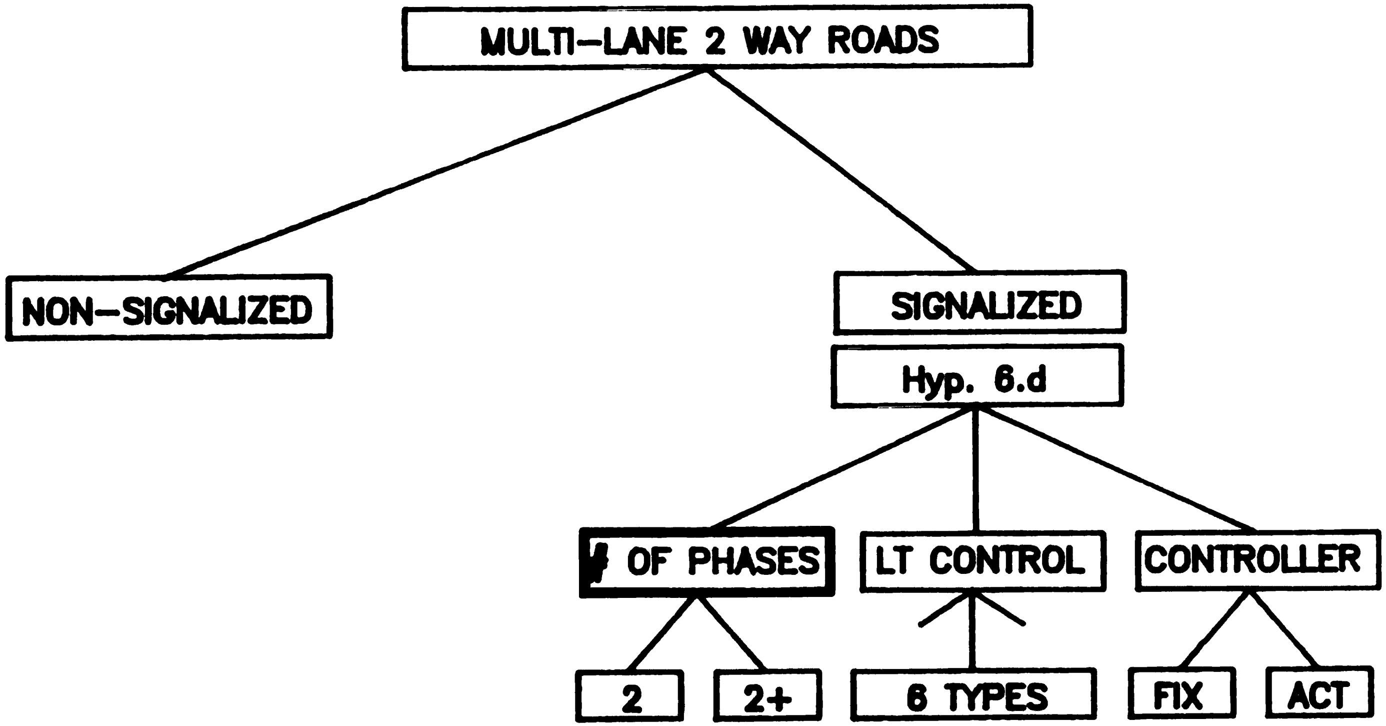

Figure 7.17. Results of testing hypothesis 6.d for young-old and old-old drivers

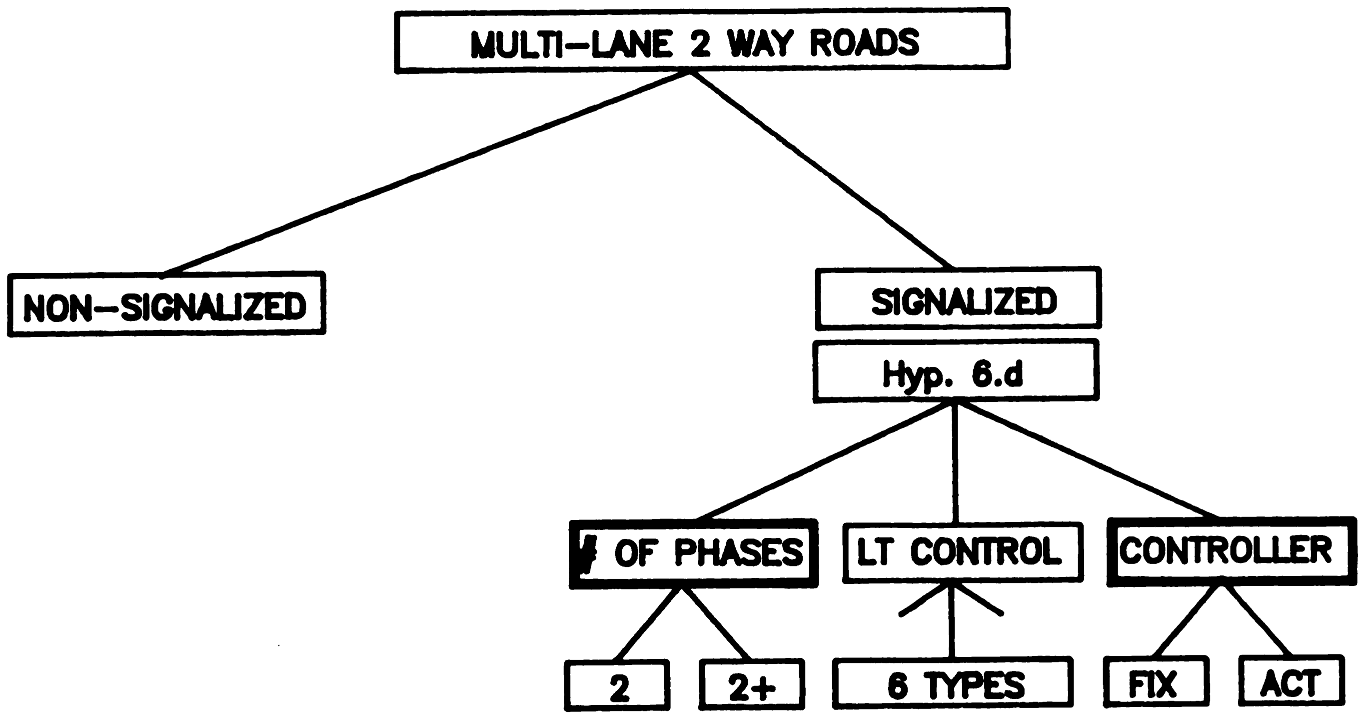

Figure 7.18. Results of testing hypothesis 6.d for middle-old drivers

signals and for fixed time signals. The tests for the middle-old showed different patterns of violations between the middle-old and middle-aged for both the 2 and the more than 2 phase signals and fixed time signals. For all these conditions the major contributor was the violation of failing to yield the right of way attributed to middle-old drivers.

In the tests for the accident types the young-old and old-old drivers indicated differences between accidents at intersections with 2 phase and more than 2 phase signals, with greater contributions from head-on accidents at intersections with more than 2 phase signals for the young-old and head-on while turning left and rear end accidents for the old-old.

For accidents at intersections either with 2 or more than 2 phase signals or fixed time signals all three groups showed differences compared to middle-aged, with the major contributor attributed to the elderly for all tests. For the 2 phase signals for the young-old the greatest contributor was head-on accidents, for the middle-old it was rear end accidents, and for the old-old they were head-on while turning left and rear end accidents. For the more than 2 phase signals the young-old had as its greatest contributor head-on accidents, while the middle-old had angle accidents, and the old-old had rear end accidents. For the fixed time signals for the young-old the major contributor was rear end accidents, for the middle-old it was head-on accidents, and for the old-old it was rear end and head-on while turning left accidents.

The violation types follow a consistent pattern when tested for the various aspects of signals. In almost all cases, elderly drivers seem to face problems associated with committing violations such as following too close and failing to yield the right of way which lead to the occurrence of corresponding accident types, such as head-on and rear end. Most of their problems are associated with multi-phase signals and for this hypothesis the size of the lens did not produce any different effects in either the accident or violation pattern. The results of these tests indicate that elderly drivers have problems with turning maneuvers and properly estimating gaps in complex traffic situations such as multi-phase signals on multi-lane two way roads.

7.2.22. Hypothesis 7.a

There is no difference between the pattern of accidents at non-signalized intersections on one way roads compared to two way roads.

This hypothesis was not rejected for any of the three groups of elderly drivers indicating that there is no difference in the accident patterns between non-signalized intersections on two way and one way roads (Figure 7.19).

The tests for exposure resulted in the acceptance of all hypotheses except for the one testing young-old and middle-aged drivers on two way roads. The results indicated a lower exposure rate of elderly drivers on one way roads.

The results from the violation and accident types indicated a tendency of elderly drivers to not properly handle the left turn movements on two way roads and lane placement on one way roads by causing accidents associated with these types of movement and

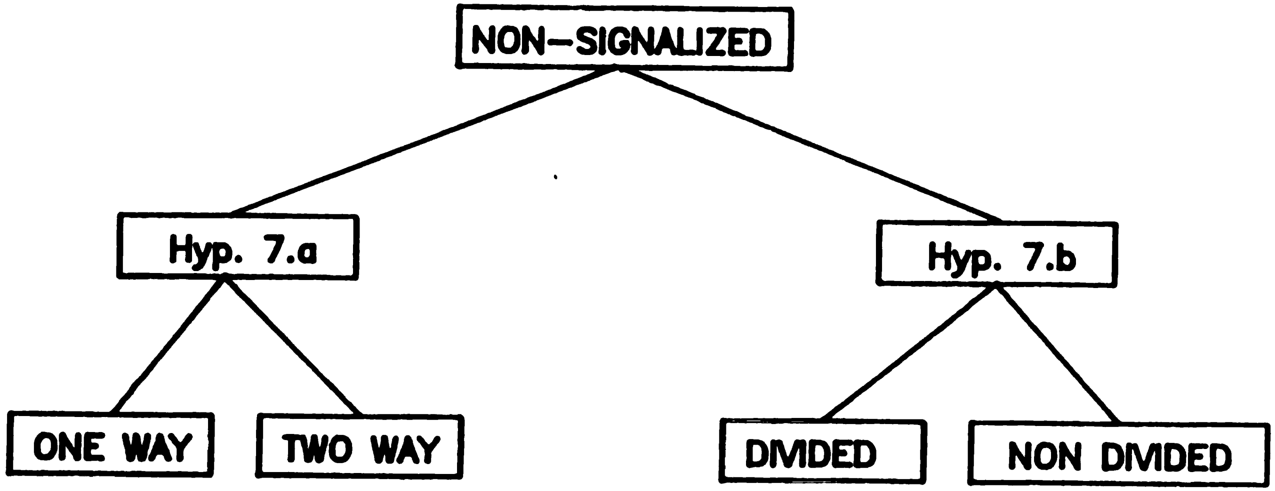

Figure 7.19. Results of testing hypotheses 7.a and 7.b for all elderly drivers

committing violations relevant to these accident types.

7.2.23. Hypothesis 7.b

There is no difference between the pattern of accidents at non-signalized intersections on divided roads compared to non-divided roads.

This hypothesis was not rejected for any of the three groups of elderly drivers indicating that there is no difference in the accident patterns between non-signalized intersections on divided and non-divided roads (Figure 7.19).

The tests for exposure resulted in the acceptance of all hypotheses except for the one testing young-old and middle-aged drivers on non-divided roads. The results indicated a lower exposure rate of elderly drivers on non-divided roads.

7.2.24. Hypothesis 8

There is no difference in the pattern of accidents of elderly drivers between a non-signalized or a signalized or a flasher controlled intersection.

This hypothesis was rejected for all three groups of elderly drivers indicating that there is a difference among the type of controller used at intersections. The major contributor for the rejection of the hypothesis was accidents caused by elderly drivers at intersections with flashers (Figure 7.20).

The tests for the exposure indicated a similar rate for all elderly groups at any type of intersection control.

The tests for the violation types led to the rejection of the null hypothesis. No specific violation was considered as a major contributor since the chi-square values were large for all violations. It has to be noted though, that the violation types attributed to flashers had the highest values compared to the other two control types. If one violation had to be accounted as the greatest contributor that would be failing to yield the right of way at non-signalized intersections or flasher controlled intersections.

For the accident types, the tests between elderly and middle-aged drivers indicated that there is a difference between these two groups for any type of intersection control. The major contributors were head-on and rear end accidents for all three types of control and the rejection of the hypothesis was attributed to the elderly drivers. The tests for the elderly drivers for testing the existence or absence of differences among the types of control rejected the null hypothesis indicating that a difference in the accident pattern exists. The major contributors to this rejection were right angle accidents at flasher controlled intersections and head-on while turning left accidents at signalized and non-signalized intersections. This pattern was observed for all three groups of elderly drivers.

The results from this hypothesis did not indicate the best or worst type of intersection control in order to eliminate or decrease the problems that the elderly drivers face. The hypotheses tested previously did not indicate significant differences between signalized

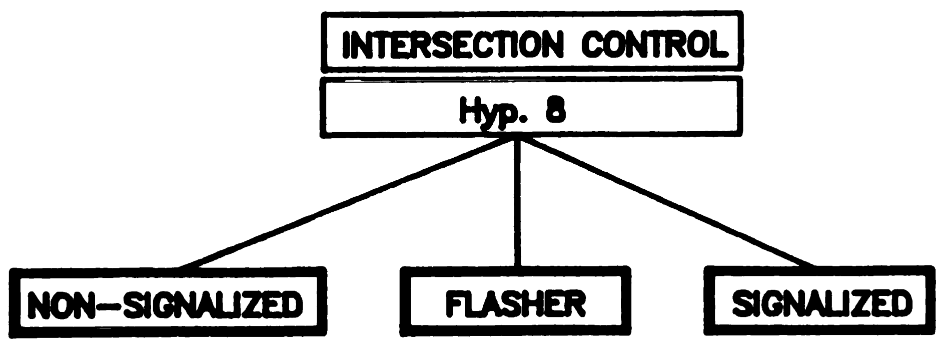

Figure 7.20. Results of testing hypothesis 8 for all elderly drivers

and non-signalized intersections sufficient to warrant a meaningful conclusion regarding the impact of the presence or absence of signal control.

The hypotheses and their results are summarized in Table 7.1 for each of the three groups of elderly drivers.

Table 7.1. Summary of the results for the tests of hypotheses

No	Hypothesis Description	Elderly Age Group Young	Middle	Old
1	Signalized = Non-signalized for females under snowy weather conditions	A	A	R
1.a	Snowy weather = Other weather conditions for females at non-signalized intersections	R	R	R
1.b	Females under snowy weather conditions at signalized intersections no difference in			
	1. Number of phases	A	I	R
	2. Control type	A	I	A
	3. Left turn controller	A	I	A
2	Signalized = Non-signalized for females at night	A	A	A
2.a	Night = Day for females at non-signalized intersections	R	R	R
2.b	For females at night at signalized intersections no difference in			
	1. Number of phases	A	A	A
	2. Control type	A	A	A
	3. Left turn controller	A	A	A
3.a	For males at signalized intersections no difference in			
	1. Number of phases	A	R	A
	2. Control type	A	A	A
	3. Left turn controller	A	R	A
3.b	For females at signalized intersections no difference in			
	1. Number of phases	A	A	R
	2. Control type	A	A	A
	3. Left turn controller	A	A	A
4	Signalized = Non-signalized for females on multi-lane two way roads	A	R	A
4.a	Multi-lane two way roads = Other roads at non-signalized intersections for females	R	A	A

Table 7.1. (cont'd)

No	Hypothesis Description	Elderly Age Group Young	Middle	Old
4.b	For females on multi-lane two way roads at signalized intersections no difference in			
	1. Number of phases	A	A	R
	2. Control type	A	A	A
	3. Left turn controller	A	A	A
5.a	Night - Day for rural non-signalized intersections	R	R	R
5.b	For rural signalized intersections at night no difference in			
	1. Number of phases	I	I	I
	2. Control type	I	I	I
	3. Left turn controller	I	I	I
5.c	Snowy weather - Other weather conditions for rural non-signalized intersections	A	R	R
5.d	For rural signalized intersections under snowy weather conditions no difference in			
	1. Number of phases	A	I	I
	2. Control type	A	I	I
	3. Left turn controller	A	I	I
5.e	For rural signalized intersections at night and under snowy weather conditions no difference in			
	1. Number of phases	I	I	I
	2. Control type	I	I	I
	3. Left turn controller	I	I	I
5.f	Rural non-signalized intersections at night and under snowy weather are the same as			
	1. Snowy weather and day conditions	R	A	A
	2. Day conditions	R	R	R
	3. Other weather conditions	R	R	R
6.a	Signalized - Non-signalized on multi-lane two way roads at night	A	A	A
6.b	Multi-lane two way roads - two lane roads at night at non-signalized intersections	A	A	A

Table 7.1. (cont'd)

No	Hypothesis Description	Elderly Age Group Young	Middle	Old
6.c	For multi-lane two way signalized intersections at night no difference in			
	1. Number of phases	A	A	A
	2. Control type	A	A	A
	3. Left turn controller	A	A	A
6.d	For multi-lane two way signalized intersections no difference in			
	1. Number of phases	R	R	R
	2. Control type	A	A	A
	3. Left turn controller	A	R	A
7.a	One way roads - Two way roads at non-signalized intersections	A	A	A
7.b	Divided roads - Non-divided roads at non-signalized intersections	A	A	A
8	Signalized - Non-signalized - Flasher controlled intersections	R	R	R

Legend A: Accept null hypothesis
R: Reject null hypothesis
I: Insufficient data to test null hypothesis

8. SUMMARY AND CONCLUSIONS

8.1. Introduction

The literature review indicated that aging impairs mental and physical factors that are required for safe driving. Several deficiencies in visual acuity are associated with age. Sensory functions also experience a deterioration with age. The decision for an action and the reaction time to a stimulus are affected by age as well. This study supported these findings, as it was determined that elderly drivers most often commit violations associated with mental and physical limitations of their aging process.

8.2. Conclusions from the Analyses

8.2.1. Ratio Analysis

First the data was analyzed using the relative accident involvement ratio of each age group of drivers to determine the relationships between the driver's age and the characteristics of the accident. The one way analysis of data was used to determine the first level interactions between the driver's age and accident characteristics. The two way analysis was then used to determine the combined effect of two variables.

The one way analysis indicated that elderly drivers experience more difficulties at intersection areas where these drivers have a higher relative accident involvement ratio than middle-aged drivers. For the total number of accidents young-old drivers showed a ratio of 1.01, middle-old a ratio of 1.32, and old-old a ratio of 1.89, while middle-aged drivers showed a ratio of 0.86.

The same analysis also indicated that female elderly drivers have a higher ratio than the average elderly driver. Female drivers showed a ratio of 1.12 for young-old, 1.65 for middle-old, and 2.22 for old-old, while the average middle-aged female driver showed a ratio of 0.85 retaining the same involvement ratio as the average middle-aged driver.

For accidents involving a turning maneuver elderly drivers showed an increased ratio from the average driver. For head on accidents while turning left young-old drivers showed a ratio of 1.43, middle-old had a ratio of 1.65 and old-old a ratio of 2.75, while middle-aged drivers retain the same ratio of 0.85. Similarly, for angle accidents while turning, young-old had a ratio of 1.10, middle-old a ratio of 1.65, and old-old a ratio of 2.30, while middle-aged drivers had a ratio of 0.82.

The two way classification of the data indicated that female drivers tend to have a higher ratio when compared to both the average driver and their male counterparts for almost all variables that were analyzed. For example, old-old female drivers (for accidents occurring at night) experienced an involvement ratio of 2.67, while the ratio for the old-old average driver at night was 2.06 and for old-old male drivers it was 1.95. Similarly, old-old female drivers showed a 2.14 ratio for accidents occurring under snowy weather with the average old-old driver having a ratio of 1.49 and the male old-old drivers having a

1.28 ratio.

The data indicated that elderly drivers, particularly middle-old and old-old, almost universally have a ratio higher than that of the average driver for head on accidents while turning left and in general for accidents where a turning movement was involved or intended. This may be attributed to their failure to either yield the right of way or to correctly estimate the available gaps and the speed of oncoming traffic. For example, old-old drivers at night had a 4.06 ratio for rear end while turning left accidents, for head on while turning left accidents a 3.66 ratio, and a ratio of 3.61 for angle while turning accidents.

8.2.2. Hypotheses Testing

Based on these results hypotheses were formulated that tested the data and examined the relationship between the driver's age and the intersection traffic control under various conditions.

The hypotheses tested can be grouped into three groups: 1) testing for differences between accident patterns at signalized and non-signalized intersections for a given set of conditions (principal hypothesis), 2) testing for differences between this set of conditions and its counterpart for non-signalized intersection accidents, and 3) testing for differences among the signal characteristics at signalized intersection accidents (secondary hypotheses). The tests for the majority of the hypotheses tested led to accepting them, or more accurately to not rejecting them.

8.2.2.1. Principal Hypotheses

The results from the principal hypotheses indicated that, in general, elderly drivers do not exhibit different accident patterns between signalized and non-signalized intersections under the conditions tested. In a few cases a difference was detected. These cases include elderly female drivers at signalized intersections under snowy weather conditions and middle-old female drivers at non-signalized intersections on multi-lane two way roads. On the other hand, elderly drivers did not seem to experience any differences between signalized and non-signalized intersection accident patterns for cases such as elderly female drivers during night and elderly drivers at night on multi-lane two way roads.

The tests for the effect of the intersection control type were inconclusive. The tests indicated that the only difference based on the type of control, was an increased involvement of elderly drivers at intersections with flashers. These tests did not indicate significant differences between signalized and non-signalized intersections.

The tests for the exposure rates indicated no different patterns for almost all conditions tested. These results tend to verify the basic assumption of this research that the innocent victim (Driver 2) is a random choice from the driving population and for either group of drivers (elderly or middle-aged) the age distribution of the innocent victim involved in the accident is the same. Only a few exceptions were noted, including at night where all elderly drivers showed a reduced involvement and between night and day for female elderly drivers indicating a lower exposure at night.

A consistent pattern was detected from the tests for the violation types. These tests indicated that when the comparison between elderly and middle-aged drivers led to the rejection of the hypothesis the elderly were the ones with the violation types that contributed the most to this rejection. In almost every case the predominant violation types were failing to yield the right of way, following too close, and improper turn. Also, to a lesser degree, the violation of improper lane use was noted for specific road types (one way and divided roads). These violation types indicate that the elderly face a significant problem involving judgement of available gaps and proper reaction to traffic conditions. Even though each one of these violations can be associated with one of the specific problems mentioned above, none of them could be considered the sole cause for these problems. For example, the violation of following too close could be attributed either to a failure to properly react to the existing condition, whereas a younger driver would have reacted properly within the same distance, or to a failure to judge the available distance (gap) and consequently to have reduced time available for reaction. Since no particular clarifications exist in the records, no further conclusions were drawn that would establish a relationship between the violation types and their possible causes.

The results from the tests for the accident types followed a pattern similar to that of the violation types. That is, accident types and violation types indicating similar deficiencies were noted for the elderly. The leading types of accidents were head-on while turning left, right angle, and rear end accidents indicating a reduced ability on the part of elderly drivers to handle turning maneuvers properly and to react to traffic conditions. A direct relation between accident and violation types was detected, but it was expected since the violation type recorded is the one that the investigating officer believed contributed most to the occurrence of the accident.

For all hypotheses where the violation and accident patterns were tested between signalized and non-signalized intersections no difference was detected for any of the three groups of elderly drivers. This indicates that the presence or absence of the signal does not have any different effect (by age) on accident and violation patterns.

8.2.2.2. Secondary Hypotheses

In the second set of hypotheses, tests were performed first between the main condition tested in the principal hypothesis and its counterpart for accidents at non-signalized intersections; and second, among the various characteristics of the traffic signal for accidents at signalized intersections.

8.2.2.2.1. Non-Signalized Intersections

For most of the tests for accidents at non-signalized intersections it was concluded that elderly drivers experience additional problems under the condition tested. These tests indicated that elderly female drivers experience a greater problem for snowy weather conditions than any other weather conditions; elderly female drivers experience a greater problem during night than at day; and elderly drivers face more problems dealing with driving at night in snowy weather conditions than either other weather conditions or during the day at rural intersections. Finally, the only case where the counterpart condition was the cause for the rejection of the hypothesis was noted for young-old female drivers on one way roads when compared to multi-lane two way roads.

The tests for the exposure rates indicated no different patterns for all conditions tested verifying that Driver 2 is a random sample of the driving population.

The tests for the violation and accident patterns indicated that the tested conditions indeed make a difference. The major contributors were similar to the ones noted for the tests between elderly and middle-aged drivers. The cases where differences were detected were for the test between snowy and other weather conditions for female drivers; between multi-lane two way and other roads (with one way roads being the major contributing type); between two way and one way roads (with one way again being the major contributor); and between divided and non-divided roads (with divided ones having contributed the most).

8.2.2.2.2. Signalized Intersections

The tests for the signalized intersections indicated that elderly drivers experience significantly more problems at signalized intersections with multi-phase (more than 2) signals, while the other characteristics of the signals did not seem to have any effect on the elderly. The problems that elderly drivers face at signalized intersections with multi-phase signals were detected for middle-old male drivers, old-old female drivers, old-old female drivers under snowy weather, old-old female drivers on multi-lane two way roads, and elderly drivers on multi-lane two way roads. The cases where no differences were detected for any of the traffic signal characteristics were for elderly female drivers at night and elderly drivers on multi-lane two way roads at night.

The exposure tests indicated no different patterns for all conditions tested. The tests for the violation and accident types showed that in almost all cases elderly drivers experience problems at intersections with multi-phase signals. For these types of signals the violation and accident pattern trends were noted to be the same as those in the principal hypotheses. The results of these tests indicate that the problems elderly drivers experience at multi-phase signals include violations such as following too close and failing to yield the right of way, and to corresponding accident types, such as head-on and rear end. These tests indicate that elderly drivers have problems with turning maneuvers in complex traffic situations and fail to react properly and timely in the existing traffic conditions. The results were more notable when the conditions became more complex such as a combination of multi-lane two way roads and multi-phase traffic signals.

8.2.3. Summary of Results

Overall, the tests indicated no significant differences in the accident patterns between accidents at signalized and non-signalized intersections. Differences were detected first among the various conditions at non-signalized intersections and second among the signal characteristics. The tests for exposure rates indicated no different patterns between the various conditions tested verifying the basic assumption of the innocent victim. The tests for the violation type showed an increased involvement of the elderly in violations such as following too close, failing to yield the right of way, and improper turning; all of which indicate a failure to properly identify the available gaps and to properly react to traffic conditions. These types of violations led to corresponding types of accidents, such as head-on while turning left, rear end, and right angle. The problems that elderly drivers face are increased when the traffic conditions become complex (multi-lane roads and multi-phase signals) indicating a possible reduced ability to handle and process information at a fast pace. Finally, elderly drivers are experiencing a significant problem dealing with multi-phase signals where the predominant accident types involve turning movements and in particular left turns. All these observations tend to support the hypotheses that elderly drivers experience a reduced ability to appropriately handle traffic situations due to a reduction in the basic skills required for safe driving.

8.3. Summary of Findings

This research identified the relationship of accident rates of elderly drivers at intersection areas with respect to road conditions and traffic control. It was found that elderly female drivers have higher involvement rates than their male counterparts. The data indicated that elderly drivers are more susceptible to head-on while turning left, angle and rear-end accidents than middle-aged drivers supporting the belief that deficiencies related to visual deterioration contribute to these accidents. It was also found that elderly drivers have a greater chance of being cited for a violation in an accident and the most common violations are for failure to yield the right-of-way, improper lane use, and improper turns.

The results indicate that the presence or absence of a traffic signal did not affect the accident involvement of elderly drivers. The only exception being that snowy weather conditions increase the probability of elderly female drivers being involved in an accident at both signalized and non-signalized intersection areas. For accidents occurring at non-signalized intersection areas elderly female drivers showed an increased involvement for snowy weather conditions and for night conditions. The increased involvement under these conditions may be attributed to vision and a slowed reaction time due to the aging process. Similarly, for accidents occurring at signalized intersection areas, elderly drivers showed a considerably higher involvement at intersections controlled by multi-phase traffic signals.

The findings also indicated that elderly drivers experience additional problems in complex traffic situations and fail to react properly and timely to existing traffic conditions. The results were more notable when the conditions became more complex such as a combination of multi-lane two way roads and multi-phase traffic signals.

Since no specific conditions and factors were identified as contributing to the increased accident involvement of elderly drivers, no specific countermeasures could be suggested based on this research, the best alternatives may include modifications in the licensing techniques and implementation of driver education and training programs. Both proposed actions should concentrate on the development of a program to evaluate the driving performance of the elderly driver and attempt to educate them by indicating the potential problems they may face due to their aging process. The programs should help them comprehend their deficiencies and indicate possible techniques for reducing their risk levels.

9. RECOMMENDATIONS

9.1. Introduction

The results from the data analysis in the preceding chapter indicated that elderly drivers are overinvolved in accidents under certain conditions. Based on these findings this chapter will present potential driver related measures for alleviating the problems that elderly drivers may encounter during their driving. Reference will also be made to future research needs.

9.2. Recommendations

A variety of countermeasures for increasing the safety of elderly drivers exist and should be considered. Such measures include licensing procedures, driver education and training, highway design, and traffic control.

This study did not produce results that justify changes in highway design or the implementation of guidelines for traffic control device implementation. This study did document the fact that elderly drivers experience difficulty as the complexity of the design and traffic control device application increases. This indicates that the major contribution to safety may come from measures that affect the driver, such as training and licensing. However, based on the findings of the literature review and the indications obtained from the data analysis, some recommendations regarding highway design and traffic control implementation have been included.

The recommendations that follow can be categorized in two groups; 1.those based on the results of this study, including the need for regulation in the licensing of elderly drivers and the development of training programs which can indicate potential problems to elderly drivers, and 2.those based on the findings of the literature review and the indications from the data analysis. The first group of recommendations include countermeasures that are specifically directed at the problems of elderly drivers and are designed to assist the elderly drivers alleviate hazardous driving characteristics associated with the aging process. The second group will present general considerations regarding the safety of elderly drivers and will indicate potential areas for further research.

9.2.1. Licensing Techniques

The increase in the use of the automobile has made the life of today's population more automobile dependant. Any attempt to restrict one's driving privileges could be considered as an infringement of their rights. Elderly drivers are not different in that aspect than any other age group of drivers. Suggestions of restricting the driving privileges of elderly people have met sharp criticism, since not all elderly drivers experience the same rate of deterioration in their driving abilities. Therefore, a specific age limit is considered to be unfair. Removal of a driver's license is considered to be a very harsh measure, particularly for those drivers who have not committed traffic violations or been involved in accidents.

A reasonable technique for licensing is a continuous examination of elderly drivers after a certain age. This study indicated that a reasonable lower limit for the elderly driver is the age of 60. From this age on the accident involvement is higher than the average and therefore, this age could be considered the cutoff point for increasing the frequency of examinations.

For most states a drivers license is renewed every 4 to 5 years. For the state of Michigan the renewal period is every 4 years and no special policies exist regarding the frequency of license renewal for elderly drivers. Also drivers have the option, based on their driving records, to renew their licenses by mail every other time. It has been suggested by others [50] that for elderly drivers the renewal period should be reduced to 2 years. This way the aging related deficiencies that occur along a continuum can be detected more accurately and corrective actions can be taken to increase the safety of elderly drivers. The shorter time period for license renewal could result in a more accurate evaluation of the capabilities of each elderly driver.

Greater effort should be made to inform elderly drivers of their limitations and introduce them gradually to a driving reduction program. This procedure will result in a less painful way of removing elderly drivers from the highway system while it will allow them to continue driving for as long as they can do so safely.

Licensing agencies need to examine the methods and procedures used to evaluate the capabilities of elderly drivers to operate safely on the highways. The effects of the aging process on driving skills should be recognized and used in the design of testing and licensing programs. Greater emphasis should be given to issuing restrictions on licenses to drivers who demonstrate physical or performance characteristics which may contribute to highway accidents. Since the availability of results from licensing procedures is so limited every program implemented should be studied very closely and its results should be evaluated carefully.

9.2.2. Driver Education and Training

It has been demonstrated that elderly drivers face physical and mental problems that can influence their driving ability and traffic safety. The role of a training and education program is to allow the elderly drivers to identify their limitations and help them to overcome those problems that may lead to highway accidents.

An educational program can help elderly drivers in two major areas. It is possible that one source of the problems that elderly drivers face today may be related to their unfamiliarity with changes in the highway system. Older drivers tend to have less current information with respect to new developments in traffic regulations and safe driving principles [25]. Their unfamiliarity is demonstrated by the fact that a number of elderly come to a complete stop before entering a freeway at the end of the acceleration lane [3]. Therefore, an educational program could help elderly drivers become accustomed to the roadway system.

Second, such a program could help elderly drivers understand their deficiencies and limitations and then provide alternatives or measures for compensation. Usually, elderly drivers are aware of the fact that the ageing process has contributed to certain physical and mental limitations that they experience, but they are not fully aware of the extent of these limitations on their driving skills and traffic safety. This could be alleviated with an educational program to identify these problems and present them to the elderly society.

Such programs should be able to identify the conditions and factors which contribute to increased involvement in accidents and to provide alternatives and suggestions. Educational and training programs have been developed at a national level by the American Association of Retired Persons (AARP) and the American Automobile Association (AAA). The AARP program provides overall information on the conditions and situations in which elderly drivers are at risk. The same program includes a testing technique which allows elderly drivers to self-evaluate their driving knowledge and skills and provides a training program for driving skills improvement. The AAA program includes an education program, training and testing sessions with behind the wheel performance, and self-assessment of the performance of the drivers both in awareness and in making critical decisions related to driving.

Based on the findings of this research such a program should focus on a two level presentation. First, the physical and mental problems should be explained and then the performance problems associated with them should be outlined.

The physical problems associated with the driving performance of the elderly could be grouped in sensory, perceptual, and motor functions. Even though it is not possible to correct sensory problems through a training program, assistance in understanding their nature and recognizing their effects should be the objectives of the training. In addition to indicating these problems, certain driving techniques may be taught to compensate for the presence of these problems. Such alternative techniques may include avoiding traffic that requires heavy visual scanning, avoiding driving under low illumination, and increasing their scanning patterns.

For the perceptual problems, the training program should have as an objective helping elderly to understand and identify these problems. Again, compensation is the best alternative to solve potential perceptual problems. Such alternatives include avoiding traffic that requires heavy perceptual load, having some help during driving to share some of the perceptual load created by navigation in unfamiliar areas, and use of alternative routing with the least possible mental load.

Finally, the problems associated with motor functions could be considered as the combined effect of sensory and perceptual functions. Motor functions include reaction time and motor skills. Based on the results from this study it was shown that the elderly have problems handling left turns and maintaining a safe distance between vehicles. Practices like these could be altered through the help of training by indicating these problems and correcting them using the alternative techniques suggested for the other problems.

The next step in the training program should include a presentation of the problems associated with the driving performance of the elderly drivers. Based on the results of this study elderly drivers experience problems with misjudgement of distances between vehicles, failure to yield the right of way to the oncoming traffic, improper handling of turning maneuvers, and improper lane changing. It is believed that most of these problems do not stem from a willful intention of the elderly but from a failure to observe the surrounding traffic. These violations of the traffic rules may be attributed to the aging effects on vision, inattention, information processing, and stimuli reaction. These data should be explained to elderly drivers to indicate the associated problems. The types of accidents in which elderly drivers have a higher involvement rate include head on while turning left and right angle accidents. Both types of accidents involve misjudgement of the available distance between vehicles and indicate possible limitations of the visual acuity of the elderly.

In addition to education regarding the problems that elderly drivers face, the training programs should also include information regarding the impact of drugs and alcohol on driving performance, encourage the use of seat belts, promote physical fitness and frequent vision testing, and encourage the elderly to practice their driving skills.

9.2.3. Other Alternatives

In addition to the countermeasures suggested in the preceding, some general considerations regarding the safety of elderly drivers include traffic control techniques and highway design.

Even though this study did not indicate significant differences in the accident involvement of elderly drivers between signalized and non-signalized intersections it is believed that some emphasis should be given to traffic control techniques for providing the most efficient and safe vehicular movement. The placement, design, and illumination of traffic signs and the installation and phasing of traffic signals are of great importance for creating a safe driving environment. A relationship between early and correct detection of traffic signs and signals is very important for practicing safe driving for all drivers and especially for elderly drivers.

It is believed that clear, unambiguous, coherent, and uniform traffic signs should be implemented to eliminate confusion in elderly drivers. The height of the letters in traffic signs should accomodate the needs of elderly drivers with vision deficiencies. Signs must be placed at locations that provide the driver with sufficient distances for proper recognition and response. The slower reaction time and diminished visual abilities of elderly drivers should be considered when the placement and design of traffic signs is undertaken.

This study did not indicate any specific problems that elderly face regarding the characteristics of traffic signals. Placement, illuminance and lens size, and phasing are some characteristics that have to be reviewed in the context of the elderly driver. The placement of traffic signals must consider the needs of different types of vehicles and drivers while increases in the illumination level would have a direct effect on drivers with diminished visual acuity.

Highway design measures generally refer to longer term improvements of the highway system. These improvements are usually made to increase the quality and safety of the highway system and usually provide improvements for all drivers. However, certain highway design improvements may be more beneficial to elderly drivers. Such improvements could include designs which separate driver decision points so as to avoid complex geometry and a series of simultaneous or closely spaced decision points.

9.3. Summary

The alternative methods suggested here include modifications of the licensing procedures, implementation of a drivers training program, and improvements in traffic control devices and highway standards.

The licensing techniques should concentrate on the development of additional vision and knowledge tests to provide a better understanding of the capabilities of elderly drivers. The use of these tests will allow the licensing agency to enforce restrictions if needed. A more frequent testing pattern should be implemented from age 60, since certain changes occur along a continuum due to the aging process.

The training programs should attempt to educate the elderly drivers by assisting them to understand the potential problems of their aging process, by helping them to comprehend their deficiencies, and by aiding them to identify possible alternative solutions and techniques for reducing their risk levels. Such techniques should include avoiding heavy traffic, avoiding driving at night if possible, and changing their visual scanning patterns.

Based on the findings of this study further research should be undertaken to identify and evaluate countermeasures to improve the overall highway safety of elderly drivers. This research identified circumstances in which elderly drivers experience a higher accident involvement rate than middle-aged drivers and examined the factors which appear to contribute to this increased involvement. Additional research which will identify and evaluate specific safety improvements to be used to counter the effects of the aging process is needed.

The purpose of this study was to identify the factors affecting the accident involvement of elderly drivers at intersection areas in relation to their traffic control. It is believed that the countermeasures proposed will minimize the influence of these factors on the elderly driver. It is expected that, by identifying these conditions and factors affecting the elderly and instituting the appropriate countermeasures, a reduction should be expected in the frequency of accidents and an increase in safety levels.

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