Strategies for Improving the Safety of Elderly Drivers

First Year Report of a Two-Year Study

Researchers

Patrick T. McCoy, Principal Investigator
Department of Civil Engineering
University of Nebraska-Lincoln

Richard D. Ashman, Associate Professor
Nebraska Safety Center
Kearney State College

Betty G. Foster, Assistant Professor
Section of Geriatrics and Gerontology
University of Nebraska Medical Center

Research Assistants

Shiuh Y. Lee
Timothy A. McCoy
Yih F. Pooh
Mohammed S. Tarawneh
Department of Civil Engineering
University of Nebraska-Lincoln

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STRATEGIES FOR IMPROVING THE SAFETY OF ELDERLY DRIVERS

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MIDWEST
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Commissioned by the
Midwest Transportation Center
A Consortium of Iowa State University
and The University of Iowa

Director
Tom Maze, Ph.D.
Manager, Iowa Transportation Center
Associate Professor of Civil and
Construction Engineering
Iowa State University

Associate Director
David J. Forkenbrock, Ph.D.
Director, Public Policy Center
Professor of Urban and Regional
Planning and of
Civil and Environmental Engineering
The University of Iowa

Advisory Committee

Barbara J. Dunn, Former Executive Director, Public Transit Association

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Larry Miller, President, Ruan Transportation Management Systems

Darrel Rensink, Director, Iowa Department of Transportation

Lee O. Waddleton, Federal Region VII Area Director, Urban Mass Transit Administration

W348 Nebraska Hall
Univesity of Nebraska-Lincoln
Lincoln, Nebraska 68588-0531
Phone: (402) 472-5019
Fax: (402) 472-2410

PREFACE

This report is the product of a research project in the University Transportation Centers Program. The Program was created by Congress in 1987 to "contribute to the solution of important regional and national transportation problems." A university-based center was established in each of the ten federal regions following a national competition in 1988. Each center has a unique theme and research purpose, although all are interdisciplinary and also have education missions.

The Midwest Transportation Center, one of the ten centers, is a consortium that includes Iowa State University (lead institution) and the University of Iowa. The Center serves Federal Region VII which includes Iowa, Kansas, Missouri, and Nebraska. Its theme is "transportation actions and strategies in a region undergoing major social and economic transition." Research projects conducted through the Center bring together the collective talents of faculty, staff, and students within the region to address issues related to this important theme.

The research presented in this report reflects the key mission of the Midwest Transportation Center by examining ways to improve the safety of elderly drivers in the region. The research was conducted by an interdisciplinary team of researchers in driver education, gerontology, and highway/traffic engineering from the Kearney State College, the University of Nebraska Medical Center, and the University of Nebraska-Lincoln.

Patrick T. McCoy, Professor of Civil Engineering at the University of Nebraska-Lincoln, served as Principal Investigator for this project. Richard D. Ashman, Associate Professor of Driver Education at Kearney State College, and Betty G. Foster, Assistant Professor of Gerontology at the University of Nebraska Medical Center were co-investigators. They were assisted by Shiuh Y. Lee, Timothy A. McCoy, Yih F. Pooh, and Mohammed S. Tarawneh, graduate research assistants in civil engineering at the University of Nebraska-Lincoln.

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EXECUTIVE SUMMARY

INTRODUCTION

Two aspects of a major transition taking place in the Midwest Region are the growth in the number of elderly people and the loss of essential services in many smaller rural communities. The impact of these changes has been a substantial growth in the elderly driver population and an increased need for the elderly to drive in order to maintain their access to essen-tial services. Unfortunately, many elderly people have problems driving. Compared to younger drivers, they have lower driving skills, poorer vision, and more accidents per mile driven.

Determination of the causes of accidents involving older drivers and the implementation of preventive and ameliorative measures would make driving safer for older drivers as well as for others with whom they share the roadways. Improvements in the safety of older drivers would enable them to maintain their mobility and preserve their independence. However, the problems of older drivers and their solutions have several dimensions. The causes of the problems of older drivers are not only rooted in the physical and mental limitations of the elderly and their diminished driving skills and lack of driving knowledge, but they are also related to the failure of traffic control devices and roadway design to account for these limitations. Therefore, the solutions to the problems of older drivers not only involve improving physical and mental conditioning but also increasing driving knowledge and skills, and improvements in traffic-control devices and roadway design.

Objective and Scope of the Research

The research is a two-year, multidisciplinary study of the problems of elderly drivers, conducted by a team of researchers from the areas of driver education, gerontology, and highway/traffic engineering. The objective of the research is to develop and evaluate ways of improving the safety of elderly drivers. During the first year, the problems of elderly drivers were examined and ways to improve the safety of elderly drivers were determined. During the second year, the safety improvement strategies that were identified as potentially the most cost-effective will be demonstrated so that their actual cost effectiveness can be evaluated. The results of the second year will provide state highway transportation agencies with information that can be used to implement safety improvement programs which effectively integrate driver education, physical and perceptual therapies, and engineering countermeasures.

Research Approach

The examination of the problems of elderly drivers involved the following components: (1) an analysis of accident data to identify the accident situations in which elderly drivers are over-involved, (2) an evaluation of the driving knowledge of elderly drivers to identify deficiencies in their driver education, especially with respect to the accident situations in which they are over-involved, and (3) an assessment of the physical, perceptual, and cognitive abilities of the elderly to determine their relationship to driving performance and the accident situations in which elderly drivers are over-involved. Based on the findings of these analyses, ways to improve the safety of elderly drivers were determined. The safety improvement countermeasures developed included: (1) driver training designed to address the problems of older drivers, (2) therapies designed to improve the physical, cognitive, and perceptual abilities related to the problems of older drivers, and (3) highway design and traffic control improvements designed to address the accidents situations in which elderly drivers are over-involved. The countermeasures were evaluated relative to their potential for reducing elderly driver accidents, their potential impact on the mobility of elderly drivers, and the feasibility of their implementations. The feasible countermeasures with the greatest accident reduction potential and no likelihood of reducing the mobility of elderly drivers were selected for demonstration and evaluation in the second year.

This report, which is the first of two reports on this project, documents the procedures, findings, and conclusions of the research conducted during the first year; and presents the plan of work for the second year. The second report will present results of the second year of the project.

PROBLEMS OF ELDERLY DRIVERS

The problems of elderly drivers were defined in terms of the accident situations in which they are over-involved, the deficiencies in their knowledge of driving, and the deficits in their physical, perceptual, and cognitive abilities.

Accidents

The description of the over-involvement of elderly drivers in traffic accidents was based on a review of the literature pertinent to elderly driver accidents and on the results of an analysis of the traffic accidents that occurred in Nebraska during 1988.

There have been several studies on the safety of elderly drivers. The studies pertinent to the objective of this research were those concerned with the rates, patterns, and injury consequences of accidents involving elderly drivers. Accident studies have found that elderly drivers have more accidents per vehicle miles of travel than do middle-age drivers. Also, elderly drivers are most likely to be involved in multivehicle accidents at intersections, and they have higher percentages of their accidents in urban areas and during the daytime. Studies have consistently found that elderly drivers are over-involved in right-angle, left-turn, backing, and parking collisions. The contributing circumstances most commonly reported for accidents involving older drivers are failure to yield, ran traffic signal, illegal turn, improper lane usage, and driver inattention or confusion.

The 1988 accident level and vehicle/driver level files maintained by the Nebraska Department of Roads were analyzed to identify the accident situations in which elderly drivers were over-involved. The accident data were sorted according to driver age. The accident rates were calculated for young, middle-age, and older drivers to determine which age groups had higher accident rates. The distributions of accident characteristics for the age groups were compared to identify statistically significant differences in the accident patterns of the age groups.

The results of the accident data analysis are consistent with the findings of the literature review. In general, elderly drivers are over-involved in multivehicle accidents, accidents at intersections, and accidents in urban areas. Conversely, elderly drivers are under-involved in single-vehicle accidents, accidents at nonintersection locations, and accidents in rural areas. Compared to middle-age drivers, elderly drivers have significantly higher percentages of their accidents during daylight, between 9:00 am and 3:00 pm, on weekdays, in clear weather, on dry road surfaces, and on straight and level roadways. Significant higher percentages of the elderly drivers involved in accidents were females, residents of the local area, and driving four-door sedans.

Elderly drivers are over-involved in right-angle, left-turn, backing, and parking collisions.

With respect to the contributing circumstances of right-angle and left-turn collisions, elderly drivers are more likely than middle-age drivers to have accidents that involve failure to yield, ran stop sign, disregarded traffic signal, and made improper turn. Also, in these types of collisions, elderly drivers are more likely than middle-age drivers to be making a left turn.

The problems of elderly drivers are the most serious for drivers 75 and older. Among the older-driver age groups (55-to-64, 65-to-74, and 75-and-older), only the 75-and-older age group was over-involved in accidents and had an accident rate significantly higher than the accident rate of middle-age drivers (25-to-54). All three older-driver age groups had higher percentages of multivehicle accidents than the younger age groups. But, drivers 75 and older had the greatest likelihood of being involved in multivehicle accidents.

The review of the traffic and roadway conditions at high elderly-driver accident locations indicated that these locations were typically found at higher volume intersections that were controlled by either stop sign or traffic signals. The elderly drivers were usually at fault, especially in the case of right-angle and left-turn collisions. Failure to yield the right-of-way and disregarding traffic signals were the most common contributing circumstances in elderly-driver accidents at these locations.

Typically, the right-angle accidents involved elderly drivers who were attempting to cross more than two lanes of traffic with volumes above 600 vehicles per hour, which at stop-sign controlled approaches would usually require the elderly driver to wait for an acceptable gap. At traffic signals, the right-angle accident problem of elderly drivers seemed to be associated most often with signal displays competing with visual clutter for the attention of the drivers. This also seemed to be the problem in the case of the rearend collisions in which elderly drivers were at fault.

The left-turn accidents involving elderly drivers typically occurred on streets with speed limits below 45 mph, and at controlled intersections where the elderly drivers were attempting to turn left across two or more opposing lanes of through traffic. Often, the opposing through traffic volume was above 300 vph, which at intersections with stop-sign control, or permitted left-turn phases, required the elderly drivers to wait for an acceptable gap. At most of the high elderly-driver accident locations, the left-turns were made from left-turn lanes without protected left-turn phases. However, in many cases, the positioning of the left-turn lanes was such that the left-turn sight distance was obstructed when opposing left-turn vehicles were present. Also, at signalized intersections, the placement of the signal display often created a wide angle between the signal heads controlling the left turns and the opposing through traffic.

The review of backing and parking-related accident locations indicated that these types of collisions were more often found on streets with angle parking. Elderly drivers seemed to be under-involved in these types of accidents on streets with parallel parking. However, it was suspected that this occurred because elderly drivers tended to avoid using parallel parking stalls and preferred to use angle parking.

Driving Knowledge

In order to drive safely, drivers must know how to drive their vehicles under a variety of roadway and traffic conditions. In addition, they must know the rules of the road, the traffic laws and regulations, and the meanings of the traffic control devices. Therefore, the driving knowledge of elderly drivers was evaluated to identify any deficiencies that might contribute to their driving problems. The evaluation included a review of the literature pertinent to the subjects of the driving knowledge and education of elderly drivers. In addition, the scores of elderly drivers on the driving knowledge portion of the Nebraska driver's license examination were analyzed to identify the questions that were most frequently missed by elderly drivers. Finally, the driver manuals of the four states (Iowa, Kansas, Missouri, and Nebraska) in the Midwest region were reviewed relative to their coverage of information pertaining to the problems of elderly drivers.

Previous studies have determined that there is a need for driver education programs for elderly drivers. Three elderly driver education courses are being offered to meet this need. These courses were developed by the National Safety Council, the American Automobile Association, and the American Association of Retired Persons. However, research has yet to prove that such programs are effective in improving the performance of elderly drivers.

The analysis of the scores of older drivers on the driver-knowledge portion of the Nebraska driver's license examination indicated that their scores were lower as their age increased. The oldest drivers (75-and-older) had a lower average score than the 65-to-74 year old drivers, and drivers 65-to-74 had a lower average score than the 55-to-64 year old drivers. In fact, the average scores of all three older-driver age groups were below the 80 percent required to pass the test. In addition, the average scores of the 75-and-older drivers on the questions relating to right-angle and left-turn accidents were also below 80 percent. Thus, the scores on the driver knowledge test indicated the need for a driver education program for elderly drivers.

Overall, the state driver manuals were found to provide good coverage of the issues pertinent to the problems of elderly drivers. However, the manuals could be improved by the addition of a section dealing specifically with the problems of elderly drivers.

Abilities

Driving is a complex task that requires incorporating perceptual, cognitive, and motor skills into operating a vehicle under varying conditions. Perceptual input comes to the driver primarily through the sensory processes such as vision and hearing. The stimulus must be registered and then recognized at the cognitive level. Again at the cognitive level, the driver must decide how to respond to the stimulus. Physical and motor level skills are then used to carry out the task or maneuver.

Literature in the fields of medicine, allied health professions, and social science were reviewed to determine the abilities of the elderly relative to the driving task. In addition, patient records from the driver rehabilitation program at Immanuel Rehabilitation Center in Omaha, Nebraska were analyzed to determine the relationship between driving performance and a number of sensory, perceptual, and cognitive factors. Also, a survey of elderly drivers was conducted to determine their perceptions of their driving abilities. Finally, the components of perception-reaction time were examined and the effects of aging were assessed. Elderly-driver perception-reaction times were derived for the driving tasks associated with the right-angle and left-turn collisions in which elderly drivers were found to be over-involved.

Literature Review

Older drivers themselves as well as other observers have reported unsafe driving practices due to loss of one or more visual capabilities, but it has been difficult to determine which deficits among many tend to cause the most difficulty. Considerable research has been done on physiological changes that occur as people age yet very little of this information has been scientifically tested as it relates to the task of driving. In a search for a practical approach to the older driver there is current interest in investigation of a link between the physiological and the functional capacity of the individual as it relates to driving. There is increasing evidence that functional capabilities should be determined and that they may be the most important measure of a person's ability to drive safely. Also, considerable literature exists regarding reaction time in older persons and, almost without exception, reaction time has been found to slow with age. Not only are single motor responses slowed, but complex forms of behavior also are affected. Studies on reaction time among older subjects have found correlations between physical fitness and psycho-motor speed. Reaction time is fastest in highly fit individuals regardless of whether or not they are trained athletes. Regular exercise therapy has been studied to a limited degree with indications of improvement in cognitive performance and retrieval activity.

Before adequate countermeasures can be designed and tested, better models of driving performance need to be developed that incorporate not only physical capabilities but perceptual, sensory, and cognitive abilities as they relate to actual driving performance. Perhaps an effective countermeasure might be training drivers with physical impairments to adopt new and less risky habits. One modification that has been suggested is giving more thought to placing appropriate restrictions on select older drivers so they can gradually curtail their driving. Specific criteria need to be developed based on functional rather than chronological age, although there is considerable justification for using 75 years as a criterion to increase frequency of testing. However, there is little research on the relationship between physiological changes with age and specific driving tasks. A few standards have been set for muscle strength, range of motion and other musculoskeletal performances, yet studies have not linked detriments in these areas to actual driving performance. Again, the literature reinforces the tremendous variability among the older population, thus making generalizations nearly impossible and pointing out the need for individual assessments or more precise tests to select out persons who are at high risk for driving.

A considerable body of literature exists that suggests decline in cognitive functioning of aging individuals. The assessment of cognitive functioning, however, is extremely complex and far from enjoying general agreement among researchers. Cognitive functioning consists of the basic elements of intelligence, learning, and memory. There is concern about performance capabilities of older drivers, yet little research is available upon which to base these concerns or the compensatory actions one might take. There are many complex and poorly understood interactions between chronic and acute illnesses, medication effects, disease states such as cardiovascular, diabetes, and Alzheimer's Disease, to mention a few. All have the potential for explaining differences in driving abilities but few studies have addressed this problem.

Analysis of Immanuel Data

The performances of older drivers were assessed using sixteen sensory, perceptual, and cognitive factors as predictor variables. A discriminant analysis technique was used to classify drivers based on their driving performance into two groups, "satisfactory" and "unsatisfactory." The results of on-the-road driving tests were the criteria used in the development of the discriminant functions. Data for 117 impaired, older drivers, 55 to 88 years old, were obtained from the Immanuel Rehabilitation Center, and used to develop the discriminant functions.

The derived functions were significant and showed a classification accuracy much higher than that achieved by chance alone. From the variables included in the discriminant models, it seems that the therapies, or compensatory measures, should be implemented for improving the depth perception, peripheral vision, brake reaction time, figure ground perception, and visual discrimination perception of older drivers.

Older Driver Survey

A survey was conducted of the Immanuel Hospital's AgeWell members 75 and older. The purpose of the survey was to obtain some information about the characteristics of elderly drivers, their perception of the driving problems, and their ideas of ways to improve highway safety. A total of 770 names were on the list of Agewell members 75 and older, and 425 surveys were returned for a response of 55 percent.

About 75 percent of the respondents reported no difficulty in renewing their last license. Ninety-two percent reported receiving no traffic tickets, 86 percent indicated that they had not been involved in an accident within the last 2 years.

The respondents indicated that most common problems they had at traffic signals were: (1) turning right on red, (2) knowing the proper lane to be in, and (3) seeing the traffic signal. The most common problems at stop signs were: (1) having enough time to cross, (2) deciding when it is safe to cross, and (3) seeing traffic on the cross street. In regard to making left turns at signalized intersections, the biggest problem was having their view blocked by vehicles turning left from the opposite direction. Other common problems turning left at traffic signals were: (1) knowing the proper lane to be in, (2) seeing when it is safe to turn, (3) knowing where to turn, and (4) knowing when to go.

Sixty-three percent of the respondents indicated that they had the most difficulty driving through intersections that were uncontrolled. Only 3 percent had the most difficulty at signalized intersections. Twenty-five percent indicated that they had the most difficulty at intersections with yield signs, and 9 percent had the most difficulty at stop signs.

The most frequently suggested ways to improve traffic safety at intersections were: (1) install traffic signal at intersections without one already, (2) install grade separation, (3) enforce, or lower, speed limit, (4) retime traffic signal, (5) widen intersection, (6) install protected left-turn phase, and (7) increase sight distance.

Nearly all of the elderly drivers (90 percent) described their vision (with glasses, if worn) as excellent or good. Fifteen percent reported cataracts, 4 percent reported glaucoma, and 10 percent considered themselves to have night blindness. Twenty-five percent reported they had trouble seeing street name signs until they were too close to do any good. The overwhelming majority had no problems with stiff or painful joints, or with controlling their cars. However, 12 percent reported they had trouble turning their head to look over their shoulder when backing up. They generally used their inside rear view mirror and driver side rear view mirror to compensate for this inability. Thirty-one percent reported they never or seldom used their passenger side rear view mirror.

Perception-Reaction Time

Highway and traffic engineering design criteria include driver perception-reaction times. Therefore, in order to assess the problems of elderly drivers with respect to highway design and traffic control, the components of driver perception-reaction time were examined and the effects of aging on driver perception-reaction time were assessed.

The perception-reaction times of elderly drivers are longer than those of younger drivers, because elderly drivers require more time for each of the components of perception-reaction time. The major increases in time are associated with the information processing components: fixation, recognition, and decision. Elderly drivers may have from 10 to 100 percent longer perception-reaction times, depending on the complexity of the driving task.

Stopping and gap acceptance are the driving tasks associated with right-angle and left-turn collisions, in which elderly drivers were found to be over-involved. The perception-reaction times for these tasks are used in highway and traffic engineering to design intersection sight distances and traffic signal change intervals to avoid these types of collisions. However, the design values of these perception-reaction times may be too short for many elderly drivers.

COUNTERMEASURES

Countermeasures designed to improve the safety of elderly drivers were identified and selected for demonstration and evaluation during the second year of the research. The countermeasures were intended to address the problems of elderly drivers, which were determined as a result of the accident data analysis of elderly driver accidents, the evaluation of the driving knowledge of elderly drivers, and the assessment of the abilities of elderly drivers. In addition, the results of a review of the literature and current practice relative to methods of improving the safety of elderly drivers were considered in the identification and selection of the countermeasures. The countermeasures selected were ones that were determined to be feasible countermeasures with the greatest potential for reducing elderly driver accidents without reducing the mobility of elderly drivers. The countermeasures were: (1) driver education, (2) physical and perceptual therapies, and (3) highway and traffic engineering measures.

Three national elderly driver education programs were found to cover the areas of driving knowledge in which elderly drivers were found to be deficient. Therefore, the development of a new program was not warranted. The American Automobile Association (AAA) "Safe Driving for Mature Operators" was selected as the driver education countermeasure. It was determined to be the most cost-effective and feasible program. It had the lowest-cost program, and AAA was the most willing of the program sponsors to allow its program to be used in the research.

Physical and perceptual therapies were selected as countermeasures to be demonstrated in the second year of the research because they address many of the deficiencies associated with poor driving performance. The physical therapy will be designed to improve trunk rotation, shoulder flexibility, and posture. The perceptual therapy will be designed to improve, or compensate for, deficiencies in figure-ground perception, visual discrimination, depth perception, and peripheral vision. The therapies will be designed as self-administered, home-based programs of physical and perceptual exercises in order to increase their feasibility and cost-effectiveness. Therapies administered at health care facilities by professional therapists were not considered to be feasible.

The engineering countermeasures selected were designed to address the problems of elderly drivers involved in right-angle and left-turn collisions. Countermeasures designed to address the other types of collisions in which elderly drivers are over-involved were not selected, because their potential cost-effectiveness was considered to be too low. Also, the countermeasures selected were limited to countermeasures that only involved signing, pavement markings, traffic signal displays, and traffic signal timing. Because of budget and time constraints of the research, it was not feasible to select countermeasures that involved considerable roadway reconstruction or the installation of expensive traffic control devices, such as grade separations, overhead sign bridges, and traffic signals.

PLAN OF RESEARCH FOR SECOND YEAR

During the second year of the research, the safety improvement countermeasures selected in the first year will be demonstrated so that their actual effectiveness can be evaluated. Based on the results of the demonstrations, the cost-effectiveness of the countermeasures will be evaluated and the most cost-effective ones will be determined. The results of the second year can be used by the state highway transportation agencies to implement safety improvement programs for older drivers that are comprehensive, coordinated, and cost-effective.

Research Approach

The research approach will involve about 120 elderly drivers, who will be divided into six study groups. The first two groups will be given the physical and perceptual therapies. One of the two groups will be given the physical therapy, and the other one will be given the perceptual therapy. The third group will be given the AAA "Safe Driving for Mature Operators," which was selected to address the driving knowledge deficiencies of elderly drivers. The fourth group will be given both the physical therapy and the driver education. The fifth group will be given both the perceptual therapy and the driver education. The sixth group will be the control group, which will not receive any therapeutic measures or driver education.

All of the drivers will be tested before and after the countermeasures have been implemented. The tests will include: (1) a driving knowledge test, (2) a series of perceptual/cognitive/functional tests, and (3) an on-street driving performance test. The particular tests used will be those designed to measure the driving knowledge and abilities found in the first year of the research to be most directly related to the problems of elderly drivers. The engineering countermeasures will be incorporated into the on-street driving performance test routes. The differences in the before and after driving performance test scores will be used to evaluate the effectiveness of the safety improvement countermeasures.

Expected Results

The results of the research will be cost-effective strategies for improving the safety of elderly drivers that integrate engineering, education, and therapeutic countermeasures in a complementary manner. The strategies will provide a basis for implementing safety improvement programs for older drivers that are comprehensive, coordinated, and cost-effective.

In addition to the final report, the results of the research will be submitted for publication and presentation to several organizations concerned with the safety of elderly drivers, such as the Transportation Research Board, Highway Users Federation for Safety and Mobility, American Association of Retired Persons, and American Automobile Association. The research findings will also be presented in workshops to state highway transportation agencies as requested.

Chapter 1

INTRODUCTION

PROBLEM

The United States has experienced a steady growth in its older population since the 1900s. At that time, only 4 percent of the total population was over age 65. By 1980, persons over 65 comprised about 11 percent of the population, with the percentage predicted to reach a little over 18 percent by the year 2030 [1].

Iowa, Missouri, Kansas, and Nebraska rank among the top ten states in percentages of their population over age 65 [2]. Table 1-1 shows the resident population 55 years and older by age and state for these states [3]. The subgroups from 55 to 64 and 65 to 74 years are larger than the 75+ group which points to a trend for increasing numbers of the very old in the near future.

Table 1-1. 1989 resident population by age in the Midwest Region [3].

State	Age Group Count and Population Percentage				
	55-64 Years	65-74 Years	75+ Years	55+ Years	Total
Iowa	252,000 8.9 %	229,000 8.1 %	192,000 6.8 %	673,000 23.7 %	2,834,000 100 %
Kansas	222,000 9.0 %	183,000 7.4 %	153,000 6.2 %	558,000 22.5 %	2,476,000 100 %
Missouri	477,000 9.3 %	392,000 7.7 %	310,000 6.1 %	1,179,000 23.1%	5,103,000 100 %
Nebraska	141,000 8.9 %	117,000 7.3 %	103,000 6.5 %	361,000 22.7 %	1,594,000 100 %
Midwest Region	1,092,000 9.1 %	921,000 7.7 %	758,000 6.3 %	2,771,000 23.1 %	12,007,000 100 %
United States	22,019,000 11.1 %	17,667,000 7.3 %	12,168,000 5.0 %	51,854,000 21.3 %	243,400,000 100 %

By the year 2020, it is estimated that 17 percent of the population will be 60 years or older; that is, more than 50 million older persons will be eligible to drive, and nearly half of them will be over 75 years of age. Today, nearly 10 percent of all drivers are at least 65 years old [4]. The older population relies on the automobile to a great extent for transportation needs, whether as a passenger or as the operator of the vehicle [5]. There is every reason to believe that increasing numbers of elderly persons will continue to depend on their cars rather than public transportation. Indeed, in many rural and suburban communities no public transportation available.

These statistics are significant because most studies and accident records indicate a marked increase in driving problems in the 75+ age group. Motor vehicle crashes are the leading cause of death from unintentional (or accidental) injury for those persons aged 65 to 74, and the second leading cause of death (next to falls) for persons 75 years or older [6]. Traffic mortality accident rates show a U-shape distribution by age. After adjusting for miles driven, the rates are equally high in the 15-24 and 75+ age groups.

When estimates are made regarding miles driven by all ages and a ratio computed of the number of reported crash involvements to total travel for each age group, the risk of crash involvements does not increase appreciably until about age 70, then dramatically increases after age 80 [6]. In addition, older drivers have a much higher probability of being fatally injured. Crashes of about equal severity are experienced across all age groups and severity of injury is approximately the same for all drivers to age 70, then severity increases slightly for those over age 70. Age of the driver appears to have a strong effect on the number of severe injuries that result in fatalities; driver fatality rate per 100 million vehicle miles of travel is 5.6 for teens, 0.85 for drivers in their forties, 9.0 for drivers 80 to 84, and over 30 for those in the 85+ group who are drivers [7].

Driving an automobile is a mark of independence and autonomy. It allows elderly persons to go where and when they want. Feelings of self esteem are often impaired when older people can no longer drive. Some older persons recognize their limitations and either limit their driving or completely stop. Others continue in the face of losing their license and occurrence of accidents. What accounts for differences between those who curtail or quit driving and those who continue is not known. Some possible explanations include the following: (1) personality characteristics, (2) misperception of capabilities, and (3) dementia or other impairments that cloud judgment.

Determination of the causes of accidents involving older drivers and the implementation of preventive and ameliorative measures would make driving safer for older drivers as well as for others with whom they share the roadways. Improvements in the safety of older drivers would enable them to maintain their mobility and preserve their independence. However, the problems of older drivers, and the proposed solutions to these problems are multidimensional. The problems of older drivers are not only rooted in the physical and mental limitations of the elderly and their diminished driving skills and lack of driving knowledge, but are also related to the failure of traffic control devices and roadway design to account for these limitations. Therefore, the solutions to the problems of older drivers not only involve improving the physical and mental conditioning of older drivers and increasing their driving knowledge and skills, but also include improvements in traffic control devices and roadway design.

OBJECTIVE AND SCOPE OF THE RESEARCH

The research is a two-year, multidisciplinary study of the problems of elderly drivers, conducted by a team of researchers from the areas of driver education, gerontology, and highway/traffic engineering. The objective of the research is to develop and evaluate ways to improve the safety of elderly drivers. During the first year, the problems of elderly drivers were examined and ways to improve the safety of elderly drivers were determined. During the second year, the safety improvement strategies that were identified as potentially the most cost-effective will be demonstrated to evaluate their actual cost effectiveness. The results of the second year will provide state highway transportation agencies with information that can be used to implement safety improvement programs which effectively integrate driver education, physical and perceptual therapies, and engineering countermeasures.

The examination of the problems of elderly drivers involved several components: (1) analysis of accident data to identify the accident situations in which elderly drivers are over-involved, (2) evaluation of the driving knowledge of elderly drivers to identify deficiencies in their driver education, especially with respect to the accident situations in which they are over-involved, and (3) assessment of the physical, perceptual, and cognitive abilities of the elderly to determine their relationship to driving performance and the accident situations in which elderly drivers are over-involved. Based on the findings of these analyses, ways to improve the safety of elderly drivers were determined. The following safety improvement countermeasures were developed: (1) driver training designed to address the problems of older drivers, (2) therapies designed to improve the physical, cognitive, and perceptual abilities related to the problems of older drivers, and (3) highway design and traffic control improvements designed to address the accidents situations in which elderly drivers are over-involved. The countermeasures were evaluated relative to their potential for reducing elderly driver accidents, their potential impact on the mobility of elderly drivers, and the feasibility of implementation. The feasible countermeasures with the greatest accident reduction potential and no likelihood of reducing the mobility of elderly drivers were selected for demonstration and evaluation in the second year.

This report documents the procedures, findings, and conclusions of the research conducted during the first year; and contains the plan of work for the second year of the research. A second report will present the results of the second year of the research. The analysis of the accident data to identify the accident situations in which elderly drivers are over-involved is presented in Chapter 2, and the conditions found at high elderly-driver accident locations are summarized in Chapter 3. The evaluation of the driving knowledge of elderly drivers and the assessment of the physical, perceptual, and cognitive abilities of elderly drivers are presented in Chapters 4 and 5, respectively. The perception-reaction times of elderly drivers with respect to highway design and traffic control are examined in Chapter 6. The driver education and physical and perceptual therapies intended to address the deficiencies of elderly drivers are discussed in Chapter 7. The design of the engineering countermeasures is also presented in Chapter 7. The work plan for the second year of the research is presented in Chapter 8.

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Chapter 2

ELDERLY DRIVER ACCIDENTS

The problems of elderly drivers were defined in terms of the accident situations in which they are over-involved, the deficiencies in their knowledge of driving, and the deficits in their physical, perceptual, and cognitive abilities. The description of the over-involvement of elderly drivers in traffic accidents was based on a review of the literature pertinent to elderly driver accidents and on the results of an analysis of the traffic accidents that occurred in Nebraska during 1988.

LITERATURE REVIEW

Studies concerned with the rates, patterns, and injury consequences of accidents involving elderly drivers were pertinent to the objectives of this research. The following is a review of the relevant studies.

Transportation Research Board Study

One of the most comprehensive studies of problems of elderly drivers was conducted by the Transportation Research Board in 1986 [1]. The study utilized 1986 traffic accident data provided by the National Highway Traffic Safety Administration (NHTSA) and information from a number of studies of elderly-driver accidents.

Of the total traffic crashes in 1986, about 13 percent of the drivers were 65 or older. Fatalities per 10,000 population were highest for teenagers and drivers older than 65. But, because of the small size of the older population and the relatively small amount of travel by elderly drivers, the total number of fatalities is considerably smaller compared to younger drivers.

Although the use of vehicle-miles of travel (VMT) provides a better basis for comparing actual exposure to risk among drivers of different age groups, it does not take into account the inequalities of risk when driving. Accident data from NHTSA and the National Accident Sampling System (NASS) showed that both accident and fatality rates based upon miles driven followed a U- shape pattern, indicating that the youngest (less than 25 years) and the oldest (more than 74 years) drivers were having higher accident involvement rates than other drivers.

The rate of fatal involvement for older drivers increased more rapidly than the total rate of involvement.

Both younger and older drivers were found to be over-involved in multivehicle crashes. Drivers over 65 and under 21 were both over-involved in right-turn crashes, but left-turn crashes were more pronounced for drivers over 54. Also, older drivers were more likely to be involved in backing, parking, and head-on collisions. Failure to yield the right-of-way and to respond to road signs and signals, and inattention were the main reasons contributing to fatal crashes.

As part of the Transportation Research Board study, Hauer [2] examined the nature of intersection accidents in relation to older drivers. He found that older persons were over-involved in fatalities when the rate was expressed in terms of fatalities per licensed driver or fatalities per unit of miles of travel. However, when the effect of frailty was eliminated from the data, the plot of involvement rate changed. Involvement rate in terms of per mile licensed driver showed no sign of increasing with advancing age, while that computed on per mile driven basis showed only a slightly increase in involvement rate after age 70. Therefore, he concluded that the main safety problem of older persons was their greater vulnerability to injury and lower recovery rate.

Hauer also found that older drivers accounted for nearly 40 percent of the fatalities and 60 percent of the injuries in accidents that occurred at intersections. He estimated that more than one-third of the fatalities and one-fourth of the injuries occurred at uncontrolled inter-sections. Most driver fatalities in the 64+ age group at intersections happened during daylight.

NHTSA Study

Ezio Cerrelli [3] presented an overview of the traffic safety problem in relation to the age of the driver in a NHTSA technical report. The emphasis of his study was on the elderly drivers. The accident data from five states (Maryland, Michigan, Pennsylvania, Texas, and Washington) were used.

The crash frequency was highest for teenage drivers, and decreased as age increased. However, involvement rate based on vehicle-miles of travel followed a general U-shape pattern with respect to driver age. The youngest drivers experienced a rather high accident rate of about 30 involvements per 1,000,000 VMT, which decreased rapidly to a value of about 4 crashes for drivers between the ages of 35 to 65, and then increased sharply to a value of nearly 40 for drivers over 85 years old.

The study found that older drivers were more likely to be involved in intersection and multivehicle crashes, particularly in urban areas. About 90 percent of elderly driver accidents occurred during the daytime. Older drivers involved in accidents had much higher percentages of right-of-way and traffic-signal violations, and were more often charged with some type of traffic violation when they were involved in accidents. No significant difference was shown in the severity of the crashes among drivers of different ages, but the number of drivers who experienced a fatal or serious injury increased with the age of the driver, particularly in the case of fatal accidents. The driver fatality rate did not vary appreciably for drivers under 70 years of age, but rose gradually to a value of 4 fatalities per 100 involvements for older drivers. The driver severe-injury rate remained constant at about 10 per 100 involvements for drivers younger than 70, but it increased to 15 for older drivers. When the rate was expressed in fatalities per 100 severe injuries, the results showed that the oldest drivers experienced the highest rate of nearly 30 fatalities per 100 injuries.

Iowa Study

The Iowa Department of Transportation [4] developed an older driver profile from an analysis of the traffic accidents that occurred in Iowa during 1987 and 1988. According to this profile, accidents per 100 drivers decreased with age; thus, based on the percentage of licensed drivers, older drivers were not over-represented in traffic accidents. This finding was apparently due to older drivers driving fewer miles and traveling during less risky driving periods. However, a general U-shape pattern in accident involvement was observed when accidents per miles driven was con-sidered. The youngest drivers had the highest number of accidents per million vehicle miles. The rate decreased with driver age up to age 65, after which it began to increase with driver age.

During 1987 and 1988, more than 85% of accidents involving older drivers occurred during daylight. Also, older drivers had higher percentages of accidents on Fridays and Wednesdays. The older drivers were over-involved in broadside collisions, and the most frequently cited contributing circumstances for older drivers were "failure-to-yield" and "ran-traffic-signal."

Michigan Study

McKelvey and Stamatiadis [5] analyzed accident data on the Michigan state trunkline system for the period from 1983 through 1985. Vehicle-miles of travel and the number of licensed drivers were used as accident exposure measures. The proportion of the number of total accidents in each age group was compared to the proportions of both the accident exposure measures. Ratios of greater than one for both measures indicated that younger drivers were over-involved in accidents. Middle-aged drivers were under-involved in accidents according to both measures. The older drivers were slightly over-involved in accidents on the basis of vehicle miles traveled, but they were under-involved in accidents based on the percentage of licensed drivers. The accident rate of younger drivers was significantly higher than the average rates in terms of accidents per licensed driver and accidents per vehicle miles of travel. Accident rates for middle-aged and older drivers were slightly less than the average for both exposure measures.

The accident data indicated that older drivers were more likely than younger drivers to be involved in multivehicle accidents. When limited to non-interstate multivehicle accidents, the data showed that older drivers were slightly more susceptible to head-on and angle-type accidents. The major violations cited for older drivers were failure to yield the right-of-way, illegal turns, and improper lane usage. Illness, fatigue, or inattention, and diminished visual acuity were the significant contributing circumstances of the older driver accidents. The fatality rate of older drivers was considerably higher than that of all drivers.

Summary

Accident studies have found that elderly drivers have more accidents per vehicle miles of travel than do middle-age drivers. Also, elderly driver are most likely to be involved in multivehicle accidents at intersections, and they have higher percentages of their accidents in urban areas and during the daytime. Studies have consistently found that elderly drivers are over-involved in right-angle, left-turn, backing, and parking collisions. The contributing circumstances most commonly reported for accidents involving older drivers are failure to yield, ran traffic signal, illegal turn, improper lane usage, and driver inattention or confusion.

ACCIDENT STUDY

The 1988 accident level and vehicle/driver level files maintained by the Nebraska Department of Roads were analyzed to identify the accident situations in which elderly drivers were over-involved. The accident data were sorted according to driver age, and accident rates were calculated for young, middle-age, and older drivers. The distributions of accident characteristics for the age groups were compared to identify statistically significant differences in the accident patterns of the age groups.

Age Groups

Although people age at different rates, chronological age is the most readily available factor for differentiating older from younger drivers. The degree to which crash characteristics vary as a function of chronological age can be helpful in understanding how age contributes to accident involvement. Therefore, the first task prior to the accident analysis was to define appropriate age groups. For this research, the drivers were grouped into five age categories: younger than 25, 25 to 54, 55 to 64, 65 to 74, and older than 74 years. These categories were selected because they have been used in previous research, and they seem to correspond to driving behavior pattern of drivers. The younger-than-25 group is less experienced and generally has been observed to take more risks and have a higher accident involvement rate. Drivers in the middle-age group (25 to 54) are typically more mature and safer drivers. Previous studies have used different ages to define older drivers: some studies have defined older drivers as those 55 and older, some have used age 65, and others have defined older drivers as those 75 and older. Therefore, in order to determine the age at which older drivers begin to have problems, three older-driver age groups were used in this research. The older-driver age groups used were 55 to 64, 65 to 74, and older than 74 years.

Accident Involvement

The number of accidents in each driver-age group which occurred in Nebraska during 1988 is shown in Table 2-1. Table 2-1 also shows the number of licensed drivers and the vehicle miles of travel in each age group during 1988. The numbers of licensed drivers were obtained from the Nebraska Department of Motor Vehicles. The vehicle miles of travel in each age group were estimated by multiplying the number of licensed drivers by the average annual vehicle miles of travel for the age group, which were obtained from the 1983-84 Nationwide Personal Transportation Study conducted by the Federal Highway Administration [6].

Table 2-1. Accident involvement by age group in Nebraska during 1988.

Age Group	Number and Percentage of			Ratio of % of Total Accidents to % of	
	Total Accidents	Licensed Drivers	VMT[a] (Million)	Licensed Drivers	VMT[a] (Million)
16-24	23,428 (36.2%)	193,894 (17.8%)	1,535 (14.2%)	2.03	2.55
25-54	31,756 (49.1%)	602,731 (55.4%)	7,312 (67.5%)	.89	.73
55-64	4,464 (6.9%)	127,336 (11.7%)	1,147 (10.6%)	.59	.65
65-74	3,062 (4.7%)	101,974 (9.4%)	600 (5.5%)	.50	.85
>74	2,018 (3.1%)	62,335 (5.7%)	233 (2.2%)	.54	1.41
Total	64,728 (100%)	1,088,270 (100%)	10,828 (100%)	1.00	1.00

[a] Vehicle miles of travel.

Involvement Ratios

Table 2-1 shows the percentages of the total number of accidents, licensed drivers, and vehicle miles of travel in each age group. The ratios of the percentage of total accidents to the percentages of licensed drivers and vehicle miles of travel are indicators of the degree of an age group's involvement in accidents. A group is considered to be under-involved in accidents if the ratio is less than 1.0. On the other hand, a group is over-involved in accidents if the ratio is greater than 1.0. A ratio of 1.0 indicates that accident involvement rate is equal to accident exposure rate.

As shown in Table 2-1, drivers between the ages of 16 and 24 were over-involved in accidents on the basis of both the accident exposure measures. The only other group of drivers that was over-involved in accidents was the older-than-74 group, which had a ratio of 1.5 based on vehicle miles driven. The lowest ratio of percentage of accidents to percentage of licensed drivers was 0.5, which was the ratio for both the 65-to-74 and the older-than-74 groups. Based on vehicle miles driven, the lowest ratio was 0.6, which was the ratio for drivers between the ages of 55 and 64.

Thus, based on number of licensed drivers, older drivers 55 and older were not over-involved in accidents. Likewise, based on vehicle miles driven, older-drivers between 55 and 74 were not over-involved in accidents. However, older drivers 75 and older were over-involved based on vehicle miles driven.

Accident Rates

Statewide accident rates in terms of accidents per million vehicle-miles of travel were computed for the age groups using the data shown in Table 2-1. The accident rates are shown in Figure 2-1. The accident rate of 15.3 for the youngest driver age group was significantly higher than those of the other driver age groups. The rate drops to a minimum of 3.9 for drivers between the ages of 55 and 64. The rate then increases to 8.6 for drivers 75 years and older, which was significantly higher than the rates for the 25-to-54, 55-to-64, and 65-to-74 age groups.

Accident Types

The accidents for each age group were categorized by accident type: multivehicle, single-vehicle, and pedestrian accidents. Figure 2-2 shows the percentages of the three accident types for each age group. Drivers 55 and older had higher percentages of multivehicle accidents than drivers younger than 55. The percentage of multivehicle accidents for drivers 75 and older was significantly higher than for the other age groups. This implies that as drivers age they have a greater tendency to be involved in accidents with other drivers. In contrast, single-vehicle accidents were more prominent for younger drivers. Drivers younger than 55 had higher percentages of single-vehicle accidents than did the older drivers. Drivers 75 and older had a significantly lower percentage of single-vehicle accidents than drivers who were younger than 55. Percentages of accidents involving pedestrians were very low and did not vary appreciably among the driver age groups.

Summary

The results of the analysis of accident involvement indicate that among the older-driver age groups only the 75-and-older age group was over-involved in traffic accidents. Likewise, the 75-and-older age group was the only older-driver age group that had an accident rate significantly higher than the middle-age group. All three older-driver age groups had higher percentages of multivehicle accidents than younger age groups. However, drivers 75 and older

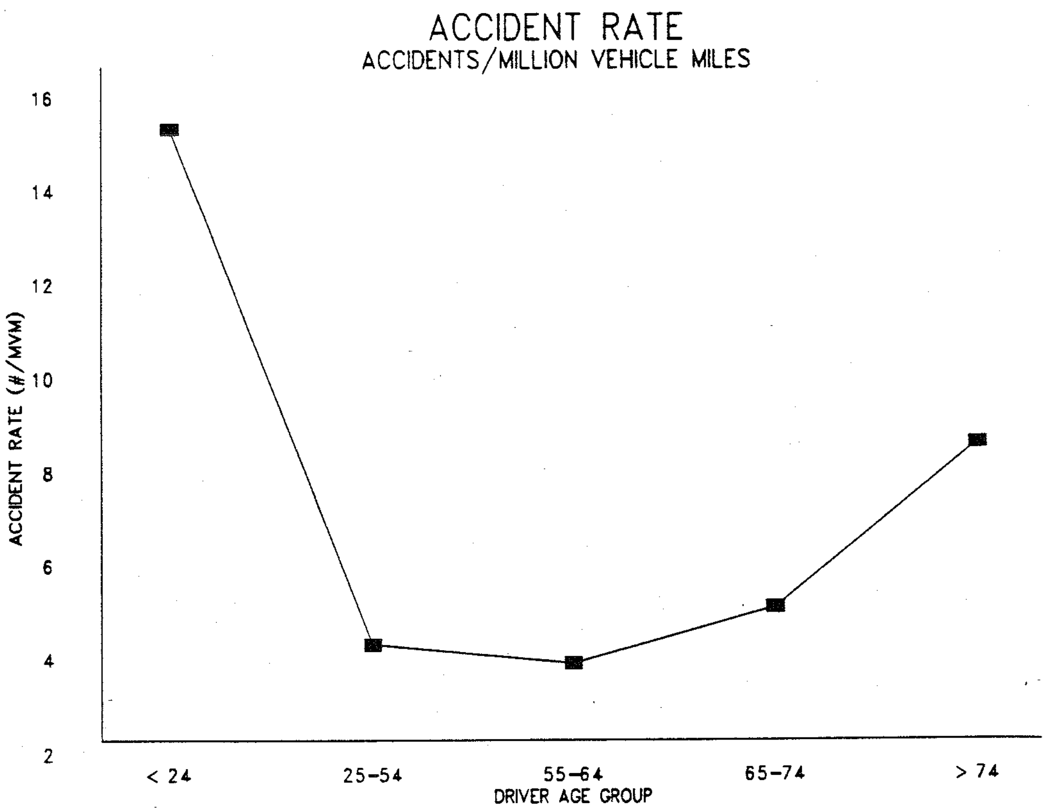

Figure 2-1. Age group accident rates in Nebraska during 1988.

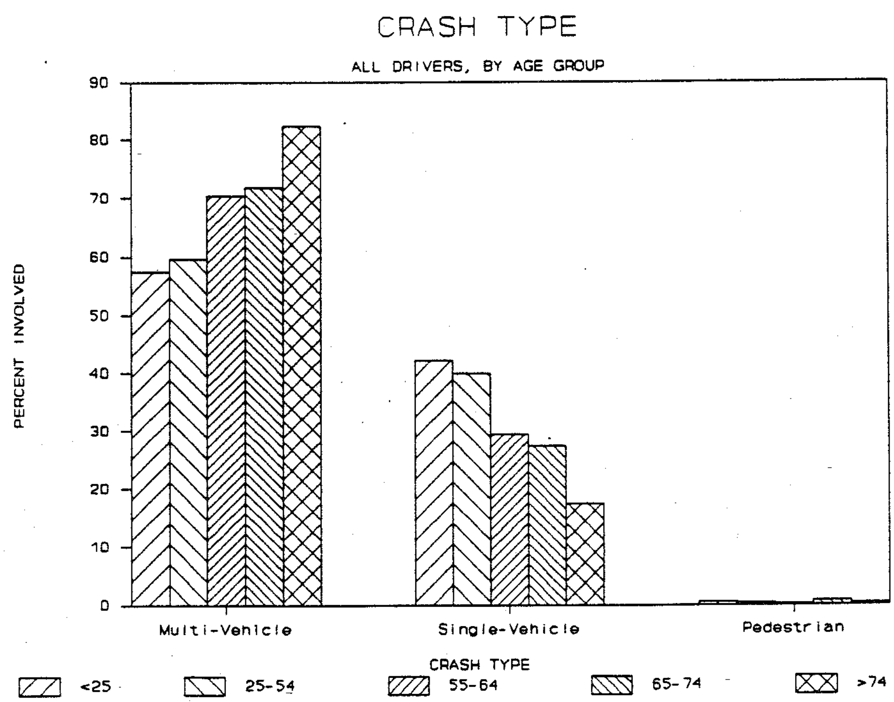

Figure 2-2. Accident types by age group in Nebraska during 1988.

had the greatest likelihood of being involved in multivehicle accidents. Therefore, the remainder of the accident study focused on a comparison of the accident characteristics of the drivers in 75-and-older age group with those in the middle-age group, 25 to 54 years old.

Accident Characteristics

The characteristics and circumstances of the accidents involving drivers in the 75-and-older age group were compared to those of the accidents involving drivers in the middle-age group (25 to 54). The distributions of the accident characteristics were used to contrast the accident experience of elderly drivers with that of middle-age drivers. The percent distributions for each accident characteristic were computed for each of the 99 counties in Nebraska that had at least one accident in each of the two age groups. Counties with no accidents in either age group were not included in the analysis because only the percent distributions in cases where accidents occurred were of interest. The average percentages were computed for each accident characteristic. A paired-data t test, conducted at the 5 percent level of significance, was used to identify significant differences in the average accident characteristic percentages of the two age groups.

The accident characteristics compared included 14 variables from the accident level data file and seven variables from the vehicle/driver level data file (Table 2-2).

Significant differences in the accident percentages between the 75-and-older and the middle-age groups were found in the case of 11 of the 14 accident level data file variables and four of the seven vehicle/driver level data file variables. No significant differences were found with respect to accident severity, road type, roadwork/maintenance activity, driver injury, driver condition, and reason for not seeing danger. Significant differences were found for urban/rural location, contributing circumstance, day of week, time of day, intersection/nonintersection, directional analysis, road character, surface condition, traffic control, weather, light condition, driver sex, driver residence, vehicle body style, and vehicle movement. The accident percentages for the variables for which significant differences were found are shown in Table 2-3. A brief discussion of the significant differences found between the elderly and middle-age driver accidents follows.

Table 2-2. Accident variables compared between 75-and-older and middle-age drivers in Nebraska during 1988.

Accident Level Data File Variables	Vehicle/Driver Level Data File Variables
Severity	Driver Injury
Urban/Rural Location	Driver Sex
Contributing Circumstance	Driver Residence
Day of Week	Driver Condition
Time of Day	Vehicle Body Style
Intersection/Nonintersection	Vehicle Movement
Directional Analysis	Reason For Not Seeing Danger
Roadwork/Maintenance Activity	
Road Character	
Road Type	
Surface Condition	
Traffic Control	
Weather	
Light Condition	

Location

Elderly drivers had a significantly higher percentage of their accidents on urban roadways. About 65 percent of the accidents involving elderly drivers occurred on urban roadways, whereas only 40 percent of the accidents involving middle-age drivers were on urban roadways. Conversely, elderly drivers had a significantly lower percentage of their accidents on rural roadways. About 35 percent of the elderly-driver accidents were on rural roadways, whereas 60 percent of the middle-age drivers' accidents were on rural roadways.

Compared to middle-age drivers, elderly drivers had a higher percentage of their accidents at intersections. Nearly 45 percent of the elderly-driver accidents were at intersections, whereas only 30 percent of the middle-age drivers' accidents were at intersections. Elderly drivers had a significantly lower 45 percent of their accidents at nonintersection locations compared to the middle-age drivers who had 60 percent of their accidents at nonintersection locations. Both age groups had about 10 percent of their accidents at driveways or alleys.

Table 2-3. Significant differences between elderly and middle-age driver accidents in Nebraska during 1988.

Variable	Percentage of Age Group Accidents	
	Elderly Drivers (75 and older)	Middle-Age Drivers (25 to 54)
Location:		
Urban	66[a]	40
Rural	34[b]	60
Intersection	45[a]	30
Nonintersection	45[b]	60
Traffic Control:		
None	63	75
Stop Sign	22[a]	14
Yield Sign	2	1
Traffic Signal	5	3
Prevailing Conditions:		
Straight & Level Road	74[a]	62
Dry Road Surface	84[a]	75
Clear Weather	80[a]	72
Daylight	86[a]	64
Time:		
9:00 am - 3:00 pm	65[a]	46
Monday - Thursday	63	55
Drivers Characteristics:		
Female	43[a]	34
Local	58[a]	32
Normal Condition	87	85
Drinking	0.7	5
Drove 4-Door Sedan	66[a]	23
Type of Collision:		
Right-Angle	31[a]	18
Left-Turn	7[a]	3
Backing	6[a]	3
Parked-Vehicle	6[a]	3
Parking Maneuver	11[a]	3

[a] Higher than the middle-age group percentage at the 5 percent level of significance.

[b] Lower than the middle-age group percentage at the 5 percent level of significance.

Traffic Control

Compared to middle-age drivers, elderly drivers had a higher percentage of accidents at locations where there was some type of traffic control, such as a stop sign, yield sign, traffic signal, or flashing beacon. About 37 percent of the elderly-driver accidents were at locations with some form of traffic control, whereas only about 25 percent of the middle-age drivers' accidents were at such locations. Elderly drivers had a significantly higher 22 percent of their accidents at stop sign locations, whereas only 14 percent of the middle-age drivers' accidents were at stop sign locations.

Prevailing Conditions

The significant differences in the prevailing conditions of elderly-driver accidents and those of the middle-age drivers were with respect to the character of the roadway, the surface condition, the weather, and light conditions. Compared to middle-age drivers, elderly drivers had significantly higher percentages of their accidents on straight and level roadways (74 versus 62 percent), on dry road surfaces (84 versus 75 percent), in clear weather (80 versus 72 percent), and during daylight (84 versus 64 percent). This reflects the tendency of elderly drivers to do more of their driving in the day time and in good weather.

Time

Elderly drivers had a significantly higher percentage of their accidents between 9:00 am and 3:00 pm. Elderly drivers had 65 percent of their accidents during this time, whereas only 46 percent of the middle-age drivers' accidents occurred in this time period. Also, elderly drivers had 65 percent of their accidents on Monday through Thursday, whereas the middle-age drivers had only 55 percent of their accidents on these days.

Driver

A significantly higher 43 percent of the elderly drivers involved in accidents were females, whereas only 34 percent of the middle-age drivers involved in accidents were females. However, this difference is probably due to the fact that women live longer than men, thus there are more women than men in the older population.

Most (53 percent) of the elderly drivers involved in accidents were from the local area where the accident took place. A significantly lower 32 percent of the middle-age drivers involved in accidents were from the local area where the accident occurred. This difference is consistent with the fact that elderly drivers drive fewer miles per year than middle-age drivers. However, it does indicate that most of the elderly drivers involved in accidents are involved in accidents on familiar roadways.

There were no significant differences found with respect to driver condition. However, a slightly higher percentage (87 versus 85 percent) of elderly drivers were in normal condition. Also, a lower percentage (0.7 versus 5 percent) of elderly drivers had been drinking.

The most common type of vehicle driven by the elderly drivers was the four-door sedan. The sedan was driven by 66 percent of the elderly drivers, but only 23 percent of the middle-age drivers, involved in accidents.

Type of Collision

Elderly drivers were over-involved in right-angle, left-turn, backing, parked-vehicle, and parking-maneuver collisions. Compared to middle-age drivers, they had significantly higher percentages of right-angle (31 versus 8 percent), left-turn (7 versus 3 percent), backing (6 versus 3 percent), parked-vehicle (6 versus 3 percent), and parking-maneuver (11 versus 3 percent) collisions. In order to examine the accident problems of elderly drivers in more detail, the characteristics and circumstances of these types of collisions involving drivers in the 75-and-older age group were compared to those involving drivers in the middle-age group. The differences in the characteristics of these types of collisions involving elderly drivers and those involving middle-age drivers were similar to the differences found for all accidents. The following are the additional differences found for each of these types of collisions. These differences are also shown in Table 2-4.

Right-angle collisions. The circumstances contributing to elderly-driver right-angle collisions more often involved a failure to yield, a ran stop sign, or a disregarded traffic signal. Compared to middle-age drivers, elderly drivers had higher percentages of right-angle collisions involving failure to yield (63 versus 54 percent), ran stop sign (10 versus 8 percent), and disregarded traffic signal (4 versus 2 percent).

Another difference occurred with respect to the type of traffic control. Some form of traffic control was involved in 69 percent of the elderly-driver right-angle collisions, whereas only 60 percent of the middle-age drivers' right-angle collisions involved some form of traffic control. Compared to middle-age drivers, elderly drivers had higher percentages of their right-angle collisions at stop signs (53 versus 48 percent), yield signs (5 versus 4 percent), and traffic signals (6 versus 4 percent).

Table 2-4. Significant differences between elderly and middle-age driver collisions in Nebraska during 1988.

Variable	Percentage of Age Group Collisions	
	Elderly Drivers (75 and older)	Middle-Age Drivers (25 to 54)
Right-Angle Collisions:		
Contributing Circumstances:		
Failure TO Yield	63	54
Ran Stop Sign	10	8
Disregarded Traffic Signal	4	2
Traffic Control:		
None	31	40
Stop Sign	53	48
Yield Sign	5	4
Traffic Signal	6	4
Vehicle Movement:		
Going Ahead	79	86
Turning Left	14	8
Reason For Not Seeing Danger:		
None	69	58
Left-Turn Collisions:		
Contributing Circumstances:		
Failure TO Yield	67	62
Ran Stop Sign	1	0.3
Disregarded Traffic Signal	14	9
Traffic Control:		
None	47	55
Stop Sign	23	17
Yield Sign	1	0.5
Traffic Signal	17	11
Vehicle Movement:		
Going Ahead	17[b]	61
Turning Left	82[a]	36
Reason For Not Seeing Danger:		
None	74	68
Backing Collisions:		
Location:		
Alley or Driveway	69[a]	48
Vehicle Movement:		
Starting From Parked Position	60	44
Stopped in Traffic Lane	4[b]	16

[a] Higher than the middle-age group percentage at the 5 percent level of significance.

[b] Lower than the middle-age group percentage at the 5 percent level of significance.

Elderly drivers involved in right-angle collisions were more likely to be making a left-turn. Fourteen (14) percent of the elderly drivers were turning left when involved in a right-angle collision, whereas only 8 percent of the middle-age drivers were turning left. Also, nearly 70 percent of the time, there was no reason given for why the elderly driver did not see the danger when involved in a right-angle collision, whereas only 58 percent of the middle-age drivers had no reason for not seeing the danger.

Left-turn collisions. As in the case of right-angle collisions, the circumstances contributing to elderly-driver left-turn collisions also involved higher percentages of failure to yield (67 versus 62 percent), ran stop sign (1 versus 0.3 percent), and disregarded traffic signal (14 versus 9 percent), when compared to those of left-turn collisions involving middle-age drivers. In addition, some form of traffic control was more often involved in elderly-driver left-turn collisions. Compared to middle-age drivers, elderly drivers had higher percentages of their left-turn collisions at stop signs (23 versus 17 percent), yield signs (1 versus 0.5 percent) and traffic signals (17 versus 11 percent).

Elderly drivers involved in left-turn collisions were more likely to be turning left than were middle-age drivers. A significantly higher percentage (82 versus 36 percent) of the elderly drivers were making a left turn when they were involved in a left-turn collision. On the other hand, a significantly lower percentage (17 versus 61 percent) of them were going straight ahead when involved in a left-turn collision. Again, as in the case of right-angle collisions, usually there was no reason given for why the elderly driver did not see the danger when involved in a left-turn collision. Almost 75 percent of the elderly drivers had no reason for not seeing the danger, whereas only 68 percent of the middle-age drivers had no reason.

Backing collisions. Elderly drivers had a significantly higher percentage (69 versus 48 percent) of their backing collisions at driveways and alleys. Also, a higher percentage (60 versus 44 percent) of the elderly drivers were starting from a parked position when involved in a backing collision. Interestingly, a significantly lower percentage (4 versus 16 percent) of the elderly drivers were stopped in a traffic lane when involved in a backing collision.

Parked-vehicle and parking-maneuver collisions. No major differences were found in the characteristics of parked-vehicle and parking-maneuver collisions of elderly and middle-age drivers other than those found in the case of all accidents.

Effect of County Population

The effect of county population on the significant differences between elderly and middle-age drivers was investigated. The 99 counties in Nebraska were grouped according to four county population ranges: less than 5,000; 5,000 to 10,000; 10,000 to 30,000; and more than 30,000. The accident characteristic percentages of the 75-and-older and 25-to-54 age driver groups were then compared to identify significant differences between the two age groups within each county population range. The results of the comparison are shown in Table 2-5.

Many of the significant differences found for the county population ranges were the same as those found in the statewide analysis of the accident data. However, some of the significant differences which were observed on the statewide basis were not significant for all county population ranges, and some significant differences not observed on the statewide basis were found for some of the county population ranges. For example, in the case of accident severity, no significant differences were observed on the statewide basis but elderly drivers were found to have a significantly higher percentage (1.6 versus 0.4 percent) of fatal accidents in counties with populations over 30,000. With respect to accident location, elderly drivers had significantly higher percentages of their accidents at intersections in counties with populations between 10,000 and 30,000 (53.9 versus 36.7 percent) and more than 30,000 (67.4 versus 52.8 percent). Although they had higher percentages of intersection accidents in counties with populations between 5,000 and 10,000 (36.5 versus 27.7 percent) and less than 5,000 (24.0 versus 16.8 percent), these percentages were not significantly higher than the intersection accident percentages of the middle-age drivers.

As was observed on the statewide basis, elderly drivers had significantly higher percentages of their accidents on dry road surfaces, during clear weather, between 9:00 am and 3:00 pm, and during the daylight in all four county population ranges. Also, in all four county population ranges, a significantly higher percentage of elderly drivers involved in accidents drove four-door sedans. In all four population ranges, higher percentages of the elderly drivers involved in accidents were female and were from the local area where the accident occurred, but these percentages were not significantly higher than the corresponding middle-age drivers' percentages in counties with populations above 30,000.

Table 2-5. Significant differences between elderly and middle-age driver accidents by county population in Nebraska in 1988.

Variable	County Population			
	< 5,000	5,000 - 10,000	10,000 - 30,000	> 30,000
Severity: Fatal				X
Location: Intersection			X	X
Traffic Control: Stop Sign			X	X
Prevailing Conditions:				
Dry Road Surface	X	X	X	X
Clear Weather	X	X	X	X
Daylight	X	X	X	X
Time: 9:00 am - 3:00 pm	X	X	X	X
Driver Characteristics:				
Female	X	X	X	
Local	X	X	X	
Drove 4-door Sedan	X	X	X	X
Type of Collision:				
Right-Angle		X	X	X
Left-Turn		X	X	X
Backing	X			
Parking		X		
Contributing Circumstances:				
Failure To Yield		X	X	X
Ran Stop Sign				X
Disregarded Traffic Signal				X
Backing Unsafely	X	X		
Vehicle Movement:				
Turning Left		X	X	X
Starting From Parked		X		
Position	X	X		
Backing Up				

X - Elderly driver percentage higher than the middle-age drivers' percentage at the 5 percent level of significance.

With respect to types of collisions, higher percentages of the elderly-driver accidents were right-angle, left-turn, backing, and parking-related collisions in all four county population ranges. Elderly drivers had significantly higher percentages of right-angle and left-turn collisions in counties with populations above 5,000. In counties below 5,000 population, these percentages were not significantly higher than those for the middle-age drivers. Backing-collision percentages were significantly higher in only the below-5,000 county population range, and the parking-collision percentages were significantly higher in only the 5,000-to-10,000 county population range. This pattern reflects the greater likelihood of elderly drivers being involved in intersection accidents in counties with larger populations. Consequently, elderly drivers were found to have significantly higher percentages of their accidents involving contributing circumstances of failure to yield, ran stop sign, and disregarded traffic signal in the counties with larger populations, and significantly higher percentages of their accidents involving backing up, backing unsafely, and starting from a parked position in the counties with lower populations. Likewise, in counties with populations above 5,000, a significantly higher percentage of elderly drivers involved in accidents were making left turns when the accidents occurred.

CONCLUSION

The results of the accident data analysis are consistent with the findings of the literature review. In general, elderly drivers are over-involved in multivehicle accidents, accidents at intersections, and accidents in urban areas. Conversely, elderly drivers are under-involved in single-vehicle accidents, accidents at nonintersection locations, and accidents in rural areas. Compared to middle-age drivers, elderly drivers have significantly higher percentages of their accidents during daylight, between 9:00 am and 3:00 pm, on weekdays, in clear weather, on dry road surfaces, and on straight and level roadways. Significantly higher percentages of elderly drivers involved in accidents were residents of the local area and drove four-door sedans.

Elderly drivers are over-involved in right-angle, left-turn, backing, and parking collisions. With respect to the contributing circumstances of right-angle and left-turn collisions, elderly drivers are more likely than middle-age drivers to have accidents that involve a failure to yield, a ran stop sign, a disregarded traffic signal, or an improper turn. Also, in these types of collisions, elderly drivers are more likely than middle-age drivers to be making a left turn.

The problems of elderly drivers are the most serious for drivers 75 and older. Among the older-driver age groups (55-to-64, 65-to-74, and 75-and-older), only the 75-and-older age group was over-involved in accidents and had an accident rate significantly higher than the accident rate of middle-age drivers (25-to-54). All three older-driver age groups had higher percentages of multivehicle accidents than the younger age groups. But, drivers 75 and older had the greatest likelihood of being involved in multivehicle accidents.

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Chapter 3

ELDERLY-DRIVER HIGH-ACCIDENT LOCATIONS

Locations where relatively high numbers of accidents involving elderly drivers occurred were examined to determine the traffic and roadway conditions. The determination of these conditions provided a basis for the development of safety improvement strategies. The examination included a review of sites where elderly-driver accidents had occurred involving collisions of the types in which elderly drivers are over-involved (i.e., right-angle, left-turn, backing, parked-vehicle, and parking-maneuver collisions). In addition, locations in Omaha with relatively high numbers of elderly driver accidents were visited. The locations of right-angle, left-turn, backing, parked-vehicle, and parking-maneuver accidents were retrieved from the 1988 Nebraska Department of Road's accident data file used in the accident data analysis presented in Chapter 2. The high elderly-driver accident locations in Omaha were determined from an analysis of the City of Omaha's traffic accident records for the 5-year period from 1985 to 1990. For right-angle and left-turn collisions, photologs from the Nebraska Department of Roads were reviewed to determine the traffic control and roadway conditions at the accident locations. In the case of the backing and parking-related accidents, streets in downtown Lincoln where these accidents occurred were investigated. Site visits were made to each of the elderly-driver high-accident locations in Omaha.

RIGHT-ANGLE AND LEFT-TURN ACCIDENTS

Only locations on the Nebraska state highway system are included in the photologs. Therefore, site selection was limited to state highways. Initially, locations that had at least two right-angle or left-turn accidents involving drivers 75 and older were selected. Because only 36 sites had at least two right-angle or left-turn accidents during 1988, some locations with only one elderly-driver right-angle or left-turn accident were also included. Altogether 131 sites were selected. Out of these 131 sites, 90 sites had right-angle collisions and 60 sites had left-turn collisions.

<u>Roadway Conditions</u>

The roadway conditions at each location were recorded from the photologs. These conditions included the type of intersection, number of lanes in each direction, presence of left-turn lanes, right-turn lanes and medians, number of cross street lanes, vertical and horizontal alinements, and types of on-street parking. In addition, other factors were noted such as the amount of visual clutter, available sight distance, type of traffic control, speed limit, and type of adjacent land use activity.

Altogether there were 108 right-angle accidents and 67 left-turn accidents at the 131 locations. The percentages of the right-angle and left-turn accidents that occurred under each of the different roadway conditions were computed. The percentage distributions are shown in Table 3-1.

Most of the right-angle and left-turn accidents involving elderly drivers occurred on roadways with speed limits of 35 mph and 40 mph. Only 15 percent of these accidents were on roadways with speed limits below 35 mph, and only 30 percent of them were on roadways with speed limits above 40 mph. Ten (10) percent of the right-angle accidents and only 5 percent of the left-turn accidents were on roadways with speed limits of 55 mph.

Fifty-five percent of the right-angle accidents involved elderly drivers attempting to cross more than two lanes of traffic. Sixty percent of the left-turn accidents involved elderly drivers attempting to turn left across two lanes of opposing traffic. Only 20 percent of the left-turn accidents involved elderly drivers turning left across just one lane of opposing traffic.

Ninety percent of the right-angle and left-turn accidents occurred at 4-legged intersections, with the remaining 10 percent occurring at 3-legged intersections. Fifty percent of the right-angle accidents were at intersections with left-turn lanes, whereas 70 percent of the left-turn accidents were at intersections with left-turn lanes. On the other hand, much lower percentages of the accidents were at intersections with right-turn lanes. Twelve percent of the right-angle and 16 percent of the left-turn accidents were at intersections with right-turn lanes. In addition, over one half (53 percent) of the right-angle and 70 percent of the left-turn accidents were at intersections with medians.

More than 80 percent of the accidents occurred on straight and level roadways. Also, most accidents happened on roadways where parking was not permitted. The sight distance available appeared to be unrestricted in 85 percent of the right-angle and 90 percent of the left-turn accidents. However, in the case of about 90 percent of the accidents, there was at least some visual clutter present which competed with traffic control devices for the attention of drivers.

Table 3-1. Roadway conditions at elderly-driver accident locations in Nebraska during 1988.

Factor		Percent of Accidents	
		Right-Angle	Left-Turn
Speed Limit (mph):	25 - 30	15	15
	35 - 40	60	55
	45 - 50	20	25
	55	10	5
Number of Lanes Crossed:	1	5	20
	2	40	60
	3	20	15
	> 3	35	5
Type of Intersection:	4-Legged	90	90
	"T"	10	10
Left-Turn Lane:	No	50	30
	Yes	50	70
Right-Turn Lane:	No	88	84
	Yes	12	16
Median:	No	45	30
	Yes	55	70
Vertical Alinement:	Level	80	88
	Upgrade	5	3
	Downgrade	15	9
Horizontal Alinement:	Tangent	85	80
	Curved	15	20
Parking:	No	88	90
	Yes	12	10
Adjacent Land Use:	Industrial/Agricultural	8	4
	Residential	20	19
	Lodging	2	4
	Recreational	2	1
	Office	10	8
	Retail	36	41
	Vacant	17	19
	Other	5	4
Visual Clutter:	None	20	15
	Some	70	60
	Extreme	10	25
Sight Distance:	Unrestricted	85	90
	Restricted	15	10
Traffic Control:	None	0	5
	Stop Sign	55	30
	Signal with LT Phase	38	47
	Signal without LT Phase	7	18

All of the right-angle accidents occurred at intersections that were controlled by stop signs or traffic signals. Fifty-five percent were controlled by stop signs, and 45 percent were controlled by traffic signals. Likewise, nearly all of the left-turn accidents occurred at controlled intersections. Only 5 percent of the left-turn accidents were at uncontrolled intersections, 30 percent of them occurred at locations with stop signs, and 65 percent occurred at signalized intersections. Forty-seven percent of the left-turn accidents occurred on intersection approaches with left-turn phases.

The accidents occurred at locations with a variety of land uses. The major land uses were residential and retail land uses, including service stations and convenience markets. About 20 percent of the accidents occurred at intersections surrounded by vacant land.

Traffic Volumes

The volumes of traffic crossed in the elderly-driver right-angle accidents and the traffic volumes opposing the left turns in the elderly-driver left-turn accidents were estimated using the annual average daily traffic volumes at each location [1] and the hourly, daily, and monthly traffic volume distributions [2]. The hourly volumes for each accident were computed based on the month, day of the week, and time of the accident. The results of these calculations for the right-angle and left-turn accidents are shown in Tables 3-2 and 3-3, respectively. The probabilities that the crossing and left-turning vehicles would not have to wait for an acceptable gap are also shown in these tables. These probabilities were computed using random arrivals and the critical gap ranges recommended for unsignalized intersections in the Highway Capacity Manual [3].

Nearly 70 percent of the right-angle accidents occurred when the cross-street volumes were over 600 vph, which is the major-street volume requirement of the minimum vehicular volume warrant for traffic signals [4]. When the volume crossed is above 600 vph, the probability of not having to wait for an acceptable gap to cross is less than 0.37. About 60 percent of the right-angle accidents involved elderly drivers attempting to cross four or more lanes, and in most of these cases, the volumes being crossed were above 600 vph.

Only about 10 percent of the left-turn accidents occurred when the opposing volumes were less than 300 vph. In most cases (56 percent), the opposing volumes were between 300 and 600 vph. The probability of the left-turning vehicle not having to wait for an acceptable gap is between 0.37 and 0.66 for opposing volumes in this range. Almost 80 percent of the left-turn accidents involved elderly drivers attempting to turn left across two lanes, and in most of these cases the opposing volumes were above 300 vph.

Table 3-2. Traffic volumes at elderly-driver, right-angle accident locations in Nebraska during 1988.

Volume Crossed (vph)	Percent of Accidents				Probability of Crossing Without Delay [a]
	Number of Lanes Crossed			Total	
	2	3	4 or more		
0 - 600	8	19	4	31	> 0.26
600 - 1200		4	23	27	0.07 - 0.37
1200 - 1800		4	15	19	0.02 - 0.14
1800 - 2400	4		19	23	< 0.05

[a] Based on critical gap sizes for crossing maneuver at unsignalized intersections between 6 and 8 seconds, which are recommended in the Highway Capacity Manual for cross roads with from 2 to 4 lanes and running speeds from 30 to 55 mph [3].

Table 3-3. Traffic volumes at elderly-driver, left-turn accident locations in Nebraska during 1988.

Opposing Volume (vph)	Percent of Accidents				Probability of Turning Without Delay[a]
	Number of Opposing Lanes			Total	
	1	2	3 or more		
0 - 300		11		11	> 0.60
300 - 600	6	44	6	56	0.37 - 0.66
600 - 900		16	6	22	0.22 - 0.43
900 - 1200		6		6	0.14 - 0.29
1200 - 1500			5	5	0.08 - 0.19

[a] Based on critical gap sizes for left-turn maneuvers from the major roadway at unsignalized intersections between 5 and 6 seconds, which are recommended in the Highway Capacity Manual for major roads with from 2 to 4 lanes and running speeds from 30 to 55 mph [3].

BACKING, PARKED-VEHICLE AND PARKING-MANEUVER ACCIDENTS

On-street parking in downtown Lincoln where backing, parked-vehicle, and parking-maneuver collisions occurred were investigated to determine if parallel or angle parking was over-involved in these types of elderly-driver accidents. The percentages of backing, parked-vehicle, and parking-maneuver accidents by type of parking were computed for each driver age group. The percentages for the older-driver and middle-age groups were compared to determine if type of parking was a significant factor in these types of elderly-driver accidents.

A total of 25 backing, parked-vehicle, and parking-maneuver accidents in the area investigated. Middle-age (25-to-54) drivers were involved in a total of 16 of these accidents; older drivers were involved in only nine accidents. Of these, drivers 55 to 64 and 65 to 74 each had four accidents, but drivers 75-and-older had only one. Therefore, the older-driver accidents were combined for the purpose of this comparison. The numbers and percentages of the accidents by type of parking are shown in Table 3-4.

Table 3-4. Backing, parked-related accidents by driver age group and type of parking in downtown Lincoln, Nebraska during 1988.

Driver Age Group	Parallel Parking		Angle Parking		Total	
	Number	Percent	Number	Percent	Number	Percent
25 - 54	11	69	5	31	16	64
> 54	3	33	6	67	9	36
Total	14	100	11	100	25	100

Sixty-nine percent of the backing, parked-vehicle, and parking-maneuver accidents involving middle-age drivers occurred on streets with parallel parking and 31 percent of them on streets with angle parking. However, the reverse was true for the older drivers: only 33 percent of the backing, parked-vehicle, and parking-maneuver accidents occurred on streets with parallel parking and 67 percent of them on streets with angle parking. Therefore, it would seem that elderly drivers have more problems with angle parking than with parallel parking. However, a chi-square test of the data in Table 3-4 indicates that the type of parking and driver age are independent factors at the 5 percent level of significance. The fact that older drivers had a higher percentage of their accidents on streets with angle parking may be due to lower use of parallel parking by older drivers because they prefer to use angle parking.

OMAHA LOCATIONS

In the 5-year period from 1985 to 1990, there were 1,918 accidents involving drivers age 74 or older. Of these accidents, 1,247 occurred at intersections and 671 occurred at midblock locations. Thirteen locations had six or more elderly-driver accidents during this time. These elderly-driver high-accident locations are listed in Table 3-5. The numbers and rates of elderly-driver accidents at these locations are also shown.

Table 3-5. Elderly-driver high-accident locations in Omaha, Nebraska during 1985 to 1990.

Intersection	Number of Elderly-Driver Accidents	Entering Volume (vpd)	Elderly-Driver Accident Rate (accidents/100 MEV)
72nd & Military	11	32,700	23.0
California & Saddle Creek	10	29,850	22.9
90th & Maple	9	48,900	12.6
72nd & Maple	8	47,500	11.5
58th & NW Radial	7	35,100	13.7
78th & W Center	7	30,200	15.9
84th & W Center	7	40,200	11.9
24th & L	7	23,500	20.4
72nd & Blondo	7	46,400	10.3
Ames & Military	6	35,000	11.7
72nd & Pacific	6	55,700	7.4
42nd & Center	6	37,500	11.0
24th & Martha	6	30,400	13.5

Accident Characteristics

The severity of the accidents at the elderly-driver high-accident locations with respect to type of collision are shown in Table 3-6. None of the accidents was fatal, 25 of them were nonfatal-injury accidents, and the remaining 72 were property-damage-only accidents. The left-turn collisions were the most common type of collision at these locations. Rearend and right-angle collisions were the second and third most common type of collision, respectively. As expected, the right-angle, left-turn, head-on, and pedestrian collisions were the most severe types of collisions, because they had the highest percentages of injury accidents.

Table 3-6. Severity of elderly-driver accidents by type of collision.

Severity	Type of Collision								Total
	Right-Angle	Rearend	Sideswipe	Head-on	Left-Turn	LT/RT[a]	Right-Turn	Ped	
Fatal									
Nonfatal Injury	3	2		1	17			2	25
PDO	8	16	6	2	34	5	1		72
Total	11	18	6	3	51	5	1	2	97

[a] Collision between left-turn and right-turn vehicles.

The contributing circumstances involved in the elderly driver accidents at the elderly-driver high-accident locations are shown in Table 3-7. The major contributing circumstances were failure to yield, disregarded traffic signal, and following too closely. Failure to yield was the most common contributing circumstance in left-turn collisions, as was disregarded traffic signal in right-angle collisions, and following too closely in rearend collisions.

The numbers of collisions in which elderly drivers were at fault are also shown in Table 3-7. Review of the accident reports indicate that elderly drivers were at fault in 86 of the 97 accidents. They were nearly always at fault in the left-turn and right-angle collisions, and least likely to be at fault in rearend collisions, which accounted for only 10 of the 18 rearend collisions.

Table 3-7. Contributing circumstances of elderly-driver accidents by type of collision in Omaha, Nebraska from 1985 to 1990.

Contributing Circumstance	Type of Collision								Total
	Right-Angle	Rearend	Side-swipe	Head-on	Left-Turn	LT/RT[a]	Right-Turn	Ped	
Failure To Yield	2[b] / 2[c]		1 / 1		44 / 45	2 / 2	1 / 1	2 / 2	52 / 53
Disregarded Traffic Signal	8 / 9			1 / 1	1 / 1				10 / 11
Improper Turn Signal					1 / 1				1 / 1
Made Improper Turn			1 / 1	1 / 1	3 / 3	1 / 1			6 / 6
Following Too Closely		9 / 15							9 / 15
Improper Lane Change			4 / 4						4 / 4
Other		1 / 1		1 / 1	1 / 1	1 / 1			4 / 4
Unknown		0 / 2				0 / 1			0 / 3
Total	10 / 11	10 / 18	6 / 6	3 / 3	50 / 51	4 / 5	1 / 1	2 / 2	86 / 97

a Collision between left-turn and right-turn vehicles.

b Number of collisions in which elderly drivers were at fault.

c Total number of collisions.

Site Conditions

The 13 elderly-driver high-accident locations were all signalized intersections on arterial streets. The speed limits on the streets were 35 and 40 mph in most cases. Most of the approaches to these intersections were on 4-lane divided streets with no parking permitted, and had left lanes with protected/permitted left-turn signal phasing. However, the positioning of the left-turn lanes at most of the locations provided limited sight distance for left-turn drivers when opposing left-turn vehicles were present. The horizontal alinement at most of the locations was tangent. However, a number of the intersections were located on vertical alinements which limited the sight distances, especially for left-turning traffic. Otherwise, restricted sight distances were not a problem at most of the locations. Although there was some visual clutter at many of the locations, the traffic signal displays were well-presented in most cases, featuring mast-arm mounted signal heads with 12-inch lenses and backplates.

It is interesting to note that all of the locations were in the vicinity of senior citizen residences or health-care facilities which generate elderly-driver trips. Therefore, it seems likely that these locations were high-accident locations for elderly-drivers, at least in part, because they have higher volumes of elderly-driver traffic.

Collision diagrams and turning movement volumes are shown for the elderly-driver high-accident locations in the appendix. The numbers of elderly-driver accidents by type of collision at these locations are shown in Table 3-8. A description of the site conditions relative to the pattern of elderly-driver accidents at each location follows.

72nd & Military

There were 11 elderly-driver accidents at 72nd and Military. Seven of them were left-turn collisions, three were rearend collisions, and one was a right-angle collision. An elderly driver was at fault in 10 of the accidents.

In the case of the left-turn collisions, the elderly drivers were turning left from either the northbound or the westbound approach and failed to yield the right-of-way to the opposing through traffic. Both approaches from which the left-turns were made had left-turn lanes and were controlled by protected/permitted left-turn phasing. However, the positioning of the left-turn lanes provided limited sight distance for left-turn drivers when opposing left-turn vehicles were present. Also, the placement of the left-turn signal heads required wide angles of view between the left-turn signal head and the opposing through traffic.

Table 3-8. Types of collisions at elderly-driver high-accident locations in Omaha, Nebraska from 1985 to 1990.

Intersection	Type of Collision								Total
	Right-Angle	Rearend	Sideswipe	Head-On	Left-Turn	LT/RT[a]	Right-Turn	Pedestrian	
72nd & Military	1	3			7				11
California & Saddle Creek	3	1			6				10
90th & Maple		4			5				9
72nd & Maple	2	1			5				8
58th & NW Radial					7				7
78th & W Center					7				7
84th & W Center	1	1	2		2	1			7
24th & L	1	1	1		2			1	7
72nd & Blondo		1		2		3		1	7
Ames & Military	2		1		3				6
72nd & Pacific	1	1			2	1			6
42nd & Center		4			2				6
24th & Martha		1	2		3				6
Total	11	18	6	3	51	5	1	2	97

[a] Collision involving left-turn and right-turn vehicles.

The rearend collisions occurred on the eastbound and westbound approaches. The elderly drivers were following too closely in two of the three rearend collisions. In the third collision, the elderly driver's vehicle was struck from behind, but a contributing circumstance and an indication of driver fault were not cited on the accident report. The right-angle collision involved a southbound vehicle, driven by an elderly driver, and an eastbound vehicle. The elderly driver disregarded the traffic signal. The signal displays on all approaches were mounted on mast arms and poles. The signal heads had 12-inch lenses and backplates. The eastbound approach was on a downgrade. The westbound and southbound approaches were on upgrades. The speed limit on the approaches was 40 mph.

California & Saddle Creek

There were 10 elderly-driver accidents at California and Saddle Creek. Six of the accidents were left-turn collisions, three were right-angle collisions, and one was a rearend collision. Elderly drivers were at fault in nine of the accidents.

The left-turn collisions involved elderly drivers turning left from Saddle Creek onto California. Elderly drivers were at fault in all cases, failing to yield the right-of-way in five of the collisions and making an improper left turn in one case. Saddle Creek was a 4-lane undivided street with a 35-mph speed limit. The intersection was located on a reversed compound curve on Saddle Creek which limited the sight distance at the intersection. There were no left-turn lanes on Saddle Creek, and the traffic signal did not have protected left-turn phases. Also, left-turns were prohibited from Saddle Creek during the morning and evening peak periods. The signal displays in each direction on Saddle Creek consisted of a mast-arm mounted signal head and pole mounted signal on the far right side of the intersection. The signal heads on the mast arms were very high so that they were difficult to see for drivers waiting in the intersection to turn left.

Two of the right-angle accidents also involved elderly drivers who were turning left from Saddle Creek and either disregarded the signal or failed to yield the right-of-way. The third right-angle collision involved an elderly driver northbound on Saddle Creek who disregarded the traffic signal and collided with a vehicle westbound on California. The signal heads had 12-inch lenses, but they did not have backplates. Therefore, the signal heads were somewhat difficult to see amongst the visual clutter along Saddle Creek.

The rearend collision involved two vehicles southbound on Saddle Creek. The vehicle driven by the elderly driver was struck from behind by a vehicle following too closely.

90th & Maple

There were nine elderly-driver accidents at 90th and Maple. Five of them were left-turn collisions, and four were rearend collisions. Both roadways were 4-lane divided arterial streets with 40-mph speed limits. All approaches to the intersection had left-turn lanes which were controlled by protected/permitted left-turn signal phasing. The signal displays were on mast arms located on the far side of the intersection. Each display consisted of three signal heads, one 5-section head mounted over the left-turn lane and two 3-section heads over the through lanes. The signal heads had 12-inch lenses and backplates. The northbound and eastbound approaches were on downgrades, and southbound and westbound approaches were nearly level.

Four of the five left-turn collisions involved elderly drivers who were turning left and failed to yield the right-of-way, disregarded the traffic signal, or made an improper turn signal. The elderly drivers were making left turns from the eastbound approach in two of the accidents, from the westbound approach in the third accident, and from the northbound approach in the fourth accident. In each case, the positioning of the left-turn lanes limited the sight distance available to drivers turning left when opposing left-turn traffic was present. Further, the placement of the left-turn signal heads required wide angles of view between the left-turn signal head and the opposing through traffic when drivers were waiting in the intersection to turn left. Interestingly, there were no left-turn collisions involving left-turns from the southbound approach, which had the highest left-turn volume. However, left-turn sight distance on this approach was less restricted by opposing left-turn traffic because the opposing through traffic was on a downgrade.

Three of the four rearend collisions involved elderly drivers who were at fault. Two of them were following too closely, and the other one was backing in a traffic lane. Two of the collisions were on the southbound approach, and the other two were on the eastbound and west-bound approaches. There was some visual clutter on the approaches, especially on 90th Street.

72nd & Maple

There were eight elderly-driver accidents at 72nd and Maple. Five of them were left-turn collisions, two were right-angle collisions, and one was a rearend collision. Both roadways were 4-lane divided arterial streets with 40-mph speed limits. All of the intersection approaches had left-turn lanes, which were controlled by protected/permitted left-turn signal phasing. The intersection was located on crest vertical curves on both 72nd and Maple Streets. The northbound and southbound approaches on 72nd Street are nearly level. However, the eastbound approach on Maple Street was on an upgrade, and the westbound approach was on the crest of the vertical curve.

All of the left-turn collisions involved elderly drivers turning left from Maple Street to 72nd Street. In every case the elderly driver was at fault. Four of the elderly drivers failed to yield the right-of-way, and the other one was confused. The sight distance for left-turns from Maple Street was extremely limited, because of the vertical alinement and the positioning of the left-turn lanes. The signal heads controlling the left-turn lanes were mounted over the adjacent through lanes creating wide angles of view between the left-turn signal heads and the opposing through traffic.

One of the right-angle collisions involved an elderly driver turning left from Maple Street and failing to yield to traffic on 72nd Street. The other right-angle collision involved an elderly driver northbound on 72nd Street who disregarded the traffic signal and struck a vehicle eastbound on Maple Street. The signal display on each approach consists a 5-section head and two 3-section heads. The 5-section head and one of the 3-section heads were mounted on a mast arm which extends to the middle of the median through lane. The other 3-section head was pole mounted on the far side of the intersection. The signal heads had 12-inch lenses and backplates. There was some visual clutter along 72nd Street.

An elderly driver was not at fault in the rearend collision that occurred on the southbound approach. The elderly driver's vehicle was struck from behind by another vehicle following too closely.

58th & Northwest Radial

All seven of the elderly-driver accidents at 58th and Northwest Radial were left-turn collisions involving elderly drivers turning left from the eastbound approach on Northwest Radial to 58th Street. In every case, the elderly driver failed to yield the right-of-way and was struck by a westbound vehicle on Northwest Radial.

The left turns were made from a left-turn lane controlled by protected/permitted left-turn signal phasing. The left-turn signal head was mounted on a pole on the opposing median. The opposing approach had a left-turn lane and three through-traffic lanes. The intersection was located on a horizontal curve on Northwest Radial, which curved to the left for traffic in the eastbound direction and limited the left-turn driver's view of the opposing through traffic. The opposing left-turn volume was very high, which might mean that opposing left-turn vehicles frequently restricted the eastbound left-turn sight distance.

78th & West Center

All seven of the elderly-driver accidents at 78th and West Center were left-turn collisions involving an elderly driver turning left from West Center onto 78th Street and failing to yield the right-of-way to opposing through traffic. In six of the cases, the elderly drivers were turning left from the eastbound direction, and in the other case, the elderly driver was turning left from the westbound direction.

West Center Street was a 4-lane divided arterial street with a 40-mph speed limit. There were left-turn lanes on both approaches. The eastbound left turns were controlled by protected/permitted left-turn signal phasing displayed by means of a 5-section signal head with 12-inch lenses and backplates. The signal head was mounted on a mast arm over the lane line between the left-turn lane and the adjacent through lane, which created a wide angle of view between the signal head and the opposing through traffic. The positioning of the left-turn lane and the crest vertical curve on the westbound approach limited the sight distance between the eastbound left turns and the opposing through traffic.

The westbound left turns were controlled by permitted signal phasing displayed by two 3-section signal heads, one mounted on a mast arm over the median through lane and the other mounted on a pole on the far right side of the intersection. The angle of view between the signal heads and the opposing through traffic was wide, and in addition, the sight distance between the westbound left turns and the opposing through traffic was limited by the positioning of the left-turn lane and the upgrade on the eastbound approach.

84th & West Center

There were seven elderly-driver accidents at 84th and West Center. Two of the accidents were left-turn collisions involving elderly drivers who failed to yield the right-of-way to opposing through traffic. Two of them were sideswipe collisions involving elderly drivers who made improper lane changes. One was a collision between a left- and a right-turning vehicle involving an elderly driver who failed to yield the right-of-way. Another was a rearend collision involving an elderly driver who was following too closely. The remaining accident was a right-angle collision in which the elderly driver was not at fault.

West Center Street was a 4-lane divided arterial street with a 40-mph speed limit. The left-turns from West Center Street were made from left-turn lanes controlled by protected/permitted phasing displayed by 5-section signal heads with 12-inch lenses and backplates. The left-turn signal heads were mounted on mast arms over the left-turn lanes.

However, the positioning of the left-turn lanes caused the left-turn sight distance to be restricted by opposing left-turn vehicles.

The two sideswipe collisions were on the south leg of the intersection on 84th Street. Both of them involved elderly drivers making improper lane changes, one going northbound and the other going southbound. Northbound there were three well-marked lanes approaching the intersection, a left-turn lane, a through lane, and a right-turn lane. Southbound there were two lanes leaving the intersection. However, there were a number of driveways on both sides of the street which generated a considerable number of lane changes.

The collision between a left- and a right-turning vehicle involved an elderly driver who was making a right-on-red turn from the eastbound approach onto southbound 84th Street. The elderly driver failed to yield the right-of-way to a vehicle turning left on a protected left-turn phase from the westbound approach.

The rearend collision was on the westbound approach. The signal display on this approach consisted of three signal heads with 12-inch lenses and backplates, which were mounted on a mast arm. A 5-section signal head was mounted over the left-turn lane, and two 3-section heads were mounted over the through lanes. There was very little visual clutter along West Center Street.

24th & L

There were seven elderly-driver accidents at 24th and L Streets. The intersection was located in a business district in south Omaha. Both streets were 4-lane undivided arterial streets with 35-mph speed limits. All of the intersection approaches had three lanes, a left-turn lane and two through lanes. The left-turn lanes on L Street and the left-turn lane on the southbound approach on 24th Street were controlled by permitted left-turn signal phasing. The left-turn lane on the northbound approach on 24th Street was controlled by protected/permitted signal phasing. The approaches on 24th Street were nearly level. However, the approaches on L Street were on a crest vertical curve which limited the left-turn sight distance on both approaches.

The seven accidents involved six types of collisions and the elderly drivers were at fault in all of the accidents. Four of the accidents involved elderly drivers turning left from left-turn lanes controlled by permitted left-turn phases. Two of them were left-turn collisions involving elderly drivers who were turning left from the eastbound left-turn lane on L Street. The view of the opposing through traffic from this lane was limited by the crest vertical curve at the intersection. The third accident was a head-on collision involving an elderly driver who turned left from the left-turn lane on the westbound approach and ran into the front of a vehicle waiting in the northbound left-turn lane. The fourth accident was a pedestrian collision involving an elderly driver who turned left from the left-turn lane on the southbound approach and struck a pedestrian crossing L Street in the east crosswalk.

One of the accidents was a right-angle collision involving an elderly driver who was eastbound on L Street, disregarded the traffic signal, and struck a vehicle southbound on 24th Street. The signal display for the eastbound traffic consisted of three 3-section signal heads. Two of the signal heads had 8-inch lenses and were mounted on poles in the far left and far right corners of the intersection. The third signal head, which was mounted on a mast arm over the lane line between the left-turn lane and the adjacent through lanes, had a 12-inch red lens and 8-inch yellow and green lenses. A changeable message advertising sign at the southeast corner of the intersection and other commercial signing in the area created considerable visual clutter, making it more difficult for the signal display to command the attention of drivers.

There were two elderly-driver accidents on the westbound approach. One of them was a sideswipe collision involving an elderly driver who made an improper lane change. The other accident was a rearend collision involving an elderly driver who was following too closely behind the vehicle ahead. The approach was on an upgrade, and the signal display was similar to the one on the eastbound approach.

72nd & Blondo

There were seven elderly-driver accidents at 72nd and Blondo, which was the intersection of two 4-lane divided arterial streets with 40-mph speed limits. The intersection was located in a sag vertical curve on 72nd Street and on an upgrade section of Blondo Street. There was a left-turn lane on each approach controlled by protected/permitted left-turn signal phasing. There was some visual clutter, especially on the approach on 72nd Street. There was a pedestrian overpass over the south leg of the intersection a few feet back from the stop line.

The seven accidents involved four types of collisions. However, six of the accidents involved left-turn movements. In three cases, the accidents were collisions between a vehicle turning left and a vehicle turning right from the opposing approach. The collisions occurred in three difficult corners of the intersection, the northeast, the northwest, and the southwest corners. The left-turn signal displays for the left turns involved in these accidents were 5-section signal heads with four 8-inch lenses and a 12-inch green-arrow lens for the left turns from

Blondo Street, and a 4-section signal head with three 8-inch lenses and a 12-inch green-arrow lens for the left turns from the northbound approach on 72nd Street. None of the left-turn signal heads had backplates, and each of them was mounted on a pole on the nose of the opposing median. The angles of view between the signal heads and the opposing through traffic were wide, and the positioning of the left-turn lanes caused the left-turn sight distance to be restricted when opposing left-turn vehicles were present. Elderly drivers were turning left and were at fault in two of these collisions. In the third collision, the elderly driver was turning right and was not at fault.

Two of the accidents involving left-turn movements were head-on collisions. In one case, an elderly driver disregarded the traffic signal and turned left from the eastbound approach into a vehicle that was in the southbound left-turn lane. In the other case, an elderly driver, who was ill, turned left from the westbound approach into a vehicle stopped on the opposing approach. The final accident that involved a left-turn movement was a pedestrian collision. In this accident, an elderly driver turned left from the southbound approach and failed to yield the right-of-way to a pedestrian in the crosswalk on the east side of the intersection.

The only accident at 72nd and Blondo that did not involve a left-turn movement was a rearend collision on the northbound approach. In this accident, the elderly driver was following too closely and struck a vehicle stopping ahead.

Ames & Military

There were six accidents at Ames and Military, which was an intersection of two 4-lane divided arterial streets with 40-mph speed limits. The intersection was located on a downgrade from west to east on Military, and at the bottom of a sag vertical curve on Ames Street.

Three of the accidents were left-turn collisions in which the elderly drivers failed to yield the right-of-way to the opposing through traffic. Two of the collisions occurred on the eastbound and westbound approaches on Military. Both of the approaches had left-turn lanes that were controlled by protected/permitted left-turn signal phasing. In each case, the left-turn signal displays consisted of 4-section signal heads with 12-inch lenses and backplates. The signal heads were mounted on mast arms over the median through lane, which created a wide angle between the signal heads and the opposing through traffic. Also, the positioning of the left-turn lanes caused the left-turn sight distance to be restricted by opposing left-turn vehicles, particularly for the eastbound approach. The third left-turn collision involved an elderly driver turning left from the left-turn lane on the southbound approach. This left-turn lane was controlled by a permitted left-turn signal phase. However, the signal display for the approach may have caused some drivers to think that the left-turn phasing was protected. The display included a 3-section signal head mounted on a pole in the opposing median and a 3-section signal head mounted on a mast arm over the lane line between the left-turn lane and the adjacent through lane. Also mounted on the mast arm beside the signal head was a lane-assignment sign showing that the left lane on the approach was a left-turn lane, but some drivers may have understood this to mean that the signal head was a protected left-turn signal.

Two of the accidents were right-angle collisions in which the elderly drivers disregarded the traffic signal. In one case, the elderly driver was on the eastbound approach, and in the other case, the elderly driver was on the westbound approach. The signal displays for the through traffic on each approach consisted of two 3-section heads with 12-inch lenses and backplates. One signal head was mounted on a mast arm over the through lanes and the other was mounted on a pole on the far-right corner of the intersection. There was very little visual clutter on the approaches. However, the intersection was very close to another signalized intersection to the west (72nd and Military) which may have confused or distracted some drivers.

One of the accidents was a sideswipe collision. This accident involved an elderly driver who made an improper lane change on the westbound approach. Again, it may have been that some drivers on this approach were distracted or confused by the signals at 72nd and Military, which was a very short distance to the west of this intersection.

72nd & Pacific

There were six accidents at 72nd and Pacific. Both of these streets were 4-lane undivided arterial streets with 35-mph speed limits. All four approaches to the intersection were nearly level and were channelized with curbed islands to provide left-turn lanes.

Three of the accidents involved left-turn movements from the northbound approach. Two of the accidents were left-turn collisions involving an elderly driver who failed to yield the right-of-way to the opposing through traffic. The left-lane on the approach was controlled by protected /permitted left-turn signal phasing. The left-turn signal display was a 5-section signal head with 12-inch lenses, which was mounted on a pole on the nose of the opposing left-turn lane channelization island. The left-turn sight distance was restricted by the opposing left-turn traffic because of the positioning of the left-turn lanes. The other accident involving a left-turn from this approach was a collision between the left-turn vehicle and a right-turn vehicle from the opposing approach, which had an exclusive right-turn lane in addition to the two through lanes. The right-turn vehicle was driven by an elderly driver who failed to see the left-turn vehicle.

One of the accidents was a right-angle collision involving an elderly driver on the westbound approach, who disregarded the traffic signal and struck a northbound vehicle. The signal display for the westbound approach consisted of a 5-section left-turn signal head and two 3-section signal heads for the through traffic. All of the signal heads had 12-inch lenses, but only the two 3-section heads had backplates. The 5-section signal head was mounted on a pole on the opposing left-turn channelization island. One of the 3-section signal head was mounted on a mast arm over the through lanes, and the other one was mounted on a pole on the far right corner of the intersection. Numerous advertising signs created a considerable amount of visual clutter for traffic on the approaches.

There was also a right-turn collision involving an elderly driver on the westbound approach who turned right-on-red into the path of a northbound vehicle. The sight distance for the right turn was restricted by a fence on the southeast corner of the intersection.

The only other accident at this intersection was a rearend collision on the northbound approach. In this accident, an elderly driver was following too closely and ran into the vehicle stopping ahead. The signal display on this approach was identical to the one on the westbound approach. However, the visual clutter for the traffic on the northbound approach was extreme, which made it difficult for some drivers to see the signal display.

42nd & Center

There were six elderly-driver accidents at 42nd and Center, which was the intersection of two 4-lane undivided arterial streets with 35-mph speed limits. The intersection was located at the bottom of a sag vertical curve on 42nd Street and on a downgrade from east to west on Center Street. All four approaches had left-turn lane channelization islands, and the southbound and eastbound approaches also had right-turn channelization islands. The signal displays on all approaches consisted of a 5-section left-turn signal head for protected/permitted left turns and two 3-section signal heads for the through and right-turn traffic. The signal heads had 12-inch lenses and backplates. The left-turn signal head was mounted on a mast arm over the left-turn lane, and the other two signal heads were mounted on the mast arm over the through lanes.

Four of the accidents were rearend collisions in which vehicles driven by elderly drivers were struck from behind by vehicles. In three of the collisions, the trailing vehicles were following too closely, but in the fourth case no contributing circumstance was reported. Three of the collisions occurred on the upgrade on the eastbound approach, and the other one was on the downgrade on the westbound approach.

Two of the accidents were left-turn collisions involving elderly drivers who failed to yield the right-of-way to the opposing through traffic. One of these collisions involved a left-turn from the northbound approach, and the other collision involved a left-turn from the westbound approach. Left-turn sight distance on the northbound approach was not restricted too much by opposing left-turn traffic because the opposing approach was on the downgrade. However, this was not the case on the westbound approach because the opposing approach was on the upgrade. Consequently, the westbound left-turn driver's view of opposing through traffic was restricted by opposing left-turn vehicles.

24th & Martha

There were six elderly-driver accidents at 24th and Martha. Martha Street was a two-lane two-way street with a 35-mph speed limit, and 24th Street was a 4-lane undivided arterial street with a 35-mph speed limit. The intersection was located at the top of a crest vertical curve on Martha Street, and the approaches on 24th Street were nearly level.

Three of the accidents were left-turn collisions. Two of these collisions involved elderly drivers who turned left from the northbound approach on 24th Street without yielding the right-of-way to opposing through traffic. There was not a left-turn lane on the approach, but there was a protected/permitted left-turn signal phase. The signal display consisted of a 5-section left-turn signal head and a 3-section signal head, both of which had 12-inch lenses and backplates. These two signal heads were mounted on a mast arm over the through lanes. In addition, there was a 3-section signal head with 8-inch lenses mounted on a pole on the far right corner of the intersection. The sight distance between left-turn vehicles and the opposing through traffic was extremely limited when there was a left-turn vehicle on the opposing approach. The third left-turn collision involved a driver who turned left from the eastbound approach in front of an elderly driver. The elderly driver was not at fault in this accident.

Two of the accidents were sideswipe collisions in which the elderly drivers changed lanes improperly or without yielding the right-of-way. In both cases, the elderly drivers were attempting to change lanes from behind left-turn vehicles ahead of them. One of these accidents was on the northbound approach and the other one was on the westbound approach.

The other accident at this intersection was a rearend collision on the southbound approach. It involved an elderly driver who was following too closely and ran into a vehicle stopping ahead. The signal display for the southbound approach consisted of two 3-sections signal heads. One of them had 12-inch lenses and was mounted on a mast arm over the through lanes, and the other signal head had 8-inch lenses and was mounted on a pole on the far right corner of the intersection. There was some visual clutter on the approach.

CONCLUSION

The review of the traffic and roadway conditions at elderly-driver high-accident locations throughout Nebraska and in Omaha and Lincoln indicated that these locations were typically found at higher volume intersections that were controlled by either stop sign or traffic signals. The elderly drivers were usually at fault, especially in the case of right-angle and left-turn collision. Failure to yield the right-of-way and disregarding traffic signals were the most common contributing circumstances in elderly-driver accidents at these locations.

Typically, the right-angle accidents involved elderly drivers who were attempting to cross more than two lanes of traffic with volumes above 600 vph. At stop-sign controlled approaches this would usually require the elderly driver to wait for an acceptable gap. At traffic signals, the right-angle accident problem of elderly drivers seemed to be associated most often with signal displays competing with visual clutter for the attention of the drivers; this also seemed to be the problem in the case of the rearend collisions in which elderly drivers were at fault.

The left-turn accidents involving elderly drivers typically occurred on streets with speed limits below 45 mph, and at controlled intersections where the elderly drivers were attempting to turn left across two or more opposing lanes of through traffic. Often, the opposing through traffic volume was above 300 vph, which required the elderly drivers to wait for an acceptable gap at intersections with stop-sign control or permitted left-turn phases. At most of the elderly-driver high-accident locations, the left-turns were made from left-turn lanes without protected left-turn phases. However, in many cases, the positioning of the left-turn lanes was such that the left-turn sight distance was obstructed when opposing left-turn vehicles were present. Also, at signalized intersections the placement of the signal display often created a wide angle between the signal heads controlling the left turns and the opposing through traffic.

The review of backing and parking-related accident locations indicated that these types of collisions were more often found on streets with angle parking. Elderly drivers seemed to be under-involved in these types of accidents on streets with parallel parking. However, it was suspected that this occurred because elderly drivers tended to avoid using parallel-parking stalls and preferred to use angle parking.

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Chapter 4

DRIVING KNOWLEDGE OF ELDERLY DRIVERS

In order to drive safely, drivers must know how to operate their vehicles under a variety of roadway and traffic conditions. In addition, they must know the rules of the road, the traffic laws and regulations, and the meanings of the traffic-control devices. Therefore, the driving knowledge of elderly drivers was evaluated to identify any deficiencies that might contribute to their driving problems. The evaluation included a review of the literature pertinent to the subjects of the driving knowledge and education of elderly drivers. In addition, the scores of elderly drivers on the driving-knowledge portion of the Nebraska driver's license examination were analyzed to identify the questions that were most frequently missed by elderly drivers. Finally, the driver's manuals of the four states (Iowa, Kansas, Missouri, and Nebraska) in the Midwest region were reviewed relative to their coverage of information pertaining to the problems of elderly drivers.

LITERATURE REVIEW

Problems of Elderly Drivers

Currently, driver licensing requirements vary among the states, although most include all or part of the federal highway safety standard. The federal standard includes the following re-examinations requirements [1]:

(1) Conduct examinations at least every four years

(2) Test for visual acuity and knowledge of the rules of the road

(3) Identify driver deficiencies and limitations

(4) Provide remedial measures for applicants

(5) Include a provision for terminating driving privileges

(6) Provide remedial procedures for improving driver performance by education and knowledge

According to Waller [1], an examiner's contact with the applicants is the only opportunity to detect potential driver problems and it should not be lost. The licensing programs should determine if an applicant meets established criteria including vision screening, knowledge testing, and skills testing.

In its report on the needs and problems of older drivers [2], the American Automobile Association (AAA) Foundation, suggests that "...there is a need for more and deeper research into the driving performance of the elderly, and into conditions that influence it." A survey of older drivers by AAA indicated that older drivers are receptive to training and recognize a deterioration in some driving skills at about age 75. Barakat and Mulinazzi [3] suggest there is convincing evidence that skills for driving safety begin to deteriorate at age 55 and that the decline increases dramatically after 75 years of age.

Brainin [4] indicated that left turns at intersections, failure to yield right-of-way, and failure to obey signs and signals were the major problems for older drivers. Waller [5] found under-representations in recklessness, following too close, and alcohol violations by older drivers. A comparison of this ranking of older-driver violations with how elderly drivers perceive their own problems indicated a wide variation. Failure to yield the right-of-way was ranked ninth of ten items by older drivers, and red-light error ranked tenth. But, the accident crash data indicated that the failure to yield ranked first and red-light errors ranked third as actual causes of accidents.

The proceedings [6] of the Older Driver Colloquium in Orlando, Florida, February, 1985, suggested needs and problems of older drivers. Included here are those of the driver:

(1) State agencies responsible for licensing should require drivers of all ages with substandard driving records to take a corrective course and/or be reexamined for the operator's license.

(2) Educational courses in traffic safety should also be made available regularly to all older drivers on a voluntary basis.

(3) Physicians and pharmacists should continually warn drivers of the potential risks in driving after taking medication.

(4) All states should be in compliance with National Highway Traffic Safety Administration

standards for vision.

(5) At least until the issue of passive restraints is resolved locally and nationally, drivers should be encouraged to take advantage of all occupant restraint and other "packaging" systems: i.e., safety belts, air bags, head restraints, interiors free of hazards.

(6) State driver manuals should be written and designed on the basis of the learning and motivational characteristics of older drivers.

(7) A road test should be the final criterion in the initial or continuing licensing of older drivers.

The Highway Users Federation and Automotive Safety Foundation in cooperation with others, sponsored a workshop on the mobility and safety of older drivers in June 1985. The following statements are some of those recommendations from the workshop [6]:

(1) Expand knowledge base and training in prescription drug use, including effects of drug use in combination with alcohol consumption.

(2) Encourage elderly drivers to practice their driving skills.

(3) Develop and promote driver education programs tailored explicitly to elderly drivers.

(4) Encourage seat-belt use by the elderly.

(5) Gain a better understanding of elderly driving deficiencies and find cost-effective ways to compensate for those deficiencies.

(6) Define the needs and uses of data to better characterize the problems of the impaired driver. Then gather more complete data than is presently available.

The colloquium recommended that driver education courses should be developed for older drivers including basic, advanced, and refresher classes. The subject matter should include the following topics: good health and nutrition, exercise, stress management, the effects of aging on driving skills, ways to compensate for impairments, the effects of medication and alcohol on driving skills, changes in laws and traffic signs or signals, and the proper use of restraint systems. In October 1988, the National Academy of Sciences Transportation Research Board recommended that the innovative pilot education programs for elderly drivers being developed by some states should be further developed under the support of the National Highway Traffic Safety Administration (NHTSA) [7].

Elderly Driver Education

The AARP NEWS release [8] of August 8, 1989, suggested that courses for older drivers promote traffic safety. "According to a new study by the California Department of Motor Vehicles (DMV), older drivers who have completed a driver education course are less likely to have serious accidents or be convicted of traffic violations." The records of over 115,000 older California drivers revealed that those graduating from older driver programs were involved in 16 percent fewer accidents with injury or fatalities and convicted of 15.7 percent fewer traffic violations than those with no formal training.

Mr. James Hedlund, Director, Office of Driver and Pedestrian Research, NHTSA, suggested that driver improvement can play an important role in the nation's highway safety strategy [8]. The agency has reviewed some 20 driver education courses. Three national courses offered today include the National Safety Council "Coaching the Mature Driver", AARP's "55 Alive/Mature Driving" and AAA's "Safe Driving for Mature Operators."

National Safety Council Course

"Coaching the Mature Driver" is an eight-hour course designed for the senior driver with years of driving experience. The course reviews critical driving concepts and introduces techniques to help offset the effects of aging on driving abilities. The program consists of the following components [9]:

(1) "Changes," a film where doctors discuss the physical effects of aging including such things as vision, hearing, reaction and flexibility, and recognizing these changes and their effects.

(2) "The Mature Driver," a film in which seniors express their concerns about how they are perceived by other drivers, how they adjust driving habits and how changes have affected their driving ability. The identification and correction of bad habits is also stressed.

(3) The slide series includes specific traffic situations and techniques on how to deal with

them. Included is a cushion of safety, multiple-lane highway driving, pedestrians in traffic, rural driving, city driving, backing/parking lots, road sign recognition, and accident preventability analysis.

(4) A workbook is used to apply new program skills such as a self-appraisal, film/slides reviews, analysis of driving situations, and a health and safety audit.

AARP Course

The American Association of Retired Persons (AARP) program "55 Alive/Mature Driving," is an eight-hour classroom refresher course available to all motorists age 50 or older. A comprehensive curriculum is designed especially for older drivers, and consists of six separate sessions. The program is given over a two-day time period with three sessions per day for a maximum of four hours each day. The six sessions provide the following information [10]:

(1) An overview of course content, characteristics of older driver, and group discussions on driving frustrations and effects of aging on driver behavior.

(2) A discussion focuses on physical changes and relationship to driving performance, and concludes with effects of alcohol and drugs (medication) on driving.

(3) The final session of the first day includes the basic rules of driving pertinent to older drivers. These involve intersections, right-of-ways, turning, passing, and a review of signs, signals, and pavement markings.

(4) The fourth session discusses the rules of the roadway, focussing on freeways, parking, and backing techniques. The use and effects of safety belts are discussed in relation to traffic accidents.

(5) Session five involves accident prevention measures and techniques with emphasis on driving at night, during inclement weather, and in rush-hour traffic. Additional discussion items include the other roadway users, driving emergencies, and recreational vehicles.

(6) The final session focuses on major driving hazards in specific driving environments, and a final review of the total curriculum.

AAA Course

The AAA "Safe Driving for Mature Operators" program involves eight hours of classroom instruction and includes a manual, an introductory module and seven subject-matter content modules. Each module addresses a specific topic critical to driver performance within the Highway Transportation System. The titles of the various modules correspond to the chapter titles in the course manual [11]:

(1) The Introductory chapter includes the effects of age on driving and a quiz on safe driving practices. A do-it-yourself reflex test is also used in this chapter.

(2) Chapter two involves visual-seeing techniques and problems.

(3) The third chapter consists of methods of communication, signs, and confusing problems.

(4) This chapter helps older drivers in adjusting speed(s).

(5) The margin of safety is introduced in chapter five including making turns and space.

(6) The driving emergencies chapter discusses safety belts, avoiding collisions, slippery surfaces, and protection.

(7) Chapter seven deals with the car's systems, maintenance, and a check list.

(8) "You, the driver" chapter, discusses the effects of drugs, medications, and fatigue on driving performance.

(9) The summary finalizes the content, and is followed by a driver aids section.

Problems of Elderly Driver Education Programs

The major problems associated with older driver education programs involve providing cost-effective in-car instruction and getting older drivers to take the needed educational programs. Studies by McKnight and others indicate that less than 2 percent of licensed drivers enroll in driver-improvement programs even though incentives may be available and cost effective [1]. The effectiveness of driver-improvement programs has not been proven to improve the performance of older drivers in accident/or violation reduction. However, the California

Department of Motor Vehicles study does indicate a reduced likelihood of serious accidents and convictions of traffic violations [9].

The driver-improvement programs of the future should consider content which would include defensive driving, emergency procedures, common older-driver problems, errors, and ways of improvement including aids. The programs should be evaluated and improved on a regular basis incorporating new learning skills, knowledge, and techniques necessary for their ever-changing needs.

A research study conducted by West Virginia University reported that there is evidence supporting the fact that the decline in physical fitness in older people results from "rusting out" and not "wearing out." In the "Physical Fitness and the Aging Driver-Phase II," report there was a strong relationship between physical fitness and safe driving performance of older drivers. The results indicated that the exercise training program was effective in improving older driver trunk rotation and shoulder flexibility. And the stress management program was effective in reducing older-driver anxiety in such driving situations as on freeways, during rain, in fog, and at night [12].

Continual research is needed to update programs, determine needs, identify causes of accidents/violations and evaluate the effectiveness of program(s) for older drivers. Time and cost of the countermeasures should also be considered when making changes in older-driver programs to improve the participation level.

NEBRASKA DRIVER KNOWLEDGE TEST SURVEY

The results of the driver-knowledge-test portion of the Nebraska driver license examination were analyzed to identify the questions most frequently missed by elderly drivers. The intent was to determine if there was any similarity between the questions missed by the elderly drivers and their accident pattern. Nebraska driver's license examinations were collected by license examiners during regular business office hours on weekdays from October 1 to December 1, 1989. All together, 2093 examinations taken by drivers 55 years or older from 59 counties were included in the survey. The counties are listed in Table 4-1.

The three different driver's license examinations used in the survey were operator's tests A, B and C. Each examination included a set of instructions, score sheet and twenty-five test items. The test items included a picture and a multiple-choice question covering the motor vehicle laws of Nebraska and driving knowledge. Altogether there were 39 different questions in the three tests. Of the 39 questions, 13 questions appeared in all the three tests, 3 in tests A and B, 3 in tests A and C, 4 in tests B and C, 6 in test A, and 5 in tests B and C each.

Table 4-1. Counties included in the Nebraska driver knowledge test survey.

Douglas	Butler	Thurston	Sarpy
Platte	Dixon	Dodge	Colfax
Cuming	Burt	Madison	Pierce
Washington	Stanton	Holt	York
Boone	Antelope	Seward	Dakota
Cedar	Hamilton	Wayne	Knox
Nance	Adams	Furnas	Polk
Webster	Phelps	Howard	Dawson
Red Willow	Greeley	Buffalo	Hayes
Wheeler	Kearney	Dundy	Merrick
Custer	Chase	Boyd	Sherman
Frontier	Cherry	Valley	Hitchcock
Rock	Garfield	Lincoln	Blaine
Loup	Keya Paha	Harlan	Brown
Franklin	Hall	Gosper	

Procedure

The test results were sorted into the following age groups: 55 to 64, 65 to 74, and 75-and-older. The percentages of correct answers in each age group were computed for all 39 questions.

Findings

The percentages of correct responses for each test question are shown for each age group in Table 4-2. By examining the percentages across the age groups, it is evident that the proportion of drivers making the correct response for each question decreased with increasing driver age. Also, the number of questions that were answered correctly by at least 80 percent of the drivers decreased with age. The number of questions answered correctly by at least 80 percent of the drivers was 24 in the 55 to 64 age group, 19 in the 65 to 74 age group, and 12

Table 4-2. Percentage of correct responses to each question on the 1989 Nebraska driver knowledge test by age group.

Question	Age Group		
	55-64	65-74	> 74
1. Effects of alcohol**	97.6	96.5	92.0
2. Effects of alcohol	84.1	73.7*	56.6*
3. Yield to motorcycle (Left Turn)	95.0	94.0	85.5
4. Yield to bicycle	71.9*	67.8*	59.7*
5. Blind spot	76.8*	73.4*	65.4*
6. Following distance	59.6*	55.5*	52.0*
7. School bus	88.9	80.2	66.7*
8. Penalties	83.6	79.2*	69.0*
9. Pedestrian yield	98.5	97.2	91.6
10. Turning signal law (distance)	71.0*	73.0*	68.3*
11. Emergency vehicle (on-coming)	94.7	92.6	86.8
12. Reduced visibility (Windshield / Nighttime)**	96.7	95.1	90.4
13. Reduced visibility (Windshield / Nighttime)	84.3	76.2*	64.4*
14. Signal at intersection	95.2	91.0	85.2
15. Child restraints	76.2*	70.4*	53.4*
16. Sign	77.3*	72.2*	63.6*
17. Railroad crossing buck	69.3*	65.1*	63.7*
18. Yield sign	81.0	74.1*	70.4*
19. Freeway Entrance	88.8	81.4	72.0*
20. Railroad signal	96.4	94.6	90.2
21. Weather wind	92.2	91.5	85.8
22. Line markings	50.8*	49.5*	45.3*
23. Freeway entrance	86.0	82.4	70.7*
24. Passing-return	41.1*	41.6*	33.8*
25. Roadway condition-ice & temperature	58.2*	51.6*	52.5*
26. Sign-divided highway ends	57.8*	57.1*	39.6*
27. Line marking (broken white)	92.4	85.1	71.9*
28. Left-turn lanes	82.5	70.8*	53.2*
29. Speed law	38.2*	32.9*	36.7*
30. Road surface	66.6*	63.4*	55.4*
31. Scanning	42.4*	41.4*	44.0*
32. Signal pedestrian green	88.4	93.0	85.5
33. Roadway signal	92.5	87.7	71.1*
34. Sign two-way traffic	92.8	91.2	79.5*
35. Construction sign	95.7	91.3	86.0
36. Signal change	95.1	89.6	86.6
37. School sign	72.4*	78.7*	81.4
38. Speed law	81.6	84.2	77.9*
39. Space management	80.6	80.3	72.1*
Average Score	79.3*	76.1*	68.6*

* Percentage of correct responses was less than 80 percent.

** There were two questions on the effects of alcohol and on reduced visibility (windshield/nighttime).

in the 75-and-older age group. Drivers 55 to 64 had an average score of 79 percent, those 65 to 74 years old had an average score of 76 percent, and drivers 75-and-older had the lowest average score of 69 percent. A score of at least 80 percent was required to pass the test. Therefore, on the average, drivers 75-and-older were more likely than the younger drivers to fail the driver knowledge test.

Only a few of the questions on the three tests were pertinent to the accident problems of elderly drivers. Out of the 39 questions, only three were related to right-angle accidents, and only four were related to left-turn accidents. None of the questions pertained to backing, parked-vehicle, or parking-maneuver accidents.

The percentages of correct answers to the questions that were related to right-angle and left-turn accidents are shown in Table 4-3. For right-angle accidents, the questions that less than 80 percent of the drivers answered correctly were "yield to bicycle" and "yield sign." The percentages of correct answers to the three questions related to right-angle accidents decreased with increasing age. Drivers 55 to 64 had an average score of 83 percent on the three questions, drivers 65 to 74 had an average score of 78 percent, and drivers 75-and-older had an average score of 72 percent.

For left-turn accidents, the questions that less than 80 percent of the older drivers answered correctly were "turning signal law (distance)" and "left-turn lanes." Except for the "turning signal law (distance)" question, all the percentages of correct responses decreased with increasing driver age. Drivers 55 to 64 had an average score of 86 percent on the four questions related to left-turn accidents, drivers 65 to 74 had an average score of 82 percent on the four questions, and drivers 75-and-older had an average score of 73 percent.

The overall average scores for the questions related to right-angle and left-turn accidents were 85 percent for drivers 55 to 64, 80 percent for drivers 65 to 74, and 73 for drivers 75-and-older. Thus, drivers 75-and-older had the most difficulty in answering the questions related to right-angle and left-turn accidents correctly.

Table 4-3. Percentages of correct responses to questions related right-angle and left-turn accidents on the 1989 Nebraska driver knowledge test.

Question Subject	Age Group		
	55-64	65-74	>74
Right-Angle Accidents :			
4. Yield to bicycle	71.9*	67.8*	59.7*
14. Signal at intersection	95.2	91.0	85.2
18. Yield sign	81.0	74.1*	70.4*
Average Score	82.7	77.6*	71.8*
Left-Turn Accidents :			
3. Yield to motorcycle (Left Turn)	95.0	94.0	85.5
10. Turning signal law (distance)	71.0*	73.0*	68.3*
28. Left-turn lanes	82.5	70.8*	53.2*
36. Signal change	95.1	89.6	86.6
Average Score	85.9	81.9	73.4*
Overall Average Score	84.5	80.0	72.7*

* Percentage of correct responses was less than 80%.

REVIEW OF STATE DRIVER MANUALS

The current driver manuals [13,14,15,16] from the states of Iowa, Kansas, Missouri, and Nebraska were reviewed to evaluate their coverage of topics pertinent to the problems of elderly drivers. The pages on which information relative to the accident problems of elderly drivers was found are shown in Table 4-4. All four manuals had some coverage pertinent to right-angle, left-turn, and parking-maneuver accidents. The Nebraska manual did not discuss backing collisions, but did include some information on collisions with parked vehicles which was not discussed in the other state manuals. The Missouri manual did not discuss backing collisions or collisions with parked vehicles. The amount of coverage, readability, and specific sections for older drivers varied among the four manuals, but the overall coverage of information pertinent to elderly drivers was good in all four manuals.

Table 4-4. 1989 state driver manual coverage of elderly-driver accident types.

Type of Accident	Page Numbers in the Manual			
	Iowa	Kansas	Missouri	Nebraska
Right-Angle	55, 78	21	19	17, 20, 38
Left-Turn	55, 70, 78	15, 21	19, 21, 22	38, 42
Backing	64	21		
Parked-Vehicle				44
Parking-Maneuver	64	22	24, 25	44

Example questions were included in some of the manuals which would be helpful to elderly drivers. The state manual with the best overall information for elderly drivers was the Iowa manual. All of the manuals could include a special section for elderly drivers and particularly a discussion of the accident problems of elderly drivers. All drivers could benefit from the additional information on collisions with parked vehicles.

CONCLUSION

Previous studies have determined that there is a need for driver-education programs for elderly drivers. Three elderly driver education courses are being offered to meet this need. These courses were developed by the National Safety Council, the American Automobile Association, and the American Association of Retired Persons. However, research has yet to prove that such programs are effective in improving the performance of elderly drivers.

The analysis of the scores of older drivers on the driver-knowledge portion of the Nebraska driver's license examination indicated that their scores fell as their age increased. The oldest drivers (75-and-older) had a lower average score than the 65 to 74 year old drivers, and drivers 65 to 74 had a lower average score than the 55 to 64 year old drivers. In fact, the average scores of all three older-driver age groups were below the 80 percent required to pass the test. In addition, the average scores of the 75-and-older drivers on the questions relating to right-angle and left-turn accidents were also below 80 percent. Thus, the scores on the driver knowledge test indicated the need for a driver education program for elderly drivers.

Overall, the state driver manuals were found to provide good coverage of the issues pertinent to the problems of elderly drivers. However, the manuals could be improved by the addition of a section dealing specifically with the problems of elderly drivers.

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Chapter 5

ABILITIES OF ELDERLY DRIVERS

Driving is a complex task that requires incorporating perceptual, cognitive, and motor skills into operating a vehicle under varying conditions. Perceptual input comes to the driver primarily through the sensory processes such as vision and hearing. The stimulus must be registered and then recognized at the cognitive level. Again at the cognitive level, the driver must decide how to respond to the stimulus. Physical and motor skills are then used to carry out the task or maneuver.

Literature in the fields of medicine, allied health professions, and social science were reviewed to determine the abilities of the elderly relative to the driving task. In addition, patient records from the driver-rehabilitation program at Immanuel Rehabilitation Center were analyzed to determine the relationship between driving performance and a number of sensory, perceptual, and cognitive factors. Finally, a survey of elderly drivers was conducted to determine their perceptions of their driving abilities.

The results of these efforts to determine the abilities of the elderly relative to the driving task are reported in this chapter. First, the three primary issues of vision, cognition, and physiological factors are discussed based on the findings of the literature review. Next, the analysis of the data from the Immanuel Rehabilitation Center is presented. The chapter concludes with a summary of the survey of elderly drivers.

VISUAL FUNCTIONING

Vision is the primary sensory input for driving. It is estimated that approximately 90 percent of total input to a driver is visual [1].

Age-related changes in the eye alter vision. These include loss of lens elasticity and of the ability of the eye to accommodate or change focus, loss of transparency in the lens, and yellowing of the lens. The pupils of the eye become smaller and this, along with the other changes, causes numerous alterations in vision. Individual differences show a wide range, but common problems include impairment of peripheral vision, the ability to perceive and distinguish colors, visual acuity, ability to distinguish an object from its competing background, depth perception, dynamic visual acuity, ability to tolerate glare and ability to see adequately in low levels of illumination. Older persons whose visual acuity is poor show improvement as light is increased. A 45-year-old driver needs about four times the light as a 19-year-old driver[2]. Further decrements continue and it is estimated that between 70 and 90 years there is a ten-fold decrease in the absolute threshold for the dark adapted eye [3].

In spite of the importance of vision ability to driving, research results are mixed as to its relationship to accidents in older drivers. Other factors that may be causative or contributory include compensatory behavior, dirty windshields, distractions, inattention, solar glare, over-confidence and fatigue. Considerable numbers of older drivers voluntarily stop driving at night because of vision deficits, so this could be attributed to compensatory behavior.

Four pathological factors have been identified as causing the majority of visual decline in older persons: cataracts, senile macular degeneration, diabetic retinopathy and glaucoma. Because of these factors and the normal aging of the eye, it is estimated that about ten percent of people between ages 65 and 74 have acuity worse than 20/30 compared to approximately 30 percent over age 75 [4].

Until it can be demonstrated that various exotic measures of visual ability bear a strong correlation to safe driving, it appears that common clinical measures of vision are likely to remain as the basis for licensure [1].

Static Visual Acuity

Static visual acuity is the ability to discriminate an object when there is no movement between the observer and the object [4].

Most studies show low-correlation measures between static acuity and accident rates among older drivers. Eye glasses compensate for much of the loss that occurs after age 50, but correction cannot be adjusted to the same level as for young persons. Approximately two-thirds of persons 65 to 75 have a corrected static acuity worse than 20/20 [1].

The only visual ability that is measured in all states is static visual acuity, even though this has been criticized as not representing actual driving conditions. Shinar (1977) found that in low-illumination situations, static acuity was the best predictor of overall accident involvement for older drivers [5].

With age and the hardening of the lens and reduced ability to focus, static acuity is reduced. The yellowing of the lens combined with decline in pupil size, both of which are normal aging characteristics, reduces the amount of light reaching the retina and further inhibits static acuity.

Standards range from 20/30 to 20/60 for best-corrected-vision and both-eyes-open, with the majority of states using 20/40 [1]. Standards are higher if blindness exists in one eye and lower if an optical device is worn.

Macular Degeneration and Diabetic Retinopathy

Macular degeneration and diabetic retinopathy contribute considerably to visual loss among the older persons. Macular degeneration prevalence is approximately 30 percent in the 75-to-85 year group with a higher rate in females. It is the most frequent cause of visual loss and the most common cause of legal blindness [5]. The macula, that region of the retina most densely packed with light receptors, receives the most detailed visual information about any object. After age 50 to 60, the macula begins to deteriorate and central vision becomes increasingly blurred and may even be blocked. Peripheral vision remains intact. While some features of age-related macula degeneration can be detected in 25 percent of persons over age 65, the majority of this group do not experience a serious vision loss as a result [6]. The prevalence of visual loss due to diabetic retinopathy is estimated at 7 percent among the 75-to-84 group [7].

Cataracts and Glaucoma

Cataracts also cause considerable visual impairment. They can be managed by periodic examination and optimum eyeglasses for an extended period if they are of a mild degree. When cataracts progress to the point of interfering with daily activities, surgery is generally indicated. An estimated 17 percent of persons age 75 to 84 and 28 percent of those 85 years and older have impaired vision due to cataracts [8].

After surgery, eyeglasses are required that are heavy and thick. They correct focus and permit excellent vision in the central area. They also increase apparent size of the object by about 25 percent, but also introduce optical distortion and alteration of peripheral vision.

Glaucoma also causes disabilities in vision. Open-angle glaucoma prevalence increases with age with males having higher rates. Approximately 7.2 percent of the 75-to-85 population experience glaucoma. These individuals also have a 50 percent loss in contrast sensitivity across the entire spatial frequency spectrum [5].

Peripheral Vision

Peripheral vision is the ability to detect motion, form or color on either side while looking straight ahead. Drivers need this ability to safely pass approaching vehicles or to see pedestrians. Ninety-eight percent of the visual information a driver receives comes from the periphery [9].

Normal binocular vision in the horizontal visual field is 170° to 200° or approximately 100° left and 100° right. Loss of peripheral vision depends on underlying visual problems with substantial individual variations in the older population. Overall, estimated loss is five times greater in the 65-and-older group. Measurement instruments vary, test procedures are vaguely defined, personnel administering tests have little training and tests are performed only along the horizontal meridian in the 19 states who routinely test peripheral visual fields [10].

Loss can be caused by age-related reduction in retinal illumination. In elderly, glaucoma, degenerative myopia, diabetic retinopathy and retinal detachment may affect the visual field. There is a lack of correlation between peripheral vision and driving in a number of studies [10]. Low specificity for peripheral-vision tests may account for low correlation. Clinical observations indicate patients with severe visual-field loss show impairment in mobility skills.

Keltner and Johnson [10] used automated visual field testing to evaluate visual fields. They examined the relationship between peripheral vision and driving in 10,000 California driver license applicants. Prevalence of visual-field loss was about 7 percent for persons 60 to 65 years and 13 percent for those over age 65. Nearly 60 percent of individuals with visual-field loss were unaware of the loss prior to testing. Drivers with visual-field loss in both eyes had accident and conviction rates two times higher than the control group with normal visual fields. In this situation, patients must compensate by turning the head instead of the eyes to see clearly to the side [10]. Use of car mirrors can also provide compensation.

Dynamic Visual Acuity

This visual component refers to the ability to discriminate an object when there is relative movement between the observer and the object. The ability to safely perform this maneuver is dependent on the sharpness of retinal forms, oculomotor coordination and cognitive functioning to name a few. The literature does not establish a clear relationship between static and dynamic acuity [4].

Tests for dynamic visual acuity tend to show the most consistent relationship to driving safely. Small but significant correlations exist between dynamic acuity, accidents and age of driver with drivers over 50 years of age having more involvement. Dynamic acuity in some studies has appeared to be a better predictor of automobile crashes [11].

There are a number of factors that play a significant role in testing dynamic acuity. Those related to driving include the following: (1) as a driver's speed increases, acuity declines; (2) by increasing exposure time, illumination, and practice, acuity can be improved; (3) as objects move from central vision to the peripheral field, there is a decline in acuity; (4) individuals with essentially the same static acuity may show marked differences in dynamic acuity [4].

Older drivers themselves as well as other observers have reported unsafe driving practices due to loss of one or more visual capabilities, but it has been difficult to determine which deficits among many are the most significant [2].

Figure Ground Discrimination

This skill is defined as the ability to distinguish an object from its competing background [12]. Fundamental mechanisms of perception are utilized in making these visual discriminations. This ability has considerable implications for safe driving.

A number of studies have shown this ability declines with age [4]. Persons with brain damage showed driving performance directly related to degree of perceptual impairment. Those who scored well on perceptual tasks tended to have better driving performance [13].

The ability to discriminate among competing objects may appear normal until a complex situation presents itself where there are multiple steps required. The ability to make a decision and carry it out under limited time constraints or under stress may then become seriously impaired [14].

In one study of figure-ground skills and driving performance, it was found that the more frequent drivers (drove at least once a day) had higher scores in identification of objects and response time [15]. Simms [15] studied post-stroke patients and their driving behaviors and found that a large percentage of patients scored below average on perceptual tests yet their driving skills were adequate. These conclusions resulted in the recommendation that in-car testing was a very important addition to the clinical assessment.

Ways To Improve Vision

To compensate for age-related changes in functional vision, older persons should have regular eye examinations and wear the prescribed corrective devices. Conditions such as cataracts and glaucoma should be treated as prescribed by an ophthalmologist.

There is some indication that instructional sessions can be designed to teach techniques that are useful in safe driving. Information-processing skills in driving targeted decision making, scanning, identification, and anticipation as part of an 8-week project at West Virginia University [16]. These researchers theorized that deterioration in driving skills that occur as one ages can be slowed by exercising functional capacities such as speed and efficiency in information processing and range of motion necessary for safe driving.

The 2-week visual training segment of the course was in addition to range-of-motion and cognitive stress-management training. The classes were held in four one-hour sessions and emphasized perceptual cuing, anticipation, scanning and decision-making. Drivers were taught how to use a systematic search pattern to identify traffic controls in a limited period of time. Three major groupings -- traffic controls, highway conditions, and other user actions -- were utilized for practice in classifying traffic and highway events. Participants learned how to search and rapidly recognize meanings of controls such as stop signs, traffic control devices and roadway markings through use of 5-second slide projections showing actual traffic situations. In identifying other user actions, flash cards were used to practice search and identification clues to other vehicle conditions and performance, changes in vehicle movement, probable actions by other drivers, motorcyclists, bicyclists and pedestrians.

Case studies were used to help in evaluating traffic situations such as hazards in advance of the 4-second stopping distance, 2-second following distance, and 12-second visual lead. Participants also practiced responding to traffic situations shown on flash cards in such things as decision making, adjusting speed to conditions, and choice of best travel path.

Results showed no evidence of improvement in information processing speed. When visual training scores were added to flexibility training and stress-management scores, drivers showed improvement in observing skills during the final two weeks of the project. Since observing was a significant factor differentiating between good and poor drivers, and given that the scores on observing showed no improvement until the final testing, it may be that the visual-perception training positively impacted this driving skill. In addition, scores on trait anxiety were correlated with those on observing and since the stress management program was effective in reducing driver anxiety, it is likely that both the stress-management and visual-perception training were responsible for improving observing skills.

The training program reported by Long and Rourke [17] involved male college students rather than elderly people but found highly significant training effects. They used a variety of apparatus and stimuli modeled after similar studies on dynamic visual acuity whereby students practiced identifying the direction of target gaps. They found the greatest improvement in dynamic visual acuity among the poorer performers, i.e. those whose need for improvement was greatest. Whether or not this technique would be applicable to older subjects is speculative.

PHYSICAL CAPABILITIES

Considerable research has been done on the physiological changes that occur as people age yet very little of this information has been scientifically tested as it relates to the task of driving [18].

Aging

Changes that are generally associated with normal aging include changes in the cardio-vascular system, the kidney, lung, gastrointestinal tract, the skeleton, the immune and nervous systems and the sensory systems. Functions that these various systems per-form all show a decrease. For example, the cardiovascular system shows decreased cardiac out-put and decreased heart rate. The changes in lung functioning indicate decreased vital capacity and decreased oxygen uptake. In the nervous system, decreased function includes slower psycho-motor performance, decreased intellectual performance, and decreased complex learning [19].

One of the greatest challenges to researchers and the medical community is to distinguish between normal aging and the pathological changes such as illness and disease. In addition there is growing consensus that people age in very different ways and at very different rates. Much of the information about changes with age comes from cross-sectional studies rather than from longitudinal studies; consequently, it is difficult to know whether these differences are simply the effects of age or the effects of environment, lifestyle, diet and activities that have occurred over a period of many years [19].

Many of the changes that are associated with the normal aging process result in very gradual loss. These losses begin in early adulthood but because the loss is not significant, functional impairment may not occur at all or, if it does, not until advanced old age. Loss of function does not become significant until it advances across a given level or threshold. The majority of older persons when administered laboratory tests will show normal values. The critical difference is that the rate of deterioration may not evidence itself until the person is subjected to a certain amount of stress or until a certain level of performance is needed [19].

Interestingly, studies that have followed cohorts of people over a period of time as they age have come to quite different conclusions than cross-sectional studies. Schaie [20] found that cognitive function can actually improve over time in an older population. Gerstenblith, Weisfeldt, and Lakatta [21] found that their patients who were free of heart disease did not show an inevitable decline in cardiac function with age. The essential thing to keep in mind is the principle of individual variation and that the best predictor of a person's performance when they are older is performance in their younger years.

Functional Capacity

In a search for a practical approach to the older driver there is current interest in investigation of a link between the physiological and the functional capacity of the individual as this relates to driving. There is increasing evidence that functional capabilities should be determined and that they may be the most important measure of a person's ability to drive safely. The fact that a person has a condition such as arthritis must be considered, yet there is no evidence in research that this disease has caused incapacity to drive or injury. There remains the possibility, however, that the functional capacity of the person could impair mobility and interfere with driving performance. It is estimated that nearly half of those people 75 and older who are living in the community are afflicted with some form of arthritis [22].

Another factor related to driving that is not apparent in most studies is that older people likely learned to drive when physical capabilities were at their best and through the years habits have not changed. On the other hand, it is known that some older drivers do compensate for their functional deficits and are able to change habits and not be prone to accidents. The problem becomes one of differentiating these potentially "safer" drivers from their accident-prone cohorts [23].

Reaction Time

What do some of the studies show relative to physical capabilities in driving? Considerable literature exists regarding reaction time in older persons and, almost without exception, reaction time has been found to slow with age [24]. Not only are single-motor responses slowed but complex forms of behavior also are affected. Separating the so-called central and peripheral components, or pre-motor and motor segments of reaction time is a complex process that uses electromyography (EMG) analysis. Most research studies have not used this technique; however, there is some evidence indicating that the central, or information processing time, is primarily responsible for age-related changes in reaction time [25]. Older drivers appear to need more time to perceive, organize and then react or respond to stimuli they encounter. As the complexity of the task increases, they are less likely to react appropriately when they are rushed and there are conflicting or confusing cues in the environment [26].

Studies on reaction time among older subjects have found correlations between physical fitness and psycho-motor speed. Reaction time is fastest in highly fit individuals regardless of whether or not they are trained athletes. Aerobic power has infrequently been assessed in relationship to physical fitness in psycho-motor studies and it is possible there are modifying variables that have not been controlled or investigated; i.e., alcohol consumption, smoking, drug usage, state of anxiety and motivation.

Regular exercise therapy has been studied to a limited degree with indications of improvement in cognitive performance and retrieval activity. In tests of changed range of motion of different functional joints, it was concluded that regular rhythmic exercises designed to flex and extend certain joints produced significantly greater flexibility in two-thirds of the participants. Changes in muscles and joints are associated with fatigue, stiffness and pain when driving. Perceptual sensitivity, especially in joint motion of the lower extremities tends to be more common among older persons. Reaction time is likely to be slowed or appropriate responses are prevented. When the spine is flexible, head rotation is possible along with better head turning and peripheral vision. Degenerative changes in the musculoskeletal system result in more fractures and greater severity of injury when an older person is involved in an auto accident [27].

Range-of-motion tests have been used to assess subjects' ability to reach and manipulate auto controls safely. Criteria included free movement with no pressure or resistance. The evaluator assessed active range of motion on both right and left sides of the neck measuring flexion, extension and rotation. Shoulders were measured for flexion, extension and horizontal abduction and adduction. Elbows, forearms, wrists, hips, knees and ankles were also measured. Degrees of movement have been established for these tests and are used as criteria [28,29].

The purpose of Cox's research was to determine if a sample of 115 older drivers with a mean age of 70 perceived their driving skills accurately as they related to those various abilities. It was found that over 87 percent rated themselves highly and that over 91 percent demonstrated the required skill in reaching and manipulating the controls. These drivers were basically aware of their driving abilities and able to rate their motor skills accurately, but not to a statistically significant degree. Data from the same sample showed a positive significance between driving frequency and performance, suggesting that driving frequency patterns may be a good indicator of overall performance [29].

<u>Musculoskeletal Strength</u>

Physiological changes resulting from the normal aging process are estimated to affect three out of five people aged 75 and older [30]. It has been postulated that in order to drive safely, a person needs adequate muscle strength, range of motion, good reaction, proprioception, light touch and localization, endurance and coordination. A decrease in muscle strength, slowing of reflex action or general bone deterioration will cause coordination and reaction abilities to be compromised [29]. Decrease in sensation, coordination and reaction skills may result in less than adequate accelerating, braking, steering, general maneuvering of vehicle, operating controls and getting into and out of the car.

Guidelines were prepared by the United States Public Health Service on musculoskeletal strength needed in the driving task [31]. Among their recommendations was that in order to make an accurate assessment of driving ability an "in car" evaluation was necessary. It was also felt that if a person's strength was as low as fair on a standardized manual muscle test where fair equals three, the person should have restrictions on driving. Except in research studies, these physical skills are not tested as they relate to driving.

While muscle strength, proprioception, light touch and localization, and reaction time all decrease with age, there are individual differences that may speed the progress or cause unevenness in the rate of change across systems. Reaction-time studies have shown mixed results. Whether or not it is only reaction time or the decision-making process that slows with age shows disagreement among researchers. Conclusions vary depending on the complexity of the task (how far one has to move) and what exactly needs to be done. One study found that reaction time was a predictor of driving ability and suggests that clinical tested times may predict performance [29].

Physical Therapies and Compensatory Measures

Before adequate countermeasures can be designed and tested, better models of driving performance need to be developed that incorporate not only physical capabilities but perceptual, sensory and cognitive abilities as they relate to actual driving performance.

Studies at West Virginia University found that range-of-motion exercises were effective in improving trunk rotation and shoulder flexibility of the older drivers in their project [32]. Through the cognitive stress management sessions in this program, these drivers learned to reduce anxiety and perceived as less stressful driving situations such as driving in fog or rain, yielding on a freeway and night driving. Not effective was the stress management as it related to speed of information processing. In addition, improvement and handling skills showed no change after flexibility and stress management sessions. The skills of observing, however, were improved after these drivers participated in a visual-perception driver-training program. This latter skill is important to a variety of driving tasks, so this finding is rather significant. Components of the observing score included such tasks as observing to the rear and to the side, and observing while driving forward and backward. Driving tasks that utilize this skill include parking, backing, changing lanes, driving straight and through blind intersections. Among recommendations for further research was the need for development of field-based assessments of older drivers and the eventual evolvement of normative performance data. This study was not designed to follow participants for any period following conclusion of the final test, so there are no data on accident reports.

Perhaps an effective countermeasure might be training drivers with physical impairments to adopt new and less risky habits. Actually, many drivers take it upon themselves to curtail driving in response to their problems. Several studies found that as people age, they increasingly restrict their driving to compensate for deficits [18]. So even though physical and/or medical problems are evident and may increase risk, it is more than compensated for by newly adopted driving patterns in a segment of the older population.

Rosenbloom [33] suggests that environmental factors are a greater barrier to older drivers than are declining physical and/or cognitive impairments. Environmental problems include roadway networks that discourage travel by elderly drivers as well as the location of activities to which older drivers might desire to travel.

One modification that has been suggested is giving more thought to placing appropriate restrictions on select older drivers so they can gradually curtail their driving. Specific criteria need to be developed based on functional rather than chronological age, although there is considerable justification for using 75 years as a criterion to increase frequency of testing [34].

There is little research on the relationship between physiological changes with age and specific driving tasks. Physiological changes due to normal aging are thought to affect three out of five people aged 75 and older, but these conditions vary considerably in degree and type across this population. Decrements or changes occur in most organ systems yet adaptations or compensations are easily made in most instances unless there are concomitant pathological conditions. Overall physical fitness and flexibility have been demonstrated to improve reaction time, cognitive performance, retrieval activity and increased energy. Poor posture due to osteoporosis or other conditions could have an effect on driving performance. A few standards have been set for muscle strength, range of motion and other musculoskeletal performances, yet studies have not linked detriments in these areas to actual driving performance. Again, the literature reinforces the tremendous variability among the older population, thus making generalizations nearly impossible and pointing out the need for individual assessments or more precise tests to select out persons who are at high risk for driving.

COGNITIVE FUNCTIONING

A considerable body of literature exists that suggests decline in cognitive functioning of aging individuals [35,36]. The assessment of cognitive functioning, however, is extremely complex and far from enjoying general agreement among researchers. Cognitive functioning consists of the basic elements of intelligence, learning and memory [37].

Intelligence

Huyck and Hoyer [38] define intelligence as a "range of abilities, including the ability to deal with symbols and abstractions, to acquire and comprehend new information, to adapt to new situations, and to appreciate and/or create new ideas." Intelligence is thought to be composed of many different components, presenting considerable difficulty in measurement.

Significant differences have been found between young and old on intelligence tests, with older people performing at a much lower level. Whether or not this is a result of a decline in intelligence or difficulty in measurement has not been thoroughly researched. Because of early cross-sectional findings, the stereotypical notion that intelligence declines in the later years has been perpetuated [37].

Factors that influence intelligence include biology, education, occupation, physical health, and sensory functions. Some studies have found poor performance on intelligence tests by elderly who are in poor health. Cardiovascular problems tend to cause a decrease in intelligence tests particularly in those that demand psychomotor speed [39]. The verbal sub-tests of intelligence tend to reflect poor scores when the subject being tested has moderate levels of hearing loss. Finally, another factor that has been found to affect intelligence test scores is anxiety. Causality for such findings has not been researched thoroughly, and it is not known whether people are slow to respond when they are in a high anxiety situation thus showing poor performance [37].

Two types of intelligence that have shown changes with age are fluid intelligence and crystallized intelligence [37]. The former consists of biologically determined skills that are independent of learning or experience, or so-called "native intelligence." Information is processed outside the context of existing knowledge. Crystallized intelligence refers to abilities and knowledge that a person acquires through experience and education.

Obviously, education and occupation affect crystallized intelligence scores, with people such as lawyers and teachers performing well on tests using verbal skills. Cognitive functioning appears to show less decline in people who use these abilities in jobs that require thinking and problem solving [37]. Abstract and fluid skills such as the occupations of architecture and engineering utilize show less decline on performance-based tests.

Physical and mental illness as well as sensory losses have more pronounced impact on intelligence in later years and may displace the positive influences of education and occupation.

<u>Learning and Memory</u>

The two other elements of intellectual processes are those of learning and memory. These are two cognitive processes that must be considered together. It is assumed that a person has learned information if he or she can retrieve that information from memory. Learning is the process whereby new information or skills are placed into one's memory; memory is the process of recalling the information that has been stored. Without going into the details of various kinds of memory, suffice it to say that with age it appears there is a reduction in the efficiency of processing information in sensory and primary memories, and subsequent retrieval from secondary memory [37]. Considerably more research needs to be done, however, before there is consensus on the reasons for these changes.

Experimentation with techniques for improving memory has been shown to be helpful for older persons; however, many do not practice the use of newly learned memory techniques either because they are not motivated or because they may forget to practice. One aspect of memory enhancement that has been found to be important is that of anxiety. When a person is anxious or stressed during the learning stage the information is not stored, thus the memory cannot retrieve this information.

It is obvious that adequate cognitive functioning is vital to the demands of safe driving. One needs to take in or learn new information, remember it, process it, organize it in some kind of logical or appropriate manner in order to make choices from that information, decide on action or maneuvers to make and then carry out that decision [40]. When new tasks need to be learned, older people can benefit from methods to help organize their learning. Techniques such as mnemonics, use of imagery and relaxation have been demonstrated to facilitate learning [37].

Numerous studies have concluded that intact cognition is a necessary component of safe driving [41,42,43]. There is ample reason to be concerned about cognitive functioning in the older population since many factors can contribute to cognitive impairment. Older individuals are considerably more prone to chronic illness and disease, especially cardiovascular and cerebrovascular diseases, diabetes mellitus, dementia and depression. These are among the most commonly treated conditions among older persons and along with the medications prescribed are important factors to cognitive functioning as it regards the driving task. It has been reported that nearly three-fourths of the 75 and older population use prescribed drugs and of the ten most often prescribed for heart disease, six are considered to cause mental confusion [44]. When one considers the inter-relationships between chronic and acute illness, and medication effects and interactions it would appear that there is potential for problems in driving, yet little research has been done to substantiate this fact.

Dementia

One of the areas of concern and disagreement among researchers is that of dementia. The most common cause of dementia is Alzheimer's Disease which has been estimated to account for about 55 percent of dementia cases [45]. A 1989 report in the Journal of the American Medical Association by Evans et al. estimates the incidence of Alzheimer's Disease at 18.7 percent for persons aged 75 to 84 and 47.2 percent in the 85-and-older population [46]. This research was conducted in a sample of community residents rather than outpatients in geriatric assessment clinics or other outpatient chronic-care institutions. While the researchers who conducted the Boston community study of the prevalence of Alzheimer's Disease acknowledge limitations to their study, it can be concluded without contention that there are considerable numbers of older people with Alzheimer's Disease, particularly in the 85 and older age group. One of the critiques of this study is that diagnoses were based only on performance of objective tests whereas functional capabilities were not a factor in the diagnosis [47].

Research has not clarified the impact of mild or moderate cognitive changes due to Alzheimer's on the ability to drive safely [48]. A few states require physicians to report to local licensing authorities patients who have medical conditions that might affect their ability to drive [49]. Making this diagnosis and subsequent reporting is not a simple matter for physicians since there are few guidelines on how to arrive at a clinical assessment of an individual's fitness to drive [48].

The impact of memory loss has been found to be important in driving capabilities. Persons with Alzheimer's Disease not only have impairment in memory functions, but also may have a variety of behavioral and cognitive changes, any or all of which may contribute to poor driving ability. These other conditions include deficits in visuospatial capabilities, reaction time, impaired judgment, visual dysfunction, attention deficits and denial of illness [45,50]. While Friedland's study had a small number of patients, it did have a control group. Nearly five times the number of people who had a crash in the previous 5 years before the study were shown to have Alzheimer's Disease. He found that most of the crashes that individuals with Alzheimer's were involved in occurred because of mistakes made in judgment, lapses in attention, slowed reaction time and perceptual distortions or defects.

Friedland went on to state that while there are few guidelines to help physicians arrive at a clinical impression of a person not being fit to drive, nevertheless there should be two guiding principles. The first is that physicians need to be aware of the issue of driving when a person has suspected Alzheimer's Disease and that it is necessary to gather relevant information including secondary data from family or significant others. The second principle is that formal evaluation of patients should be done to guide the physician in making a recommendation about driving. The decision that a physician makes is like walking on a tight wire. In some instances the patient may be able to drive for some time even though there are substantial intellectual deficits. When informants state that an older person's driving abilities are compromised and there is evidence of dementia, the physician should recommend a complete evaluation and certainly an on-road driving test.

Another author recommends more research to distinguish among safe and unsafe drivers who may have symptoms of mild dementia. Lucas-Blaustein et al. [51] found that 30 percent of their patients sampled had at least one accident since the symptoms of dementia began. Since Alzheimer's Disease is a progressive dementing illness with cognitive impairment, these clinicians recommend driving be discontinued once the diagnosis is made. If diagnosis is made early in the course of the disease, it may be possible to use a process of discontinuation rather than a sudden halt to driving. Having some time to develop alternatives is likely to be helpful to the patient and family.

An unpublished study by the University of Nebraska Medical Center points out that dementia appears to be a contributing factor in a considerable number of accidents and that there are some tests that appear to be usable in detecting factors that may help explain these accidents. The Geriatric Assessment Clinic at the University of Nebraska Medical Center found in their multidisciplinary evaluation of 154 patients from August, 1988 to August, 1989, that 74 (average age of 79 years) were drivers at time of appointment or had stopped driving within the last 3 years. Nineteen percent of the 74 current or recent drivers reported having accidents and 51 percent reported getting lost while driving.

A variety of clinical tests were administered to these patients. These tests included the Mini Mental State Exam (MMSE), a hand-function performance test (PerfT), and a neuropsychological screen (Reg E) that tested mental control, logical memory, word fluency, and visual scanning/short term memory. The Trail Making Test A (TMT A) was a sub-test of the Reg E. In addition, scores were determined on a cumulative illness rating scale (CIRS) and a cumulative-dementia rating (CDR) scale. Of the 74 current or recent drivers, 31 percent had a CDR of 1.0 or higher, indicating dementia. Eleven of this group scored as moderately demented with nine having driven in the last 3 years. T-tests revealed significant differences in MMSE scores ($p<.03$), Reg E ($p<.01$), TMT A ($p<.002$), and PerfT ($p<.005$) with recent drivers performing more poorly than those who were still driving. Those who reported accidents within the last 3 years scored lower on the MMSE ($p < .05$), Reg E ($p < .03$), and TMT A ($p < .05$) than those with no accidents. The former groups were also more likely to get lost while driving ($p < .0005$).

In addition to dementia caused by Alzheimer's Disease, there are other causes of dementia, confusion and delirium [52]. Dementia can be the result of multiple small or large cerebral infarcts. This type is estimated to occur in 8 to 29 percent of all dementias. Other causes are normal pressure hydrocephalus, prescription or over-the-counter drugs, alcohol induced, depressive disorders, and metabolic disorders such as liver failure, hyperglycemia, and nutritional deficiencies. Following criteria from the Diagnostic and Statistical Manual of the American Psychiatric Association, these symptoms must be observed in the diagnosis of dementia: (1) loss of intellectual ability resulting in social or occupational impairment, (2) memory impairment, (3) impairment in abstract thinking, judgment, other higher cortical functions or a personality change, (4) clear state of consciousness, and (5) documented or presumed evidence of an organic cause [53].

For the primary dementias such as Alzheimer's Disease and multi-infarct, there are no specific treatments available to delay or reverse cognitive deficits [52]. Certain medical treatments may offer reversal or control in other types of dementia, confusion or delirium.

Since driving is a complex task requiring a number of cognitive, sensory and psychomotor skills, it appears persons who are afflicted with these irreversible conditions and those in the acute stages of other conditions would be impaired drivers. The medical community, however, is not in agreement regarding dementia-diagnosed patients driving [47,50,54]. Certainly screening tests are needed to assist in identifying drivers who are at risk, then a complete evalua-tion plus driving test administered in order to accurately detect incompetent older drivers [54].

ANALYSIS OF DATA FROM IMMANUEL REHABILITATION CENTER

Research during the past few decades has provided a knowledge of certain specific impairments of older people. As related to the driving task, these impairments may be classified into three categories: (1) sensory impairments, which include any deficiency in human senses that may affect the amount or quality of information received while driving; (2) perceptual impairments, which are related to the human ability to identify objects presented while driving;

and (3) cognitive impairments, which are related to the human ability to match the perceived information with past experience and decide on the proper action to be taken.

Several sensory, perceptual, and cognitive factors have been evaluated as possible discriminators between young and old drivers. For example, static acuity, dynamic acuity, target detection, visual tracking, reaction time, short-term memory measures, long-term memory measures, memory-organization measures, attention, cognitive-flexibility measures, cognitive overload, and many others have been measured for young and old people to determine if any differences exist between the two age groups [55]. To various degrees, all of the above factors have been found to exhibit some age differences. However, the degree of discrimination was not the same for all factors, and it was highly dependent on the type of task and on the age difference between the two groups of younger and older drivers being considered. Also, people of the same age, either young or old, usually have different sensory, perceptual, and cognitive abilities due to factors other than the age. Consequently, age alone has not been found to be a reliable indicator of driving performance.

A driving performance model composed of sensory, perceptual, and cognitive factors would be helpful in identifying therapies and behaviors that would improve, or compensate for, the abilities associated with these factors, and, in turn, improve driving performance. The objective of this study was to evaluate a set of sensory, perceptual, and cognitive factors relative to their ability to predict the driving performance of older drivers. The results of this determination was used as a basis for identifying appropriate therapies and compensatory behaviors for improving the driving performance of older drivers.

Factors

The factors evaluated in this study were far acuity, near acuity, depth perception, right peripheral vision, left peripheral vision, brake reaction time, and five measures of visual perception.

Vision

Static visual acuity (SVA) is the only function that is routinely checked by all state licensing authorities. SVA is highly dependent on the illumination conditions and target background contrast. Forbes [56] found an age decrement under low-illumination conditions. Burge [57] and Pollack [58] found that overall SVA declines significantly after about age 45. However, individual variability remains quite large as age increases.

According to Henderson and Burg [59], the central movement in depth (CMD) is defined as the ability to perceive a change in image size in the central portion of the visual field. Performance appears to deteriorate after the age of 55, and is definitely poorer for subjects who are 65 years or older [60]. There is some evidence relating CMD to driving performance [61].

The visual field is highly important for the driving process since many of the cues utilized by the driver are located on both sides of the roadway. According to Allen [62], the central vision requires 1/5 to 1/4 second to fixate each portion of the field, thus greatly lengthening the time necessary for the driver to update his internal model at the traffic situation. Wolf [63] found that the lateral visual field narrows with age, beginning in the fifth decade and proceeding by up to 10 degrees decrements in each succeeding decade. Burg [64] reported similar results.

Reaction Time

The marked reaction-time differences between young and old people suggest that as people age, they have more difficulty with the processes involving the central nervous system. According to Birren [65], Birren and Renner [66], and Welford [67], age-related motor deficits are due to impairments in the speed with which the central nervous system can process the information to respond. The absolute magnitude of the effects of age on speed vary with the specific dependent variable under investigation, but for many variables the proportional difference between adults in their 60's and those in their 20's is between 20 and 60 percent, suggesting that the speed loss ranges from 5 to 15 percent per decade [68].

Visual Perception

The Motor-Free Visual Perception Test (MVPT), designed and standardized on children by Ronald Colarusso and Donald Hammill [69], was used in this study to assess the visual perception capabilities of older drivers. The test is composed of thirty-six questions divided into five groups. Each group assesses one aspect of visual perception. The groups are: (1) spatial relationships, which is the ability to orient one's body in space and perceive the positions of objects in relation to oneself and other objects; (2) visual discrimination, which is the ability to discriminate dominant features in different objects; (3) figure-ground, which is the ability to distinguish an object from its background; (4) visual closure, which is the ability to identify incomplete figures when only fragments are presented; and (5) visual memory, which is the ability to recall dominant features of one stimulus item or to remember the sequence of several items [70]. A modified version of MVPT has been used to evaluate brain-damaged people [69], but the use of MVPT to evaluate elderly people has not been reported in the literature.

Methodology

The data for the study were obtained from the driver rehabilitation program of the Immanuel Rehabilitation Center in Omaha, Nebraska. Discriminant analysis was used to identify the factors most highly correlated with the driving performance of older drivers.

Data

The data were obtained from the patient records of 117 drivers in the driver rehabilitation program. The drivers were between the ages of 55 and 88 years. The data included measures of each driver's near and far visual acuity, depth perception, left and right peripheral vision, brake reaction time, and on-the-road driving performance. The vision measures were taken with a Keystone telebinocular testing device. The brake reaction times were measured with a Doron L225 driving simulator. The stimulus was a variable display of two single-digit numbers. When the numbers presented were identical, the subject was to release the gas pedal and push the brake pedal as fast as possible.

The driving performance was evaluated using an on-the-road driving test similar to the one administered by the Nebraska Department of Motor Vehicles. Based on the results of the test, a subject's driving performance was classified as either "satisfactory" or "unsatisfactory." "Satisfactory" performance meant that the driver passed the driving test. "Unsatisfactory" performance meant that the driver failed the driving test.

For 46 of the 117 drivers, MVPT scores were also obtained. For each of the five visual perception measures (i.e., figure ground, spatial relationships, visual memory, visual closure, and visual discrimination), two scores were available per subject. One was the mean time required for the subject to answer the questions pertaining to the given measure, and the other was the number of questions answered correctly. Unfortunately, one or more data points were missing for many of the subjects which limited the sample sizes to less than 46.

Analysis

The dependent variable in the data analysis was the driving performance of the older drivers which was based on the results of the on-the-road driving test. This dependent variable took one of two values: "satisfactory," which represented the driver who passed the on-the-road driving test, or "unsatisfactory," which represented the driver who failed the on-the-road driving test. Thus, the dependent variable was a categorical one. On the other hand, the independent variables in the data analysis were age and the aforementioned sensory, perceptual, and cognitive factors, which were continuous variables.

Discriminant analysis is a statistical method that is suited to the analysis of this type of data, where the dependent variable is categorical and the independent variables are continuous. It selects the linear combination of independent variables, called a discriminant function, that will discriminate best between a priori defined groups. This is achieved by the statistical decision rule of maximizing between group variance and minimizing within group variance [71]. In other words, discriminant analysis separates the groups by determining the factors that best separate the members in a multidimensional space. A profile of the group members can be developed from the discriminant function, and the discriminant function can be used to predict the group membership of new and untested units.

Two discriminant analyses of the older driver data were conducted. The first analysis included all of the independent variables except the MVPT scores. The second analysis included all of the independent variables. The application of MVPT in the evaluation of older drivers was not found in the literature. Therefore, the two analyses were done in order to determine if the MVPT data would improve the discriminant function.

The "discriminant" procedure of the SPSSX computer package [72] was used to conduct the discriminant analyses. The package uses the step-wise procedure for entering variables into the discriminant function. Optionally, the package allows specifying any of five different step-wise methods. These methods enter and remove variables one at a time, selecting them on the basis of specific criteria. The Mehalanobis' step-wise method, which selects the variable that maximizes the Mehalanobis' distance between the two closest groups, was used in the analyses.

The SPSSX package allows specification of a fraction of the sample to be randomly selected from the whole sample to develop the discriminant functions. The package uses the remaining fraction in the validation stage of the analysis. In both analyses, 60 percent of the data was used in the function-development stage, and the remaining 40 percent was used in the validation stage. Also, the option in the package that allows substituting means for missing values during validation was selected. Cases with missing values were not used during the development stage. But during validation, means were substituted for missing values and cases containing missing values were classified.

Results

Without MVPT Scores

In the first analysis, which did not include the MVPT scores, the univariate F-test statistics for the equality of group means for each variable resulted in four variables to be significant: (1) age ($F_{1,26}=24.20$, $p<0.0001$), (2) far acuity ($F_{1,26}=4.54$, $p<0.0427$), (3) left visual field ($F_{1,26}=7.28$, $p<0.0121$), and (4) reaction time ($F_{1,26}=16.93$, $p<0.0003$). These results indicate that the two groups of older drivers, namely "satisfactory" and "unsatisfactory," were significantly different from each other with respect to age, far acuity, left visual field, and reaction time.

An evaluation of the derived discriminant function, shown in Table 5-1, indicates that the derived function is highly significant. Table 5-2 shows the standardized coefficients of the independent variables and the pooled within-group correlations between the independent variables and the function. Both measures, the standardized coefficients and the correlations, show the relative importance or weight of each variable in the function.

Table 5-1. Evaluation of discriminant functions from analysis data from Immanuel Rehabilitation Center in Omaha, Nebraska.

Analysis	Eigenvalue	Wilks' Lambda	Chi-Squared	Degrees of Freedom	Significance
With MVPT Scores	1482.21	0.00067	40.161	7	0.0000
Without MVPT Scores	2.07	0.32590	27.469	3	0.0000

The discriminant function group mean for the "satisfactory" drivers was -0.72376, and the group mean for the "unsatisfactory" drivers was 2.65377. Therefore, based on the standardized coefficients shown in Table 5-2, younger age, faster brake-reaction time, and wider right peripheral vision would favor membership in the group of "satisfactory" drivers.

Table 5-3 shows the validation results of the discriminant function. The upper half of the table shows the classification of the cases used in developing the discriminant function, while the lower half shows the classification of the remaining validation cases, which were not used to develop the discriminant function. The overall classification accuracy for the validation cases, as shown at the bottom of the table, was 64.29 percent.

Table 5-2. Standardized coefficients and pooled within-group correlations for analysis without MVPT scores of data from Immanuel Rehabilitation Center in Omaha, Nebraska.

Variables in the Function	Standardized Coefficients	Pooled Within-Group Correlations
Age	0.723	0.671
Right Vision	-0.409	-0.170
Reaction Time	0.794	0.561

Table 5-3. Classification results for analysis without MVPT scores of data from Immanuel Rehabilitation Center in Omaha, Nebraska.

Actual Group	No. of Cases	Predicted Group Membership	
		Group 1	Group 2
* Classification results for cases selected for use in the analysis			
Group 1	32	31 96.9%	1 3.1%
Group 2	16	6 37.5%	10 62.5%
Ungrouped	23	14 60.9%	9 39.1%
Percent of "grouped" cases correctly classified = 85.42%			
* Classification results for cases not selected for use in the analysis			
Group 1	15	14 93.3%	1 6.7%
Group 2	13	9 69.2%	4 30.8%
Ungrouped	18	14 77.8%	4 22.2%
Percent of "grouped" cases correctly classified = 64.29%			

With MVPT Scores

In the second analysis, which included the MVPT scores as independent variables, the univariate F-test statistics for the equality of group means for each variable resulted in four variables being significant: (1) age ($F_{1,9}$=7.41, $p<0.0235$), (2) left visual field ($F_{1,9}$=8.12, $p<0.0191$), (3) brake reaction time ($F_{1,9}$=12.21, $p<0.0068$), and (4) accuracy in spatial relationships test ($F_{1,9}$=6.82, $p<0.0282$). These results indicate that the two groups of older drivers, namely "satisfactory" and "unsatisfactory," are significantly different from each other in their age, left visual field, brake reaction time, and accuracy in answering the spatial relationships questions on the MVPT.

An evaluation of the derived discriminant function is shown in Table 5-1. From this table, the derived function is highly significant. Table 5-4 shows the standardized coefficients of the independent variables and the pooled within-group correlations between the independent variables and the function. The discriminant function group mean for the "satisfactory" drivers was -16.42, and the group mean for the "unsatisfactory" drivers was 73.87. Based on the information in Table 5-4, membership in the "satisfactory" driver group would be favored by better depth perception, faster brake reaction time, faster response time for answering the figure-ground test questions, and greater accuracy in answering the visual-discrimination test questions.

Table 5-4. Standardized coefficients and pooled within-group correlations for analysis with MVPT scores of data from Immanuel Rehabilitation Center in Omaha, Nebraska.

Variables in the Function	Standardized Coefficients	Pooled Within-Group Correlations
Depth Perception	-4.428	0.012
Reaction Time	30.552	0.030
Figure Ground (Reaction Time)	31.228	0.013
Spatial Relationships -4.327 (Reaction Time)	0.010	
Visual Memory (Reaction Time)	-10.696	0.003
Spatial Relationships 25.916 (Accuracy)	-0.023	
Visual Discrimination -22.358 (Accuracy)	-0.017	

Table 5-5 shows the results of the discriminant function validation. The upper half of the table represents the classification of the cases used in developing the discriminant function, while the lower half represents the classification of the validation cases. The overall classification accuracy for the validation cases, as shown at the bottom of the table, was 80 percent.

Table 5-5. Classification results for analysis without MVPT scores of data from Immanuel Rehabilitation Center in Omaha, Nebraska.

Actual Group	No. of Cases	Predicted Group Membership	
		Group 1	Group 2
* Classification results for cases selected for use in the analysis			
Group 1	12	11 91.7%	1 8.3%
Group 2	6	0 0.0%	6 100.0%
Ungrouped	11	3 27.3%	8 72.7%
Percent of "grouped" cases correctly classified = 94.44%			
* Classification results for cases not selected for use in the analysis			
Group 1	6	5 83.3%	1 16.7%
Group 2	4	1 25.0%	3 75.0%
Ungrouped	7	3 42.9%	4 57.1%
Percent of "grouped" cases correctly classified = 80.00%			

Discussion

The evaluation measures of the derived functions in Table 5-1 indicate that the discriminant function derived from the analysis using all the variables, including the MVPT scores was better than the one from the analysis which excluded the MVPT scores. The eigenvalues represent the between-groups sum of squares to the within-group sum of squares ratio. Large eigenvalues are associated with "good" functions. Wilks' Lambdas (U-statistics), the third column in the Table 1, represent the ratio of within-groups sum of squares to the total sum of squares. A lambda of "1.0" occurs when all observed group means are equal, and a lambda close to "0.0" occurs when within-groups variability is small compared to the total variability (i.e., when most of the total variability is attributable to differences between the means of the groups). Based on Wilks' Lambda, a test could be made of the null hypothesis that there was no difference between the group means in the populations from which the samples were drawn. Lambda can be transformed to a variable which has approximately a Chi-square distribution. The last three columns in Table 5-1 show the Chi-square value, the degrees of freedom, and the level of significance as translated from Wilks' Lambda values. It is clear from the last column that both functions are significant.

It is important to remember that even though Wilks' Lambda may be statistically significant, it provides little information about the effectiveness of the discriminant function in classifying the drivers into the two groups. It only provides a test of the null hypothesis that the population means are equal. Small differences may be statistically significant, but still not provide good discrimination among the groups.

On the other hand, the percentage of correct classification for the cases that were used in deriving the discriminant functions, is an inflated estimate of the true performance in the population, just as R^2 is an overly optimistic estimate of a model's fit in regression. The uninflated estimate of the true performance in the population can be based on the percentage of the validation cases classified correctly. When evaluating this measure, it is important to compare the observed correct classification rate to that expected by chance alone. The objective is the correct identification of the members of both groups, and the cases are of unequal sample sizes. Therefore, the proportional chance criterion can be used to calculate the classification accuracy by chance according to Equation 5-1.

$$C = \sum_{i}^{n} P_i^2 \tag{5-1}$$

where,

C = classification accuracy by chance,

P_i = proportion of group's i sample size to the total sample size, and

n = number of classification groups.

Table 5-6 summarizes the results of classification accuracy by chance as well as the classification accuracy obtained from the discriminant functions. The last column in this table shows the accuracy added by the discriminant functions over the accuracy obtained by chance alone. The minimum acceptable classification accuracy depends on the cost in relation to the value of the information. But, the cost versus value argument is not applicable in this analysis. Hair et al. [71] suggested that the minimum acceptable classification accuracy should be at least 25 percent greater than that achieved by chance. Comparing this criterion with the percentiles in the last column of Table 5-6, both discriminant functions provided the minimum. However, the discriminant function derived in the analysis with the MVPT scores had the higher classification accuracy, 80 percent, which was about 54 percent greater than that provided by chance alone.

Table 5-6. Functions' classification abilities compared to chance for data from Immanuel Rehabilitation Center in Omaha, Nebraska.

Analysis	Classification Accuracy by Chance	Classification Accuracy with Function	Percent > Chance
With MVPT Scores	52.00	80.00	53.85
Without MVPT Scores	50.26	64.29	27.91

Conclusion

A number of factors associated with vision, reaction time, and visual perception were found to be predictors of the driving performance of older drivers. The inclusion of the MVPT scores improved the ability of the discriminant function to classify older drivers into two groups, "satisfactory" and "unsatisfactory" drivers. Based on the results of the study, it seems that therapies, or compensatory behaviors, concerned with improving the older driver's depth perception, peripheral vision, brake reaction time, figure-ground perception, and visual discrimination may improve the driving performance of the older driver.

It is interesting to note that age was not one of the predictor variables in the discriminant function when the MVPT scores were included in the analysis. It is well known from previous research that many perceptual and cognitive abilities, especially those involving nervous system processes, deteriorate with age, and so in the presence of many perceptual and cognitive variables the age has no place.

OLDER DRIVER SURVEY

A survey was conducted of the Immanuel Hospital's AgeWell members 75 and older. The purpose of the survey was to obtain some information about the characteristics of elderly drivers, their perception of the driving problems, and their ideas ways to improve highway safety.

The survey procedure involved four mailings. First, a letter was mailed on July 30, 1990, telling the subjects that they would receive the questionnaire within a few days and explained the purpose of the survey. A second letter, the questionnaire, and a postage-paid return envelope was mailed August 2, 1990. The third mailing was sent on August 7, 1990 to thank subjects if they had already returned the survey and remind them to send it if they had not. The fourth mailing was sent August 10, 1990, and contained essentially the same information as the third.

Demographics

A total of 770 names were on the list of Agewell members 75 and older, and 425 surveys were returned for a response of 55 percent. The mean age of the respondents was 79.5 years. Their age range was 64 to 91. Nineteen were younger than 75 years, because they were responding to the survey which had been sent to their spouses who were 75 and older. Sixty percent of the respondents were female, and 40 percent were male respondents.
Most (90 percent) lived in the metropolitan Omaha area with 6 percent living in nearby towns under 50,000 population and 10 percent residing in rural areas. Fifty-two percent were married, 42 percent were widowed, and 6 percent were single. Eighty-six percent had high school or higher educational levels. Only 4 percent were employed. They reported a mean monthly income of $2,301.

Driving Experience

Of the 425 who returned the survey, 341 were driving (80 percent). The average number of years they had been licensed to drive was 55. Only 39 (9 percent) of the drivers had taken a driver-education class when they first got their license. Ninety-three (22 percent) had since completed a course for older drivers. However, 320 (75 percent) reported no difficulty in renewing their last license.

The average number of miles driven in the past year was 6,541. The majority (89 percent) drove between the hours of 8:00 am and 4:00 pm. Eighty-eight percent either didn't drive at night, or drove less than 15 percent of time at night.

Ninety-two percent reported receiving no violation tickets. Of those who did, 13 people were ticketed for speeding. Eighty-six percent indicated that they had not been involved in an accident within the last 2 years.

Driving Problems

Questions were asked about common driving problems. The majority indicated no problems. The most common problems at traffic signals were:

1. turning right on red (7 percent)
2. knowing the proper lane to be in (5 percent)
3. seeing the traffic signal (4 percent)
4. knowing where to stop (2 percent)
5. knowing when to stop (2 percent)
6. knowing when to go (1 percent)

The most common problems at stop signs

1. having enough time to cross (7 percent)
2. deciding when it is safe to cross (6 percent)
3. seeing traffic on the cross street (3 percent)
4. seeing the stop sign (3 percent)
5. remembering to look for traffic on the cross street (3 percent)
6. knowing where to stop (2 percent)

Respondents were asked about problems making left turns at signalized intersections. Most did not report any problems, but of those who did, the biggest problem (26 percent) was having their view blocked by vehicles turning left from the opposite direction. Other common problems turning left at traffic signals were the following:

1. knowing the proper lane to be in (7 percent)
2. seeing when it is safe to turn (6 percent)
3. knowing where to turn (4 percent)
4. knowing when to go (4 percent)
5. knowing when to stop (3 percent)
6. understanding the green-arrow left-turn signal indication (3 percent)
7. knowing where to stop (2 percent)
8. seeing the traffic signal 2 percent)

Sixty-three percent of the respondents indicated that they had the most difficulty driving through intersections that were uncontrolled. Only 3 percent had the most difficulty at signalized intersections. Twenty-five percent indicated that they had the most difficulty at intersections with yield signs, and 9 percent had the most difficulty at stop signs.

Safety Improvements

Forty-three intersections in the Omaha area were identified by 123 of the respondents as being the most difficult to drive through. Five of the 13 elderly-driver high-accident locations described in Chapter 3 were among those identified. The most frequents suggested ways to improve traffic safety at these locations were the following:

1. install traffic signal at intersections without one already (19 percent)
2. install grade separation (12 percent)
3. enforce, or lower, speed limit (12 percent)
4. retime traffic signal
5. widen intersection (9 percent)
6. install protected left-turn phase (9 percent)
7. increase sight distance.

Sixty-seven intersections in the Omaha area were identified by the elderly drivers asbeing the most difficult at which to make a left turn. Six of the 13 elderly-driver high-accident locations described in Chapter 3 were among those identified. The most common suggestions for improving traffic safety at these locations were:

1. install a protected left-turn phase (19 percent)
2. install traffic signal (19 percent)
3. enforce, or lower, speed limit (13 percent)
4. increase protected left-turn time (6 percent)
5. increase sight distance (6 percent)
6. install grade separation (5 percent)

This group nearly all reported as valuable to traffic safety left-turn lanes, protected left-turn signal phases, stop signs, and traffic signals. Also, they generally considered as valuable larger signs, lower speed limits, more stop signs and traffic signals and wider parking spaces.

Vision and Physical Condition

Nearly all of the elderly drivers (90 percent) described their vision (with glasses, if worn) as excellent or good. Fifteen percent reported cataracts, 4 percent reported glaucoma, and 10 percent considered themselves to have night blindness. Twenty-five percent reported they had trouble seeing street name signs until they were too close to do any good.

The overwhelming majority had no problems with stiff or painful joints, or with the ability to control their cars. However, twelve percent reported they had trouble turning their head to look over their shoulder when backing up. They generally used their inside rear view mirror and driver side rear view mirror to compensate for this inability. Thirty-one percent reported they never or seldom used their passenger-side rear-view mirror.

CONCLUSION

There are a number of categories of older drivers:

(1) Those who are careful, safe drivers with little, if any, physical, perceptual or cognitive deficits that impair driving ability.

(2) Those who are careful, safe drivers who may have limited deficits related to the aging process or to disease and who compensate for these problems by altering their behavior to accommodate. An example: a person's night vision impaired to a significant degree and thus doesn't drive at dusk and dark.

(3) Those who have significant impairments in physical and/or cognitive abilities and continue to drive because they can't or won't recognize their deficits and driver testing may not be selective or specific enough to identify these high risk individuals. An example: a person with Alzheimer's Disease who does not realize impairments and gets lost, forgets what signs mean and creates havoc for himself and others on the roadways. No estimates are available as to the numbers of people in each of these groups.

It is known that many decrements of age don't manifest themselves to any significant degree until the mid 70s and later. No studies were found where the mean age of subjects was 75 and older, or where normative capabilities of older people were established, so inferences need to be made to this age group from other studies using younger subjects. It is known that accidents per mile driven increase dramatically for those drivers 75 and older and that the risk of being fatally injured in an automobile accident is high. Older drivers appear to be involved in more accidents where the driving maneuver requires greater driver performance and perceptual skills such as making left turns and entering or crossing the roadway from a cross road.

A further complicating factor is the difficulty encountered in differentiating among the various tasks involved in driving and their relationship to visual and cognitive capabilities and roadway conditions. An example: is making an inappropriate left turn against on-coming traffic a factor of poor vision, slow reaction time, unawareness of signal message, or misperception of distance and speed of approaching traffic?

There is considerable research on decrements that occur as people reach advanced years, but little as to how these relate to the complex task of driving and even less as to what remedial measures or "therapies" can be implemented to improve or compensate for deficits.

The three factors of vision, physiological capabilities and cognitive impairment have been discussed in general and more specifically, how they relate to driving. It has been estimated that 90 percent of total input to a driver is visual. Static visual acuity is the most often used vision test administered at driver testing sites; however, dynamic vision is thought to be more closely related to the driving task but is seldom tested. Both static and dynamic acuity show small but statistically significant correlations with accidents. In one study, static acuity was the best predictor of overall accident involvement in older drivers in low illumination situations. Of all the visual functions, dynamic acuity appears to demonstrate the most consistent relationship to a driving record.

There is some evidence that training improves dynamic acuity in younger persons. Studies have shown that acuity declines as the drivers' speed increases. Exposure time, illumination and practice have been shown in a few instances to improve acuity. Acuity declines as objects move from the central field to the peripheral field. Even among individuals with essentially the same static acuity, marked differences exist. Visual discrimination and figure-ground skills are a result of fundamental mechanisms of perception. These abilities may appear normal until a person is required to perform multiple-step activities under time limitations or stressful conditions.

Brain-damaged victims have shown improvements in perceptual skills and improved driving performance through training in specific tasks such as visual scanning, directed eye movements, spatial perception and discrimination, figure/ground differentiation and others. Whether or not this training would be beneficial to certain cognitively impaired older persons is not known. A West Virginia study found that visual perception training in older drivers was effective in improving tasks such as observing to the rear and sides when performing various driving maneuvers.

Regarding physical capabilities there has been little research on the relationship between physiological changes with age and specific driving tasks. It is known that decrements or changes occur in most organ systems yet adaptations or compensations are easily made in most instances unless there are concomitant pathological conditions. Overall physical fitness and flexibility have been demonstrated to improve reaction time, cognitive performance, retrieval activity and increased energy. Poor posture due to osteoporosis or other conditions could have an affect on driving performance, but there are no studies to support this notion. Physiological changes due to normal aging are thought to affect three out of five people over the age of 75 but these conditions vary considerably in degree and type across this population. A few standards have been set for muscle strength, range of motion and other musculoskeletal performances, yet studies have not linked any of these decrements to driving performance.

Regarding cognitive function, there is concern about performance capabilities of older drivers, yet little research upon which to base these concerns or compensatory actions one might take. There are many complex and poorly understood interactions between chronic and acute illnesses, medication effects on function, disease states such as cardiovascular, diabetes, and Alzheimer's Disease, to mention a few. All have the potential for explaining differences in driving abilities but few studies have done so.

Johns Hopkins data indicate that incapacitating dementing impairment among elderly drivers may be a significant social problem. Thirty percent of their sample had at least one accident after the diagnosis of dementia. The University of Nebraska Medical Center Clinic data on 154 patients indicted that 24 percent of drivers with dementia had accidents and 51 percent experienced disorientation or getting lost according to a collateral source. A study out of Toronto, Canada recognized the problem of dementia and calls for research on guidelines for driver testing and clinical judgments as to driving capabilities. Varied results have come from studies on divided attention and selective attention (distraction, memory, etc.). It is commonly acknowledged that changes in cognitive function occur as part of the normal aging process but how normal changes relate to driving is not clear.

If dementia is diagnosed there are no therapies known that will compensate. This group of people cannot learn new tasks since memory is deficient. The same may not be true for some brain damaged persons who can, in some instances, be retrained to use different pathways of the brain.

As increasing numbers of people reach their seventies and eighties, the issue of the aging driver will assume greater importance. How society can adapt and develop alternatives will have an impact on preserving the freedom of older persons who wish to continue driving in spite of normal and/or pathological changes.

More research is needed on how specific visual, physiological and cognitive functions relate to driving tasks and how at-risk drivers can be identified. After identification, there should be consideration give to those who could continue driving if they had opportunities to exercise, practice certain skills, and otherwise improve driving capabilities.

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Chapter 6

PERCEPTION-REACTION TIME

Highway- and traffic-engineering design criteria include driver perception-reaction times. Therefore, in order to assess the problems of elderly drivers with respect to highway design and traffic control, the components of driver perception-reaction time were examined and the effects of aging on driver perception-reaction time were assessed. Elderly-driver perception-reaction times were derived for the driving tasks associated with the right-angle and left-turn collisions, which were types of accidents in which elderly drivers were found to be over-involved.

COMPONENTS

The components of perception-reaction time are [1]: (1) latency time, which is the time period from the onset of the stimulus until the beginning of eye movement toward the stimulus; (2) eye/head movement time, which is the time needed by the eyes and head to rotate to the stimulus; (3) fixation time, which is the time required to get enough information from the stimulus so that it can be identified; (4) recognition time, which is the time required by the mental processes to determine the possible courses of action; (5) decision time, which is the time taken to decide on the proper course of action from among the alternative courses of action; and (6) limb movement time, which is the time required to move the foot from the brake to the accelerator, or from the accelerator to the brake. Values for these components have been determined from previous research. However, these values were determined from studies of average drivers rather than elderly drivers. Therefore, these values would have to be adjusted for the effects of aging in order to obtain values for elderly drivers. A brief discussion of the findings of previous research relative to the values of the components of perception-reaction times of average drivers follows.

Latency

Rackoff and Rockwell [2] found that during the day drivers fixate straight ahead 93% of the time on freeways and 64% of the time on rural highways. The percentages of time drivers spent viewing within the 3-degree cone of vision are shown in Table 6-1. It is clear from these results that drivers fixate somewhere other than the focus of expansion about 25% of the time. Laboratory studies conducted by Bartlett et al [3] have provided latency times for stimuli located at different angles from the visual axis. The 50th to 99th percentile latency times for a stimulus located 20 degrees from the visual axis are shown in Table 6-2. These values range from 0.24 to 0.45 seconds.

Table 6-1. Percent time spent viewing in the 3-degree cone of vision [2].

Route	Time	Percent
Nonilluminated Freeway	Day Night	84.0 69.0
Illuminated Freeway	Day Night	71.1 75.4
Rural Two-Lane Highway	Day Night	76.0 78.0

Table 6-2. Latency times for stimuli located 20 degrees from the visual axis [3].

Percentile	Latency (sec)
50	0.24
75	0.27
80	0.29
85	0.31
90	0.33
95	0.35
99	0.45

Eye/Head Movement

Gordon et al. [4] measured the eye and head movements for fixating on a target located 60 degrees from the visual axis. The average lateral speeds of eye and head movements were 250 and 140 degrees per second, respectively. Head movement lagged behind eye movement by 0.050 seconds, which meant that the head started its rotation after the eyes had already rotated 12.5 degrees. The study found that the eye movement stopped its rotation at about 40 degrees for all targets located more than 40 degrees from the visual axis. Based on these findings, the head starts its rotation after the eye has already rotated 12.5 degrees, then both the eye and head continue to rotate at different rates until the eye reaches a maximum rotation of 40 degrees, beyond which the head continues to rotate until the target is reached. Thus, an eye/head rotation of 20 degrees would require 0.08 seconds, which is in close agreement with the findings of White et al. [5], who obtained a value of 0.09 seconds for targets 20 degrees from the visual axis.

Fixation

The fixation time is from 0.1 to 0.3 seconds according to Matson et al. [6]. Mourant et al. [7] found that the fixation time was 0.27 seconds during open road driving. Williams [8] determined that since there were about three fixations per second, about 0.30 seconds was devoted to each fixation.

Recognition

Measurement of the recognition time is difficult, because recognition involves a series of mental processes that are very sensitive to the complexity of the information processing task. Previous research related to the recognition time is summarized in Table 6-3. The table shows the range of recognition times as well as the task parameters. It is clear from the table that some fixation and limb movement times were included in the recognition time values.

The findings of Dewar et al. [9] indicate that the classification task was simpler than the identification task, because the recognition times were shorter for the classification task. For the classification task, the findings of Ellis and Dewar [10] were comparable to those of Dewar et al.. The shorter recognition times found by Ellis et al. [11] clearly shows the effect of automatic information processing. The six signs used by Ellis et al. were dealt with by the subjects as one group of specific characteristics rather than as six different signs. Therefore, the comparison process was automatic, and consequently, took less time.

Whitaker and Stacey [12] found that the verbal response has the same recognition time as the simple ballistic movement. Also, since the tasks were identification tasks, their results were in general agreement with the identification task recognition times found by Dewar et al. The sensitivity of the recognition time to the degree of task complexity is illustrated by the findings of Gordon [13], which are presented at the bottom of Table 6-3. The difficulty in selecting the proper value for the recognition component of the perception-reaction time is apparent from the variability of the findings presented in Table 6-3.

Decision

The decision component of the perception-reaction time, like the recognition component, is dependent on the complexity of the task involved. With respect to driving, the decision can be a simple one like deciding to stop at a stop sign, or it can be a complex one like deciding on the proper gap while crossing a busy two-way street. Lunenfeld [15] determined 85th-percentile driver decision times as a function of the information content involved for both expected and unexpected situations. These values, which are listed in Table 6-4, were higher for unexpected situations than they were for expected situations. In another study, Gibbs [16] allowed subjects 1.0 second to decide on accepting or rejecting a gap from one side. He concluded that 1.0 second was close to the actual decision times utilized by drivers. Further, Cleveland et al. [17] conducted an experiment in which perception-reaction times were measured under two conditions. In the first condition, unalerted drivers responded to a low-contrast obstacle shaped like a short railroad tie centered in the lane of travel on the reverse slope of a crest. In the second condition, alerted drivers released the accelerator and tapped the brake pedal in response to the lighting of a red lamp mounted on the hood of the test car. The 95th-percentile perception-reaction times were 1.60 and 1.10 seconds under the two conditions, respectively. Both values included the fixation, recognition, and limb movement components. However, the decision time in the second value was negligible. Therefore, the decision component can be taken as the difference between the two values, 0.50 seconds.

Limb Movement

The last component of the perception-reaction time is the limb-movement time. Limb movement is required to move the foot from the brake pedal to the accelerator, or vice versa. This component is the time for the physical movement of limb exclusive of the other time components. It is not easy to determine the value of this component, because in measuring it, there must be a stimulus to which the limb movement responds. Even for the simplest stimuli, some mental processes are involved.

Table 6-3. Summary of recognition time research.

Study	Recognition Time (sec)	Stimulus	Reaction
Ellis and Chase [14], 1971	Range 0.424-0.653	A letter presented on the screen.	Press one of two keys depending on if the letter size matches a base size
Dewar et al. [9], 1976	Range 0.514-0.646	A slide showing a warning, regulatory, or information sign.	Verbally say "yes" if the sign is either warning or regulatory (classification task).
	Range 0.653-1.068	Same as above.	Verbally reply with the meaning of the sign only if it is warning or regulatory (identification task).
Ellis and Dewar [10], 1980	Range 0.574-0.904	Slide showing a sign, meaning of sign given before its projection.	Verbally say "yes" or "no" depending on if the sign matches the description given before its presentation.
Ellis et al. [11], 1980	Range 0.417-0.476	Slide showing a sign.	Press the proper key for "yes" or "no" depending on if the sign is one of six types of rail crossing signs.
Whitaker and Stacey [12], 1981	Range 0.726-1.090	Visual display of a directional sign.	Verbally saying "left" or "right" depending on sign direction.
	Range 0.654-1.036	Same as above.	Moving a metal slide a distance of 15 centimeters (simple ballistic movement).
Gordon [13], 1981	Mean 1.85 95th %-tile 4.56	Slide showing a typical freeway sign.	Press one of four keys depending on the selected lane that will lead to a preassigned direction.
	Mean 1.84 95th %-tile 4.76	Same as above but with more information added to the sign (more complex sign)	Same as above.
	Mean 2.51 95th %-tile 4.19	Projected slide showing 3, 5, or 8 freeway signs displayed together.	Press one of eight keys corresponding to sign numbers that carry the place name or route number searched for.

Table 6-4. 85th-percentile driver decision times [15].

Information Content (bits)	Decision Time (sec)	
	Expected	Unexpected
0	0	0
1	0.7	1.0
2	1.3	1.6
3	2.0	2.6

Konz and Daccarett [18] required subjects to depress the brake pedal of a stationary vehicle at the onset of either of two lights positioned 15 feet ahead of the front bumper and in line with the headlights of the vehicle. The time was measured between the onset of the light and the onset of the brake light. The time was measured for two starting positions: (1) the right foot on the depressed accelerator and (2) the left foot on brake. The mean time was 0.59 seconds in the first case, and 0.39 seconds in the second case, which did not require any limb travel from the accelerator to the brake pedal. Therefore, the limb movement time derived from these measurements is 0.20 seconds.

Greenshields [19] used a simulator to measure limb movement from a depressed accelerator to the brake pedal in response to a simulated red traffic light. The mean time recorded for 1,461 subjects was 0.496 seconds. Obviously, this value included some mental-processing time. Similarly, Barrett and Thornton [20] used a simulator to measure the time required for subjects to press the brake pedal in response to the sudden presentation of a pedestrian dummy. The starting position was the right foot on a depressed accelerator. The mean time was in the range of 0.24 to 0.61 seconds. Again, this time also included some mental-processing time.

In another study, Barrett et al. [21] measured the simple reaction time using a simulator. The stimulus was a red disc projected at varying intervals for a total of 10 trials. The subject was to depress the brake pedal upon seeing the red disc. The mean response time was 0.40 seconds for young drivers and 0.41 seconds for old drivers. The mean perception-reaction time components prior to limb movement totaled 0.23 and 0.24 seconds for young and old drivers, respectively. Thus, the limb movement time derived from these measurements was 0.17 seconds for both young and old drivers.

EFFECTS OF AGING

The literature was reviewed to determine the effects of aging on the six components of perception-reaction time. The percentage increases in these component times found in the literature for older people are shown in Table 6-5. A brief summary of the literature used to determine these increases follows.

Table 6-5. Range in the effects of aging on components of perception-reaction time found in the literature.

Component	Percent Increase Due To Aging
Latency	25 - 35
Eye/Head Movement	unknown
Fixation	15 - 45
Recognition	5 - 45
Decision	20 - 100
Limb Movement	20 - 90

Latency Time

Latency times from the onset of target motion to the beginning of smooth pursuit eye movement, which is the voluntary sweeping motions of the eyes used to track objects crossing the visual field, were measured by Sharpe and Sylvester [22]. Measurements were taken for two age groups. The younger age group had a mean age of 23 years, and the older age group had a mean age of 77 years. The target velocities ranged from 5 to 20 degrees per second, and all targets were within 10 degrees of the visual axis. The latency times of the older subjects were longer than those of the younger subjects by about 34 percent for target speeds of 5 degrees per second, 33 percent for target speeds of 10 degrees per second, and 26 percent for target speeds of 20 degrees per second. Therefore, it seems that older subjects may require from about 25 to 35 percent more latency time than young subjects.

Eye/Head Movement Time

Two types of eye movement were defined in the literature : (1) smooth-pursuit eye movement which is the voluntary, sweeping motions of the eyes used to track objects crossing the visual field; and (2) saccadic movement which is a short, rapid, ballistic movement that occurs between successive fixations. Sharpe and Sylvester [22] have noted a distinct slowing of smooth-pursuit eye movements with increasing age. However, most, if not all, driving tasks involve the saccadic type of eye movement. Unfortunately, no pertinent literature was found on the effects of age on this type of movement.

Fixation Time

From the literature reviewed, it seems that older people integrate information over longer periods of time than younger people. Consequently, older people need more time to identify a stimulus. For example, Eriksen et al. [23] carried out an experiment in which the size and details of the stimuli were adjusted to provide stimuli of equivalent recognizability. In this way, all age groups responded to their own particular stimuli, which were different in terms of physical dimension, but equal in terms of perceptual difficulty. The results indicated that the time required to identify the stimuli increased with the age of the subject. Earlier research by Eriksen and Steffy [24] found that 30 to 45 percent longer stimulus presentation times were required for subjects in their sixties to attain the same level of performance as those in their twenties. Crossman and Szafran [25] carried out a card-sorting experiment in which the level of visual discrimination required was varied. The results of this experiment indicated that higher levels of visual discrimination required longer sorting times. The mean sorting time of the subjects older than 60 years was from 15 to 30 percent longer than the mean sorting time of the younger subjects, depending on the level of visual discrimination required. Thus, based on previous research, it seems likely that older subjects may require from 15 to 45 percent more fixation time than younger subjects.

Recognition Time

Recognition times can be derived from simple reaction-time experiments, in which the signal and response are both known in advance. Therefore, the reaction time is essentially the time needed to recognize that the signal has occurred and to initiate a prepared response. In these experiments, the fixation time is practically zero, because the stimuli are extremely clear. Therefore, the time interval between onset of the stimulus and the initiation of movement is approximately equal to the recognition time. The results of several simple reaction time studies indicate that the mean recognition time of subjects over 60 years old was from 5 to 45 percent longer than the mean recognition time of younger subjects [26].

Decision Time

Estimates of decision time can be made from the results of choice reaction time experiments involving simple stimuli and serial tasks, because the fixation and recognition components in these experiments are negligible. Such an experiment was one conducted by Leonard [27], in which the subjects sat facing a display of five neon bulbs at the corners of a regular pentagon. On a board in front of the subject, there was a display of five disks arranged in the form of a regular pentagon corresponding to the arrangement of the neon bulbs. The subjects were to slide a stylus from the center of the disk display to the peripheral disk that corresponded to the illuminated light and then return the stylus to the center of the display. Another light was illuminated the instant that the stylus was returned to the center of the display. The time spent in the center of the disk display was considered to be the decision time. The mean decision time of subjects in their sixties was 49 percent longer than the mean decision time of subjects in their twenties. Singleton [28,29] conducted two experiments similar to the one conducted by Leonard. The results of these experiments indicated that the mean decision time of subjects in their sixties was 20 to 100 percent longer than that of subjects in their twenties.

Limb-Movement Time

Several studies involving the measurement of ballistic movement times have been conducted. Some of the studies have shown that these times increase with the age of the subject. In experiments involving arm movements, Szafran [30] found that the movement times for subjects in their fifties were about 30 percent longer than those of subjects in their twenties. Similarly, the results of the experiments conducted by Leonard [27] indicated that arm movement times of subjects in their sixties were about 25 percent longer than those of subjects in their twenties. Singleton [28] found that movement times were about the same for subjects between the ages of 20 and 60 years, but the movement time for subjects in their sixties were about 30 percent longer. In another experiment, Singleton [29] also found that subjects in their sixties had about 30 percent longer movement times than subjects in their twenties. Pierson and Montoye [31] found a linear increase of about 90 percent in movement time between the ages of 20 and 80 years old. Other studies [32,33] have also found increases of 20 to 30 percent in movement times between the ages of 25 to 65 years. Thus, the results of these studies suggest that older people require 20 to 90 percent more limb movement time than younger people.

INFORMATION-PROCESSING MODELS

The fixation, recognition, and decision components are cognitive processes. The manner in which the times for these components are combined to compute the perception-reaction time depends on the information-processing model used. Although there are several models that could be used, it was decided for the purposes of this study to use the two models that would give the likely range of perception-reaction time values. Therefore, the sequential model was used to provide the maximum value, and the parallel model was used to provide the minimum value.

Sequential Model

In the sequential model [34,35], the mental processes (fixation, recognition, and decision) are performed in sequence. Therefore, the response time is the sum of the time required to complete each process. Sternberg [34] noted that if two experimental factors are manipulated, and each affects a different mental process in the series, then the combined effect of both factors will be the sum of their individual effects. According to this model, the decision component starts only after the recognition component is completed, and the recognition component starts only after the fixation component is completed. Thus, the perception-reaction time computed with this model is simply the sum of these three components plus the sum of the other three components (latency, eye/head movement, and limb movement). This represents the maximum expected value of perception-reaction time.

Parallel Model

In the parallel model [36], when a mental process begins it immediately starts sending output to the other mental processes. Therefore, the fixation, recognition, and decision components start at the same time and continue until the longest time component is completed. Thus, the perception-reaction time computed with this model is the longest mental process time plus the sum of the latency, eye/head movement, and limb movement times. This represents the minimum expected value of perception-reaction time.

ELDERLY-DRIVER PERCEPTION-REACTION TIMES

Using the component times and the effects of aging found in the literature, perception-reaction times of elderly drivers were derived for the driving tasks associated with the right-angle and left-turn collisions. These driving tasks were: (1) stopping in response to an unexpected hazard, (2) stopping in response to a traffic signal, (3) crossing an intersecting roadway from a stopped position, and (4) turning left through opposing traffic. The first three tasks are associated with problems of elderly drivers involved in right-angle collisions, and the fourth one is associated with the problems of elderly drivers involved in left-turn collisions. In each case, the perception-reaction times were derived using both the sequential and parallel information processing models. The elderly-driver times were computed by applying the percentage increases for elderly drivers shown in Table 6-5 to the component times for the average driver.

Stopping In Response To Unexpected Hazard

The driving task of stopping in response to an unexpected hazard on the roadway requires that the driver do the following: (1) direct eyes toward the hazard, (2) fixate on the hazard, (3) recognize the hazard, (4) decide to stop, and (5) move foot from accelerator to brake pedal. It is apparent that this task involves all six components of perception-reaction time.

Latency

According to Table 6-1, drivers on the open road may spend up to 25 percent of the time looking somewhere other than in the direction of the focus of expansion. Therefore, it is necessary to include the latency component in the calculation of the perception-reaction time for stopping in response to an unexpected hazard. The 95th-percentile latency time for objects located 20 degrees from the visual axis is shown in Table 6-2. This value is 0.35 seconds, which was the value used for the latency time for this task.

Eye/Head Movement

Assuming that the driver's eyes are focused toward an object up to 20 degrees from the visual axis, the eye movement time would be 0.08 seconds based on a speed of 250 degree per second, according to Gordon et al. [4]. The same angle requires 0.09 seconds according to White et al. [5]. Based on these figures, 0.10 seconds was used as the eye movement time.

Fixation

In this driving task, the stimulus is unexpected and could be any object. From previous studies [6,7,8], it seems that 0.30 seconds is the upper limit for fixation, which would accommodate unexpected , unfamiliar stimuli. Therefore, this value was used for the fixation time.

Recognition

Recognition times from several studies are shown in Table 6-3. The recognition component in responding to an unexpected hazard would appear to be similar to the case of recognizing the stimuli in the sign recognition studies conducted by Dewar et al. [9] and Ellis et al. [11]. The mean value of the upper values of the two ranges of recognition times found in these studies was 0.56 seconds, which was the value used for the recognition time for this task.

Decision

Cleveland et al. [17] conducted an experiment to measure the perception and braking response times for stopping sight distance. The measurements were taken for unalerted and alerted drivers. The difference between the unalerted and alerted driver values provided a measure of the stopping decision time. The results of the study provided a 95th-percentile decision time of 0.50 seconds.

Limb Movement

The combined times of recognition and limb movement from a number of studies are shown in Table 6-6. The times were measured between the onset of the stimulus and the illumination of the brake lights. Subjects in all of the experiments were alerted; therefore, the fixation times were negligible. If one of the two components is known, the other one can be obtained by subtracting the known value from the mean combined time of all studies in Table 6-6. Fortunately, Barrett et al. [21] measured the recognition times and found the mean recognition time to be 0.24 seconds. Therefore, the mean limb movement time obtained by subtracting 0.24 seconds from the mean of all the studies in Table 5-6 is 0.25 seconds. Assuming that the combined recognition and limb movement times are normally distributed with a mean of 0.49 seconds and a standard deviation of 0.0913 seconds, which was the standard deviation found by Greenshields [19], the 95th percentile combined recognition and limb movement time would be 0.64 seconds. Assuming that the recognition and limb movement times are about equal at the 95th-percentile level, as suggested by the means, then the limb movement time would be 0.32 seconds.

Table 6-6. Combined recognition and limb movement times.

Study	Time (sec)	Stimulus
Konz and Daccarett [28]	0.59	Two light bulbs in front of the front bumper.
Greenshields [19]	0.496	Simulated red traffic light.
Barrett and Thornton [20]	0.43	Sudden presentation of pedestrian dummy.
Barrett et al. [21]	0.405	Red disc projected in front of parked vehicle.
Cleveland et al. [17]	0.54 (median value)	Red lamp mounted on the hood.
Mean of all studies	0.49	

Perception-Reaction Time

The perception-reaction times derived for stopping in response to an unexpected hazard are shown in Table 6-7. The perception-reaction times computed for elderly drivers were from 1.52 to 2.18 seconds using the parallel model, and from 2.45 to 3.43 seconds using the sequential model. The design value used in highway and traffic engineering to compute stopping sight distance is 2.5 seconds [37]. Therefore, according to the sequential model, the current design value used for stopping sight distance may be too short for some elderly drivers.

Stopping In Response To Traffic Signal

The driving task of stopping in response to a traffic signal which has changed from green to yellow requires that the driver do the following: (1) direct eyes toward the signal, (2) fixate on the signal, (3) recognize that it has changed to yellow, (4) decide to stop, and (5) move foot from accelerator to brake pedal. However, in the design of traffic-signal change intervals, it is assumed that the driver is alerted and has fixated on the signal. Therefore, the latency, eye/head movement, and fixation components are not included in the calculation of this perception-reaction time [38]. The perception-reaction time for signal change intervals includes only the recognition, decision, and limb movement components.

Table 6-7. Derived perception-reaction times for stopping in response to an unexpected hazard.

Component	Time (seconds)		
	Average Drivers	Elderly Drivers	
		Minimum	Maximum
Latency	0.35	0.44	0.47
Eye/Head Movement	0.10	0.10	0.10
Fixation	0.30	0.34	0.44
Recognition	0.56	0.59	0.81
Decision	0.50	0.60	1.00
Limb Movement	0.32	0.38	0.61
Sequential Model	2.13	2.45	3.43
Parallel Model	1.33	1.52	2.18

Recognition and Limb Movement

The mean combined recognition and limb-movement time under alerted conditions from the studies cited previously are summarized in Table 6-6. Since results of the studies were comparable, it seems reasonable to assume that the mean combined recognition and limb-movement time is 0.49 seconds, which was the mean of all of the studies. But, it was necessary to isolate these two components in order to be able to compute the perception-reaction time using the parallel model of information processing. Barrett et al. [21] found that the mean recognition time for alerted conditions was 0.24 seconds. Therefore, the mean limb movement time would be 0.25 seconds. Since Johansson and Rumar [39] found reaction times under alerted conditions to be normally distributed, it seemed reasonable to assume that the combined recognition and limb movement times were also normally distributed with a mean of 0.49 seconds and a standard deviation of 0.0913 seconds, which was the standard deviation found by Greenshields [19]. Thus, according to this distribution, the 95th percentile combined recognition and limb movement time would be 0.64 seconds. Assuming that the recognition and limb movement times are about equal at the 95th-percentile level, as suggested by the means, then each component would have a value of 0.32 seconds.

Decision

The yellow signal indication is simple stimulus assumed to contain less than one bit of information. Therefore, decision time under alerted conditions would be shorter than 0.70 seconds, which is the 85th-percentile decision time given in Table 6-4 for expected situations. However, the 0.50-second decision time found by Cleveland et al.[17] is more appropriate, because the stimulus used was similar to a traffic signal.

Perception-Reaction Time

The perception-reaction times derived for stopping in response to a traffic signal are shown in Table 6-8. The perception-reaction times computed for elderly drivers were from 0.98 to 1.61 seconds using the parallel model, and from 1.32 to 2.07 seconds using the sequential model. The design value used in traffic engineering to compute the traffic signal change interval is 1.0 seconds [38]. Therefore, according to both models, the current design value used may be too short for some elderly drivers.

Table 6-8. Derived perception-reaction times for stopping in response to a traffic signal.

Component	Time (seconds)		
	Average Drivers	Elderly Drivers	
		Minimum	Maximum
Latency	0	0	0
Eye/Head Movement	0	0	0
Fixation	0	0	0
Recognition	0.32	0.34	0.46
Decision	0.50	0.60	1.00
Limb Movement	0.32	0.38	0.61
Sequential Model	1.14	1.32	2.07
Parallel Model	0.82	0.98	1.61

Crossing An Intersecting Roadway From A Stopped Position

The driving task of crossing an intersecting roadway from a stopped position requires that the driver do the following: (1) turn eyes and head about 90 degrees to the right, (2) fixate on traffic approaching from the right, (3) recognize the gaps in traffic approaching from the right, (4) select an adequate gap approaching from the right, (5) rotate eyes and head about 180 degrees to the left, (6) fixate on traffic approaching from the left, (7) recognize gap in traffic approaching from the left, (8) decide if gap approaching from the left is adequate, and (9) if gap approaching from the left is adequate, move foot from brake pedal to accelerator. Although this task description includes two eye/head movements, only the 180-degree eye/head rotation from right to left is considered in the calculation of the perception-reaction time, because the search simply continues if the gap from the left is not adequate. The critical eye/head movement on which the decision to cross is made is the last one [40]. Thus, the perception-reaction time required to cross is measured from the instant an adequate gap approaching from the right is selected until the driver's foot is on the accelerator.

Latency

The latency component is the period of time between the onset of the stimulus and the beginning of the eye movement toward it. However, in this case, inclusion of a latency component in the perception-reaction time is not appropriate. Because during the latency time, the vehicle is stopped in a position removed from conflict with the traffic on the intersecting roadway. Therefore, the value used for latency time was zero.

Eye/Head Movement

Assuming that the intersecting main roadway is tangent, the maximum angle of the combined eye and head movement from one leg of the intersecting roadway to the other leg is 180 degrees. Using Gordon's [4] values for the speeds of eye and head movements of 250 and 140 degrees per second, respectively, and assuming a lag time of 0.050 seconds between the eye and head movements, 1.05 seconds are needed for the eye and head to rotate 180 degrees.

Fixation

Fixation time is a function of the nature of the stimulus. If the stimulus is an object that the driver has never seen before, then it may take a considerable amount of time to fixate. But, if the stimulus is a familiar one, it may take a very small amount of time to be fixated. The stimuli presented to a driver waiting for a gap in traffic are other vehicles, which are familiar stimuli. From previous research [6,7,8], 0.30 seconds was selected as the appropriate fixation time in this case.

Recognition and Limb Movement

The recognition and limb movement components for this driving task are similar to those in the task of stopping in response to a traffic signal, because both tasks are under alerted driver conditions. Therefore, 0.32 seconds was used for each of these components.

Decision

The stimuli involved in waiting for a gap in traffic would not be more than one bit of information. Therefore, the 85th-percentile decision time would not be more than 1.0 second according to the information in Table 6-4. A 1.0-second decision time for gap acceptance is also supported by Gibbs [16].

Perception-Reaction Time

The perception-reaction times derived for crossing an intersecting roadway from a stopped position are shown in Table 6-9. The perception-reaction times computed for elderly drivers were from 2.63 to 3.66 seconds using the parallel model, and from 3.31 to 4.56 seconds using the sequential model. The design value used in highway and traffic engineering to compute the intersection sight distance is only 2.0 seconds [37]. Therefore, according to both models, the current design value used may be too short for most elderly drivers.

Turning Left Through Opposing Traffic

The driving task of turning left through opposing traffic requires that the driver do the following: (1) fixate on opposing traffic, (2) recognize the gaps in the opposing traffic, (3) select an adequate gap in the opposing traffic, (4) rotate eyes and head about 75 degrees to the left to see if turning path is clear, (5) fixate on turning path, (6) recognize objects in turning path, (7) decide if turning path is clear, and (8) if turning path is clear, move foot from brake pedal to accelerator. The perception-reaction time for this task does not include a latency time component, because the vehicle is stopped in a position removed from conflict with the opposing traffic during the latency time.

Table 6-9. Derived perception-reaction times for crossing an intersecting roadway from a stopped position.

Component	Time (seconds)		
	Average Drivers	Elderly Drivers	
		Minimum	Maximum
Latency	0	0	0
Eye/Head Movement	1.05	1.05	1.05
Fixation	0.30	0.34	0.44
Recognition	0.32	0.34	0.46
Decision	1.00	1.20	2.00
Limb Movement	0.32	0.38	0.61
Sequential Model	2.99	3.31	4.56
Parallel Model	2.37	2.63	3.66

Eye/Head Movement

The maximum angle of the combined eye and head movement from the opposing approach to the turning path is approximately 75 degrees. Using Gordon's [4] values for the speeds of eye and head movements of 250 and 140 degrees per second, respectively, and assuming a lag time of 0.050 seconds between the eye and head movements, 0.30 seconds are needed for the eye and head to rotate 75 degrees.

Fixation

The fixation component in this task is similar to the fixation component in the driving task of crossing an intersecting roadway from a stopped position. Therefore, a 0.30 -second fixation time was used for this task.

Recognition and Limb Movement

The recognition and limb movement components for this driving task are similar to those in the task of crossing an intersecting roadway from a stopped position. Therefore, a time of 0.32 seconds was used for each of these components.

Decision

The decision time component for this driving task is the same as that in the task of crossing an intersecting roadway from a stopped position. Therefore, a 1.0-second decision time was used.

Perception-Reaction Time

The perception-reaction times derived for turning left through opposing traffic are shown in Table 6-10. The perception-reaction times computed for elderly drivers were from 1.88 to 2.91 seconds using the parallel model, and from 2.56 to 3.81 seconds using the sequential model. The design value used in highway and traffic engineering to compute the intersection sight distance is only 2.0 seconds [37]. Therefore, according to both models, the current design value used may be too short for many elderly drivers.

Table 6-10. Derived perception-reaction times for turning left through opposing traffic.

Component	Time (seconds)		
	Average Drivers	Elderly Drivers	
		Minimum	Maximum
Latency	0	0	0
Eye/Head Movement	0.30	0.30	0.30
Fixation	0.30	0.34	0.44
Recognition	0.32	0.34	0.46
Decision	1.00	1.20	2.00
Limb Movement	0.32	0.38	0.61
Sequential Model	2.24	2.56	3.81
Parallel Model	1.62	1.88	2.91

CONCLUSION

The perception-reaction times of elderly drivers are longer than those of younger drivers, because elderly drivers require more time for each of the components of perception-reaction time. The major increases in time are associated with the information processing components: fixation, recognition, and decision. Elderly drivers may have from 10 to 100 percent longer perception-reaction times, depending on the complexity of the driving task.

Stopping and gap acceptance are the driving tasks associated with right-angle and left-turn collisions in which elderly driver were found to be over-involved. The perception-reaction times for these tasks are used in highway and traffic engineering to design intersection sight distances and traffic signal change intervals to avoid these types of collisions. However, the design values of these perception-reaction times may be too short for many elderly drivers.

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Chapter 7

COUNTERMEASURES

Countermeasures designed to improve the safety of elderly drivers were identified and selected for demonstration and evaluation during the second year of the research. The countermeasures were intended to address the problems of elderly drivers, which were determined as a result of the accident data analysis of elderly driver accidents in Chapters 2 and 3, the evaluation of the driving knowledge of elderly drivers in Chapter 4, and the assessment of the abilities of elderly drivers in Chapter 5. In addition, the results of a review of the literature and current practice relative to methods of improving the safety of elderly drivers were considered in the identification and selection of the countermeasures. The countermeasures selected were ones that were determined to be feasible countermeasures with the greatest potential for reducing elderly driver accidents without reducing the mobility of elderly drivers. The countermeasures were: (1) driver education, (2) physical and perceptual therapies, and (3) highway and traffic engineering measures. The identification and selection of the countermeasures is presented in this chapter.

DRIVER EDUCATION

The evaluation of the driving knowledge of elderly drivers in Chapter 4 indicated that drivers 75-and-older had driving knowledge deficiencies with respect to the following:

(1) Right-angle intersection procedures

(2) Correct and safe following distances

(3) Correct lane positioning and selection

(4) Left-turn procedures and laws

(5) Safe backing procedures, including parking maneuvers

(6) Emergency techniques instruction with discussions of other roadway problems spotlighting animals, parked vehicles, and lane-space cushions

The best way to increase the knowledge of elderly drivers relative to these driver education needs is to provide driver-improvement programs for older drivers.

The education of elderly drivers could be provided by any of the three national older-driver improvement programs described in Chapter 4, or by the development of a new program of instruction designed by the research team. The three national programs are: (1) the National Safety Council (NSC) "Coaching the Mature Driver," (2) the American Association of Retired Persons (AARP) "55 Alive/Mature Driving," and (3) the American Automobile Association (AAA) "Safe Driving for Mature Operators." An examination of the three programs indicated all three provided adequate coverage of the information needed to address the accident situations in which older drivers were over-involved. All three of the national programs cover these basic content needs as shown in Table 7-1. Therefore, it was determined there was no need to develop another program.

Table 7-1. Basic content coverage of older-driver education programs.

Type of Collision	National Program		
	AAA (page numbers)	AARP (session no.)	NSC (page numbers)
Right-Angle	9, 34, 51, 52	3	3, 8, 9, 23
Rearend	12, 42-45, 62	6	3, 5, 6, 13, 23
Sideswipe	44, 45, 48	3	10
Left-Turn	8, 10, 28	3	3, 4, 26
Backing	12, 13	4	4, 28
Parked-Vehicle	34, 44	6	25
Parking-Maneuver	13,22	4	28, 29
Animal	59, 60, 62	5	18

The costs associated with the three programs include materials and instructor time. The current per student costs in Nebraska are $15.00 for the NSC program, $7.00 for the AARP program, and $7.00 for the AAA program. The NSC program was eliminated from further consideration, because its coverage of the required information was not any better than that of the other two programs and it was the most expensive program. The AARP and AAA programs cost the same amount, but the AARP did not respond to a request to use their program in the research. On the other hand, the AAA was willing to allow their program to be used. Therefore, the AAA program was selected as the driver education countermeasure because it was the most cost-effective and feasible older driver program.

PHYSICAL AND PERCEPTUAL THERAPIES

The assessment of the abilities of elderly drivers presented in Chapter 5 indicated there has been considerable research on decrements that occur with aging, but little research has been done on the relationship between these decrements and the driving performance, and even less research has addressed the subject of therapies that can be implemented to improve or compensate for the deficits. The literature suggested that the primary factors related to driving performance are vision, physiological capabilities, and cognitive impairments. The analysis of the patient records of the driver-rehabilitation program at the Immanuel Rehabilitation Center indicated that the performance of impaired, elderly drivers was related to depth perception, peripheral vision, brake reaction time, figure-ground perception, and visual discrimination.

Previous research and the experience of the driver rehabilitation program at the Immanuel Rehabilitation Center indicate that physical and perceptual therapies might improve the performance of elderly drivers. Overall physical fitness and flexibility have been demonstrated to improve reaction time, cognitive performance retrieval activity, and energy level. Perceptual therapies have been shown to improve visual scanning, spatial perception and discrimination, and figure-ground differentiation. Therefore, physical and perceptual therapies were identified as countermeasures to be demonstrated and evaluated in the second year of this research.

The physical therapy will be designed to improve trunk rotation, shoulder flexibility, and posture. The perceptual therapy will be designed to improve, or compensate for, deficiencies in figure-ground perception, visual discrimination, depth perception, and peripheral vision. The specific therapies will be designed by registered physical and occupational therapists at the Immanuel Rehabilitation Center and the University of Nebraska Medical Center.

Therapies administered at health care facilities by professional therapists are expensive, and the feasibility of implementing such therapies on a large percentage of the elderly population is very low. Therefore, in the interests of cost effectiveness and feasibility, the therapies will be designed as self-administered, home-based programs of physical and perceptual exercises.

ENGINEERING COUNTERMEASURES

The engineering countermeasures are intended to address the accident situations in which elderly drivers are over-involved. The identification of possible engineering countermeasures was based on:

(1) the findings of the accident data analysis in Chapter 2

(2) the review of elderly-driver high-accident locations in Chapter 3

(3) a review of the literature and current practice relative to highway and traffic engineering efforts to improve the safety of elderly drivers

(4) the results of the survey of older drivers in Chapter 5

(5) the analysis of elderly-driver perception-reaction times in Chapter 6

(6) the recommendations of the Engineering Countermeasures Review Panel

The Engineering Countermeasures Review Panel was organized to ensure that the engineering countermeasures were identified and selected properly. The Panel was composed of engineers from the Nebraska Department of Roads and the City of Omaha, who would be concerned with the implementation of highway and traffic engineering designs to improve the safety of elderly drivers. The members of the Panel are listed in Table 7-2.

Table 7-2. Engineering Countermeasures Review Panel.

Monty Fredrickson	District Engineer District 2 Nebraska Department of Roads
Michael N. Gorman	City Traffic Engineer City of Omaha
Kenneth Gottula	Division Engineer Traffic Engineering Division Nebraska Department of Roads
Bob Grant	Highway Safety Analyst Highway Safety Division Nebraska Department of Roads
Gerald Grauer	Division Engineer Roadway Design Division Nebraska Department of Roads
Richard J. Ruby	District Engineer District 1 Nebraska Department of Roads
Walter E. Witt	Project Scheduling Engineer Nebraska Department of Roads

Elderly-Driver Accident Problems

The results of the accident data analysis in Chapter 2 indicated that elderly drivers are over-involved in multivehicle accidents, accidents at intersections, and accidents in urban areas. Conversely, elderly drivers were found to be under-involved in single-vehicle accidents, accidents at nonintersection locations, and accidents in rural areas. Compared to middle-age drivers, elderly drivers were found to have significantly higher percentages of their accidents during daylight, between 9:00 am and 3:00 pm, on weekdays, in clear weather, on dry road surfaces, and on straight and level roadways. Elderly drivers were found to be over-involved in right-angle, left-turn, backing, and parking collisions. The analysis indicated that elderly drivers are more likely than middle-age drivers to have right-angle and left-turn collisions that involve failing to yield the right-of-way, running stop signs, disregarding traffic signals, and making improper turns. The problems of elderly drivers were found to be the most serious for drivers 75 and older.

The review of the traffic and roadway conditions at elderly-driver high-accident locations in Chapter 3 indicated that these location were typically found at higher volume intersections that were controlled by either stop signs or traffic signals. The elderly drivers were usually at fault, especially in the case of right-angle and left-turn collision. Failure to yield the right-of-way and disregarding traffic signals were the most common contributing circumstances in elderly-driver accidents at these locations. Typically, the right-angle accidents involved elderly drivers who were attempting to cross more than two lanes of traffic with volumes above 600 vph, which at stop-sign controlled approaches would usually require the elderly driver to wait for an acceptable gap. At traffic signals, the right-angle accident problem of elderly drivers seemed to be associated most often with signal displays competing with visual clutter for the attention of the drivers. This also seemed to be the problem in the case of the rearend collisions in which elderly drivers were at fault.

The left-turn accidents involving elderly drivers typically occurred on streets with speed limits below 45 mph, and at controlled intersections where the elderly drivers were attempting to turn left across two or more opposing lanes of through traffic. Often, the opposing through traffic volume was above 300 vph, which at intersections with stop-sign control, or permitted left-turn phases, required the elderly drivers to wait for an acceptable gap. At most of the elderly-driver high-accident locations, the left-turns were made from left-turn lanes without protected left-turn phases. However, in many cases, the positioning of the left-turn lanes was such that the left-turn sight distance was obstructed when opposing left-turn vehicles were present. Also, at signalized intersections, the placement of the signal display often created a wide angle between the signal heads controlling the left turns and the opposing through traffic.

The review of backing and parking-related accident locations indicated that these types of collisions were more often found on streets with angle parking. Elderly drivers seemed to be under-involved in these types of accidents on streets with parallel parking. However, it was suspected that this occurred because elderly drivers tended to avoid using parallel parking stalls and preferred to use angle parking.

The survey of elderly drivers in Chapter 5 indicated that, at signalized intersections, elderly drivers have the most difficulty turning right on red, knowing the proper lane to be in, seeing the traffic signal, and knowing where to stop. When making left turns at traffic signals the biggest problem indicated by elderly drivers was having their view blocked by vehicles turning left from the opposite direction. Other common problems turning left at traffic signals were knowing the proper lane to be in, seeing when it is safe to turn, knowing where to turn, knowing when to go, knowing when to stop, and understanding the green-arrow left-turn signal indication. The most common problems at stop signs were having enough time to cross, deciding when it is safe to cross, seeing traffic on the cross street, seeing the stop sign, and remembering to look for traffic on the cross street.

The analysis of the perception-reaction times of elderly drivers in Chapter 6 indicated that the perception-reaction times of elderly drivers are from 10 to 100 percent longer than those of younger drivers, depending on the driving task. Longer times for the perception-reaction time components associated with information processing were found to account for most of the increase in the perception-reaction times of elderly drivers. The elderly-driver perception-reaction times derived for the driving tasks associated with right-angle and left-turn collisions were longer than the design values used in highway and traffic engineering to compute intersection sight distance requirements and timing traffic signal change intervals. The disparities between the design and derived values of perception-reaction time were greatest in the left-turn and crossing-maneuver driving tasks.

Possible Countermeasures

Possible engineering countermeasures were identified from a review of the literature and state activities for improving the safety of older drivers reported by the Federal Highway Administration. The countermeasures found are listed in Table 7-3. These countermeasures were reviewed by the Engineering Countermeasures Review Panel to determine the ones that seemed to be the most applicable to problems of elderly drivers found in this study.

The countermeasures in Table 7-3 that were eliminated from further consideration by the Panel have a line drawn through them. The use of bigger and brighter speed limit signs was eliminated, because there was no indication that elderly drivers were over-involved in accidents in which speeding was a primary factor. Wider and brighter center lines, lane lines were eliminated, as were delineators on horizontal curves of 3 degrees or more, because elderly drivers were not over-involved in multivehicle sideswipe and head-on collisions and single-vehicle run-off-the-road collisions. Improved signal coordination was not considered by the Panel to be a very cost-effective way of reducing the right-angle and rearend collisions involving elderly drivers at traffic signals. The roadway lighting countermeasures were eliminated, because elderly drivers were not over-involved in nighttime accidents. Likewise, longer no-passing zones and lower speeds in areas of complex maneuvers were judged by the Panel to be inapplicable to the accident situations in which elderly drivers were over-involved.

Elderly drivers were under-involved in accidents on roadway surfaces that were not dry; thus, the Panel eliminated the use of higher friction pavements from the list of counter-measures. All of the other highway design countermeasures were determined by the Panel to be applicable to the problems of elderly drivers; however, the increased levels of access control, street layouts with offset T-type intersections, and simplified intersections designs were judged by the Panel to be too expensive to be implemented and evaluated in the second year of the research.

The revised perception-reaction time for rail-highway crossings and a new passing sight distance model for no-passing zone design were eliminated by the Panel because elderly drivers were not over-involved in accidents at rail-highway crossings and no-passing zones. The revised perception-reaction times for stopping sight distance, intersection sight distance, and vehicle change intervals and the revised sign letter legibility criteria were recommended by the Panel for use in the design of the other engineering countermeasures.

Table 7-3. Possible engineering countermeasures.

1. Signing/Marking/Delineation
    - a. Bigger and Brighter Signs
        - (1) Stop Signs
        - (2) Street Name Signs
        - ~~(3) Speed Limit Signs~~
    - b. More Advance Warning and Guide Signs
        - (1) Further In Advance
        - (2) Better Spacing
        - (3) More Redundancy
    - c. Overhead Signing
    - d. Remove Unnecessary Signing and Other Visual Clutter at Intersections
    - ~~e. Wider and Brighter Center, Lane, and Edge Lines~~
    - f. Left-Turning Path Control Lines
    - g. Greater Use of Stop Lines
    - ~~h. Delineators on 3° Degree and Greater Curves~~
    - i. Greater Use of Raised Pavement Markers
    - j. Improved Maintenance

2. Traffic Signals
    - a. Protected Left-Turn Phases
    - b. Better Positioning of Signal Faces
    - c. Larger Lenses
    - d. Greater Use of Backplates
    - ~~e. Improved Signal Coordination~~

~~3. Roadway Lighting~~
- ~~a. More Illumination~~
- ~~b. Less Glare~~

~~4. Traffic Control~~
- ~~a. Longer No Passing Zones~~
- ~~b. Lower Speeds in Areas of Complex Maneuvers~~

5. Highway Design
    - a. Left-Turn Lanes (Improve Sight Distance)
    - b. Improve Intersection Sight Distance
    - ~~c. Increase Level of Access Control~~
        - ~~(1) Median Openings~~
        - ~~(2) Driveways~~
    - ~~d. Higher Friction Pavements~~
    - ~~e. Offset T-Type Intersections~~
    - ~~f. Simplified Intersections~~

6. Wider Parking Spaces

7. Revised Standards
    - a. Perception-Reaction Times
        - (1) Stopping Sight Distance (2.5 => 3.2 sec)
        - (2) Intersection Sight Distance (2.0 - 2.5 => 3.0 - 4.5 sec)
        - ~~(3) Rail Highway Crossings (2.5 => 3.5 sec)~~
        - (4) Vehicle Change Interval (1.0 => 2.0 sec)
    - ~~b. New Passing Sight Distance Models~~
    - c. Sign Letter Legibility (50 ft/in => 26 ft/in)

Besides eliminating the possible countermeasures described above, the Panel also determined that it was feasible to consider, for the purposes of this research, countermeasures that only involved signing, pavement markings, traffic signal displays, and traffic signal timing. Budget and time constraints did not permit the selection of counter-measures that involved considerable roadway reconstruction or the installation of expensive traffic control devices, such as grade separations, overhead sign bridges, and traffic signals.

Of the types of collisions in which elderly drivers were over-involved, the right-angle and left-turn collisions were determined by the Panel to be the most susceptible to remediation by cost-effective engineering countermeasures. They are usually more severe than the other types of collisions (i. e., parked-vehicle, parking-maneuver, and backing) in which elderly drivers were over-involved. Consequently, they offer greater potential accident cost savings. Also, right-angle and left-turn collisions are often concentrated at intersections. But, parked-vehicle, parking-maneuver, and backing collisions typically occur at widely scattered locations, making them more difficult to address in a cost-effective manner. Therefore, the Panel recommended that the selection of countermeasures be limited to those which address the problems of elderly drivers in right-angle and left-turn collisions.

Recommended Countermeasures

Right-Angle Collisions

The problems of elderly drivers involved in right-angle collisions were associated with gap acceptance and stopping. The longer perception-reaction times of elderly drivers require greater sight distances and larger gaps for elderly drivers to travel safely through intersections. The problems elderly drivers have in stopping at intersections are concerned with: (1) not knowing where and when to stop at stop signs and traffic signals and (2) slower perception-reaction times in response to the vehicle change interval at signalized intersections. These problems require greater conspicuity of the traffic control devices and longer vehicle change intervals.

The countermeasures recommended by the Panel to deal with the problems of elderly drivers involved in right-angle collisions are shown in Table 7-4. The first countermeasure listed is the addition of a stop bar. At some intersections, elderly drivers may often stop in positions that do not provide them with enough sight distance to see the arrival of vehicles on the cross road far enough in advance to allow them to safely enter the intersection. In such cases, the addition of stop bars may help elderly drivers to stop in positions that provide adequate sight distances and facilitate their ability to accept large enough gaps.

Table 7-4. Recommended right-angle collision countermeasures.

Problems:

Gap Acceptance:	Longer perception-reaction times require greater sight distances and larger gaps.
Stopping:	Not knowing where and when to stop requires better conspicuity of traffic control devices, and longer perception-reaction times require longer traffic-signal change intervals.

Countermeasures:

Add Stop Bar:	To position vehicles to provide drivers with more sight distance.
Larger Stop Sign:	To increase conspicuity of stop sign.
Improve Signal Display:	To increase conspicuity of traffic signal.
Adjust Signal Change Interval:	To eliminate the dilemma zone for elderly drivers.
Add Side-Mounted Signal Head:	To increase conspicuity of traffic signal.

Larger stop signs, improved traffic signal displays, and the addition of side-mounted signal heads are intended to improve the conspicuity of these traffic control devices and reduce the chances of elderly drivers running stop signs and disregarding traffic signals. The adjustment of the signal change interval would be designed to eliminate dilemma zones for elderly drivers on signalized intersection approaches caused by their longer perception-reaction times. Elimination of these dilemma zones would increase the ability of elderly to stop in response to traffic signal change intervals, thereby reducing their chances of disregarding the traffic signals.

Left-Turn Collisions

The problems of elderly drivers involved in left-turn collisions were associated with gap acceptance, the field of view, and the turning path. The longer perception-reaction times of elderly drivers require greater sight distances and larger gaps for them to turn left safely. The placement of the traffic signal heads at some intersections creates a wide-angle field of view between the signal controlling the left turns and the opposing traffic. Such wide fields of view increase the perception-reaction times involved in making left turns, which in turn increases the difficulty elderly drivers have in accepting adequate gaps. Elderly drivers also have problems turning left at wide intersections, because they have difficulty identifying the proper path to follow through the large unmarked area within the intersection.

The countermeasures recommended by the Panel to deal with the problems of elderly drivers involved in left-turn collisions are shown in Table 7-5. The first countermeasure listed is the addition of a protected left-turn phase. This countermeasure would create adequate gaps in the opposing traffic stream and relieve drivers of the gap acceptance task.

The addition of a far left-side signal head, a turning path line, and a left-turn/right-turn separation lane line are the next three countermeasures listed in Table 7-5. These countermeasures are intended to make it easier for elderly drivers to make left turns. The addition of the far left-side signal head would reduce the angle of the field of view between the signal head controlling the left turns and the opposing through traffic in which the driver must find an acceptable gap. The turning path line and the left-turn/right-turn separation line are designed to improve the elderly drivers ability to identify the correct turning path and facilitate turns into the proper lanes.

Table 7-5. Recommended left-turn collision countermeasures.

Problems:	
Gap Acceptance:	Longer perception-reaction times require greater sight distances and larger gaps.
Field of View:	Wide field of view increases perception-reaction times.
Turning Path:	Wide intersections make it more difficult to find proper turning path.
Countermeasures:	
Add Protected Left-Turn Phase:	To create adequate gaps in opposing traffic stream.
Add Far Left-Side Signal Head:	To narrow the field of view.
Add Left-Turn Turning Path Line:	To facilitate left turns into the proper lane.
Add LT/RT Separation Line:	To facilitate turns into the proper lanes.
Widen LT Lane Line:	To improve left-turn sight distance by offsetting opposing left-turning vehicles.
Reduce Width of LT Lane Median Nose:	To improve left-turn sight distance by offsetting opposing left-turning vehicles.

The last two left-turn collision countermeasures listed in Table 7-5 are designed to improve the sight distance available to drivers turning left by eliminating, or at least reducing, the sight-distance obstruction caused by opposing left-turn vehicles. The sight-distance obstruction is reduced by offsetting the opposing left-turn vehicles. The widening of the left-turn lane line is intended to offset the opposing left-turn vehicles by shifting them to the left side of their respective left-turn lanes. The narrowing of the width of the left-turn median nose is intended to offset the opposing left-turn vehicles by offsetting the left-turn lanes themselves.

Cost-Effectiveness Analysis

A cost-effectiveness analysis of the recommended engineering countermeasures was conducted. The results of the analysis is presented in Table 7-6. The first cost, maintenance cost, and service life estimates were provided by the City of Omaha Department of Public Works. The accident costs were computed for the severities of right-angle and left-turn collisions involving drivers 75 and older, which were determined in the accident data analysis in Chapter 2. The revised relative severity index figures (i. e., $1,700,000 per fatal accident, $14,000 per injury accident, and $3,000 per property-damage-only accident), which were published by the Nebraska Department of Roads on January 17, 1989 [1], were used in the calculation of the accident costs. These figures were from a Federal Highway Administration advisory and adapted by the Nebraska Department of Roads to apply to specific types of impacts. The accident reduction factors were those found in the literature [2,3,4,5] for similar types of safety improvements. However, none of the accident reduction factors were reported as being applicable to a specific age group. Therefore, it was assumed they would be applicable to drivers 75 and older.

The breakeven number of accidents per year of the particular collision type involving drivers 75 and older was computed for each countermeasure. In the case of a right-angle collision countermeasure, the implementation of the countermeasure at a particular location would be cost effective only if the actual number of right-angle collisions per year involving drivers 75 and older at the location was equal to or greater than the breakeven number. Likewise, in the case of a left-turn collision countermeasure, the implementation of the countermeasure at a particular location would be cost effective only if the actual number of left-turn collisions per year involving drivers 75 and older at the location was equal to or greater than the breakeven number. All of the breakeven numbers in Table 7-6 are less than one accident per year, and all but two of them are less than 0.5 accidents per year. The average number of right-angle, or left-turn, collisions at many of the elderly-driver high-accident locations reviewed in Chapter 3 was more than one accident per year. Therefore, it seems likely that all of the countermeasures could be cost effective at many elderly-driver high-accident locations.

Table 7-6. Cost-effectiveness analysis of recommended engineering countermeasures[a].

Countermeasure	First Cost ($)	Maint. Cost ($/yr)	Service Life (yrs)	Accident Cost ($/acc)[b]	Accident Reduction Factor[c]	Break-even Acc/Yr
Right-Angle Collisions						
Add Stop Bar	50	0	1	32,100	0.10	0.017
Larger Stop Sign	70	0	1	32,100	0.20	0.012
Improve Signal Display	1,370	0	10	32,100	0.30	0.232
Adjust Signal Change Interval	100	0	1	32,100	0.10	0.034
Add Side-Mounted Signal Head	620	25	10	32,100	0.10	0.039
Left-Turn Collisions						
Remove Permitted Left-Turn Phase	650	0	10	17,200	0.85	0.007
Add Protected Left-Turn Phase	1,900	50	10	17,200	0.85	0.025
[d]Add Protected Left-Turn Phase: 1 appr	17,900	50	10	17,200	0.85	0.202
[d]Add Protected Left-Turn Phase: 2 appr's	24,900	75	10	17,200	0.85	0.282
[d]Add Protected Left-Turn Phase: 3 appr's	31,900	100	10	17,200	0.85	0.362
[d]Add Protected Left-Turn Phase: 4 appr's	38,900	125	10	17,200	0.85	0.442
Add Far Left-Side Signal Head	890	25	10	17,200	0.10	0.099
Add Left-Turn Turning Path Line	50	0	1	17,200	0.10	0.032
Add LT/RT Separation Line	75	0	1	1,190	0.10	0.687
Widen Left-Turn Lane Line	800	0	1	17,200	0.10	0.512
Narrow Left-Turn Lane Median Nose	3,500	400	20	17,200	0.10	0.472

a 10% interest rate.

b $1,700,000/fatal accident; $14,000/injury accident; $3,000/PDO accident.

c Accident reduction factors from NCHRP Reports 162 and 197, FHWA Report FHWA-TS-82-232, and City of Lincoln's 1989 Accident Report.

d Includes new controller and mast arms.

SUMMARY

Based on the analysis of the problems of elderly drivers, countermeasures for improving the safety of elderly drivers were selected for demonstration and evaluation during the second year of the research. The countermeasures selected were those judged to be the most cost effective and feasible ways to address the problems of elderly drivers without reducing their mobility. The countermeasures selected included driver education, physical and perceptual therapies, and highway and traffic engineering measures.

Three national elderly driver education programs were found to cover the areas of driving knowledge in which elderly drivers were found to be deficient. Therefore, the development of a new program was not warranted. The AAA "Safe Driving for Mature Operators" was selected as the driver education countermeasure. It was determined to be the most cost-effective and feasible program. It had the lowest cost program, and AAA was the most willing of the program sponsors to allow its program to be used in the research.

Physical and perceptual therapies were selected as countermeasures to be demonstrated in the second year of the research, because they address many of the deficiencies associated with poor driving performance. The physical therapy will be designed to improve trunk rotation, shoulder flexibility, and posture. The perceptual therapy will be designed to improve, or compensate for, deficiencies in figure-ground perception, visual discrimination, depth perception, and peripheral vision. The therapies will be designed as self-administered, home-based programs of physical and perceptual exercises in order to increase their feasibility and cost-effectiveness. Therapies administered at health care facilities by professional therapists were not considered to be feasible.

The engineering countermeasures selected were designed to address the problems of elderly drivers involved in right-angle and left-turn collisions. Countermeasures designed to address the other types of collisions in which elderly drivers are over-involved were not selected, because their potential cost-effectiveness was considered to be too low. Also, the countermeasures selected were limited to countermeasures that only involved signing, pavement markings, traffic signal displays, and traffic signal timing. Because of budget and time constraints of the research, it was not feasible to select countermeasures that involved considerable roadway reconstruction or the installation of expensive traffic control devices, such as grade separations, overhead sign bridges, and traffic signals.

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Chapter 8

PLAN OF RESEARCH FOR SECOND YEAR

During the second year of the research, the safety improvement countermeasures selected in the first year will be demonstrated so that their actual effectiveness can be evaluated. Based on the experience of the demonstrations, the cost-effectiveness of the countermeasures will be evaluated and the most cost-effective ones will be determined. The plan of research for the second year is presented in this chapter.

RESEARCH APPROACH

The research approach will involve about 120 elderly drivers who will be divided into six study groups. The first two groups will be given the physical and perceptual therapies. One of the two groups will be given the physical therapy, and the other one will be given the perceptual therapy. The third group will be given the AAA "Safe Driving for Mature Operators," which was selected to address the driving knowledge deficiencies of elderly drivers. The fourth group will be given both the physical therapy and the driver education. The fifth group will be given both the perceptual therapy and the driver education. The sixth group will be the control group; this group will not receive any therapeutic measures or driver education.

All of the drivers will be tested before and after the countermeasures have been implemented. The tests will include: (1) a driving-knowledge test, (2) a series of perceptual/cognitive/functional tests, and (3) an on-street driving performance test. The particular tests used will be those designed to measure the driving knowledge and abilities found in the first year of the research to be most directly related to the problems of elderly drivers. The engineering countermeasures will be incorporated into the on-street driving performance test routes. The differences in the before and after driving performance test scores will be used to evaluate the effectiveness of the safety improvement countermeasures.

The plan for the before and after evaluation of the driving performance of the six study groups is shown in Table 8-1. There will be two driver-performance-measure (DPM) routes. The first route, Route A, will be used to evaluate the driving performance of all of the elderly drivers before any of the countermeasures are implemented. In addition, Route A will be used to evaluate the driving performance of one half of the drivers in each of the six study groups after the physical therapy, perceptual therapy, and driver education have been implemented. The second route, Route B, will be used to evaluate the driving performance of the other half of the drivers in each study group after the therapies and driver education have been implemented. Route B will be the same as Route A except that it will contain the engineering countermeasures. The engineering countermeasures will not be implemented on Route A. Thus, only one half of the drivers in each study group will be exposed to the engineering countermeasures. Therefore, it will be possible to analyze the driving performance data for the individual as well as the combined effects of the countermeasures.

Table 8-1. Experimental design for the second year of the research.

Group	DPM Route[a]	
	Before	After
I - Physical Therapy	A	50% - A 50% - B
II - Perceptual Therapy	A	50% - A 50% - B
III - Driver Training	A	50% - A 50% - B
IV - Physical Therapy & Driver Training	A	50% - A 50% - B
V - Perceptual Therapy & Driver Training	A	50% - A 50% - B
VI - Control	A	50% - A 50% - B

[a] A - DPM route <u>before</u> engineering countermeasures are implemented.

B - DPM route <u>after</u> engineering countermeasures are implemented.

The physical therapies and the tests related to the physical therapies will be designed and administered by physical therapists from the University of Nebraska Medical Center. The perceptual therapies and the tests related to the perceptual therapies will be designed and administered by occupational therapists from the Immanuel Rehabilitation Center in Omaha. The physical and perceptual therapy testing will be conducted at the Immanuel Rehabilitation Center under the supervision of Jill Moon, Registered Occupational Therapist, Immanuel Rehabilitation Center.

The driver training will be conducted by instructors with the AAA elderly driver program. The driver-knowledge testing and the driver training will be conducted at the Immanuel Rehabilitation Center. The driving-knowledge tests and the on-street driving performance tests will be administered by certified driver education instructors, who are experienced in the Driver Performance Measurement method of evaluating on-street driving performance.

The engineering countermeasures will be installed by the Nebraska Department of Roads and City of Omaha. The installation will be done after the driving performance of the first half of the drivers in each study group has been tested.

RESEARCH TASKS

The research in the second year will consist of eight tasks. The schedule for the research is shown in Table 8-2. A brief description of each tasks follows.

Task 1: Design Driver-Measure-Performance Routes. The first on-street DPM route, Route A, will be designed to evaluate the driving performance of older drivers. The routes will include the driving tasks which were found during the first year of the study to be involved in the accident situations in which elderly drivers were over-represented. The second DPM route, Route B, will be the same as Route A except it will have the engineering countermeasures installed on it.

Task 2: Obtain Test Subjects. About 120 elderly drivers will be used as the test subjects. They will be paid volunteers solicited through the AgeWell Program at Immanuel Hospital in Omaha, which has over 3,000 members, and other senior citizen groups. During the first year of the study, drivers over 74 years were the only older drivers found to have accident rates significantly higher than those of drivers between 25 and 54 years. Therefore, if possible, all of the test subjects will be over 74 years old. In addition, the subjects will be individuals who: (1) have a valid driver's license, (2) are still driving on a regular basis, (3) can show evidence of financial responsibility, (4) have a vehicle that they are willing to use in the driving performance tests, (5) have not taken an older-driver training course, and (6) have a medical release from their physician to participate in the research or a similar type of consent.

Table 8-2. Schedule for the second year of the research.

Task	Month											
	O	N	D	J	F	M	A	M	J	J	A	S
1: Design DPM Routes	**	*										
2: Obtain Subjects	**	*										
3: Pretest Subjects		*	*									
4: Form Groups			*	*								
5: Implement Strategies				*	**	**	***	**				
6: Retest Subjects						*	*	*	*			
7: Evaluate C/E									*	**		
8: Prepare Final Report											**	**

* - two weeks.

Task 3: Pretest Subjects. Each of the test subjects obtained in Task 2 will be tested to determine their driving knowledge, their perceptual/cognitive/functional abilities, and their on-street driving performance over the test routes designed in Task 1. The results of these tests will serve as the benchmarks to which the post-treatment test results will be compared. The test results will also serve as the basis for dividing the subjects into the six study groups in Task 4.

Task 4: Form Study Groups. Based on the results of the pretests given in Task 3, the drivers will be randomly assigned to each of the six study groups so that the distribution of pretest scores for the subjects in each group will be representative of the overall distribution of pretest scores. This will minimize the confounding effects of inherent driving ability.

Task 5: Implement Countermeasures. The therapeutic measures and driver training will be administered to the appropriate study groups. It is anticipated that the therapeutic measures will require about 24 hours of self-administered treatment at home over a two-month period of time. The driver training is expected to require about eight hours of instruction over a two-day period of time. Each study group receiving driver education and/or a therapy will be divided into two halves. The first half will begin to receive its driver education and/or therapy about two months before the second half of the group, because the first half will be retested on DPM Route A and the second half will be retested on DPM Route B. It will take about two months to install the engineering countermeasures on Route A to create Route B.

*Task 6: **Retest Subjects.*** After the therapeutic measures and driver training have been administered in Task 5, the subjects will be retested. The tests will be similar to the pretests given in Task 3, but they will not be identical, in order to control for learning effects.

*Task 7: **Evaluate Cost-Effectiveness of Countermeasures.*** The differences in the driving performance test scores between Tasks 3 and 6 will be the primary measures of effectiveness used to evaluate the safety improvement strategies. The experimental design in Task 4 will enable the evaluation of the relative and absolute effectiveness of the countermeasures. The costs of implementing the countermeasures will be estimated, and the most cost-effective countermeasures will be identified.

*Task 8: **Prepare Final Report.*** A final report documenting the procedures, findings, and conclusions of the research will be prepared. The report will recommend the most cost-effective countermeasures for improving the safety of elderly drivers in rural areas of the Midwest Region.

EXPECTED RESULTS

The results of the research will be cost-effective strategies for improving the safety of elderly drivers, which integrate engineering, education, and therapeutic countermeasures in a complementary manner. The strategies will provide a basis for implementing safety-improvement programs for older drivers that are comprehensive, coordinated, and cost-effective.

In addition to the final report, the results of the research will be submitted for publication and presentation to several organizations concerned with the safety of elderly drivers, such as the Transportation Research Board, Highway Users Federation for Safety and Mobility, American Association of Retired Persons, and American Automobile Association. The research findings will also be presented in workshops to state highway transportation agencies requesting them.

APPENDIX

Collision Diagrams and Turning Movement ADT's for High Elderly-Driver Accident Locations in Omaha, Nebraska (1985-1989)

← Day of Week/Military Time/Year/Road Surface Condition/Weather

* Sex of Elderly Driver, Contributing Circumstance

○ Personal Injury Accident

Day:	Road Surface Condition:	Weather:
Su - Sunday	D - Dry	C - Clear
M - Monday	W - Wet	R - Rain
T - Tuesday	I - Icy	S - Snow
W - Wednesday	S - Snow	Cl - Cloudy
R - Thursday	O - Other	O - Other
F - Friday		
Sa - Saturday		

Contributing Circumstance:

FTY - Failure To Yield

DTS - Disregarded Traffic Signal

ITS - Improper Turn Signal

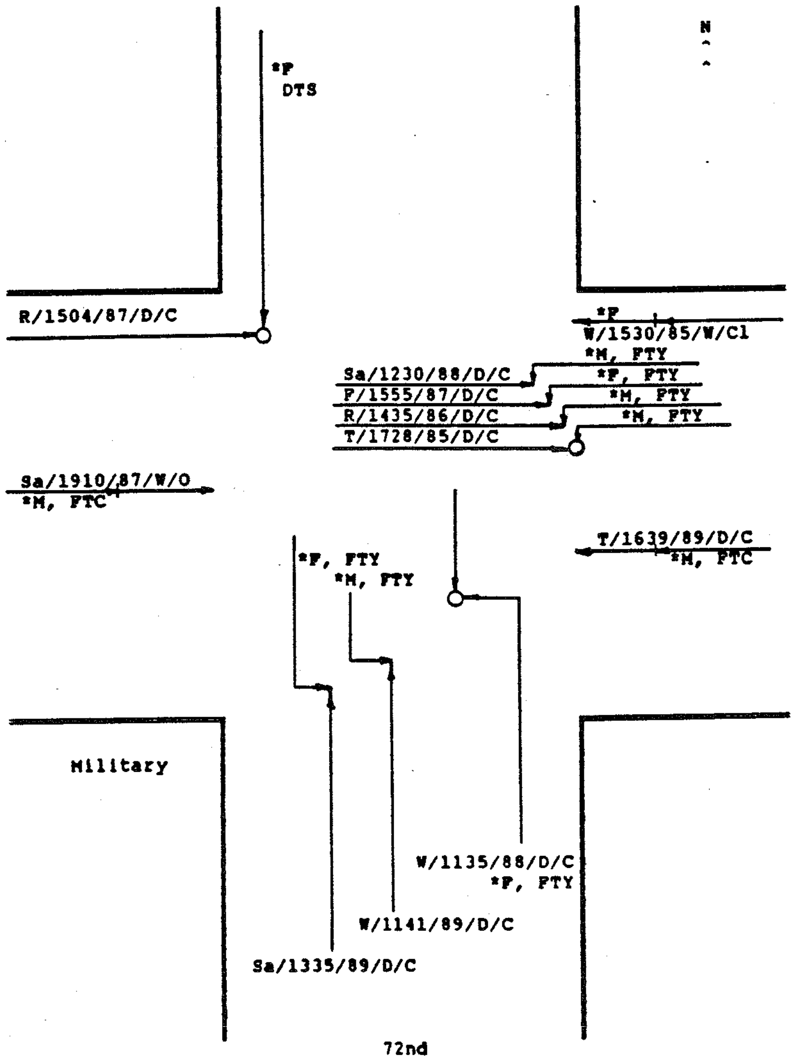
MIT - Made Improper Turn

ILC - Improper Lane Change

FTC - Following Too Closely

O - Other

72nd & Military



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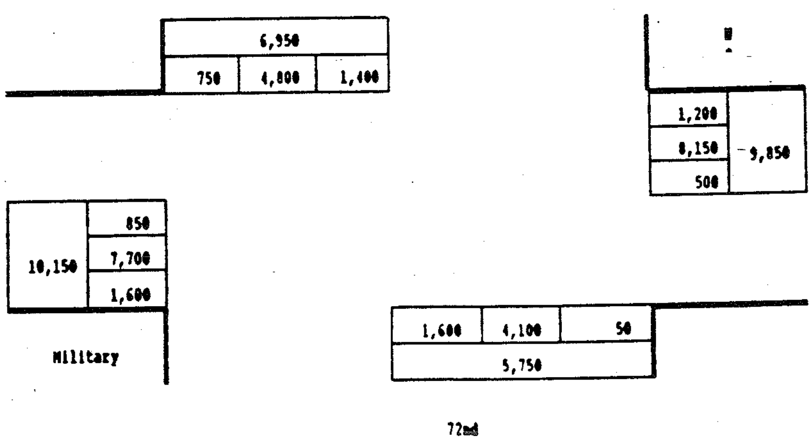
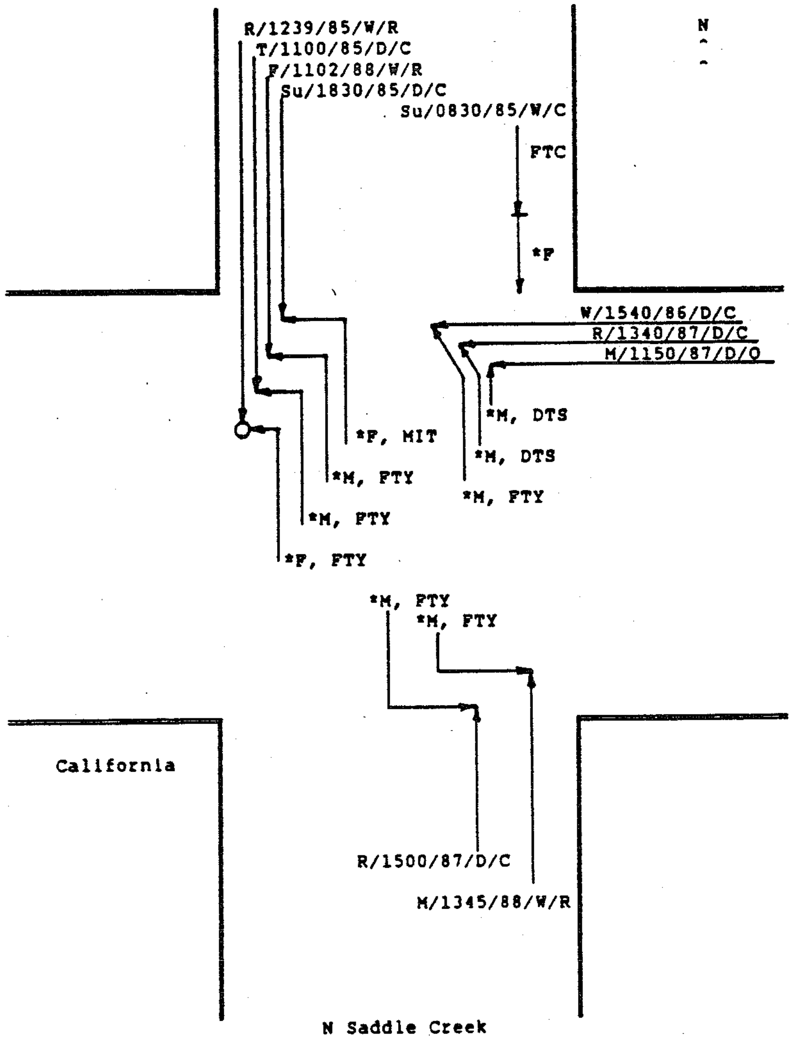


California & N Saddle Creek



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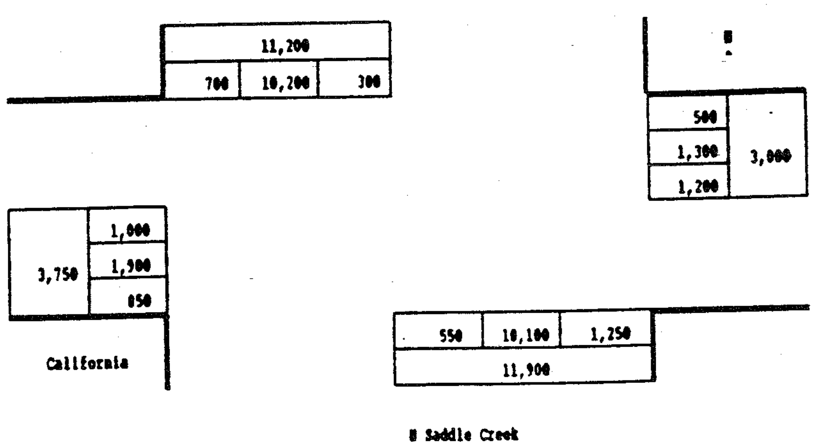
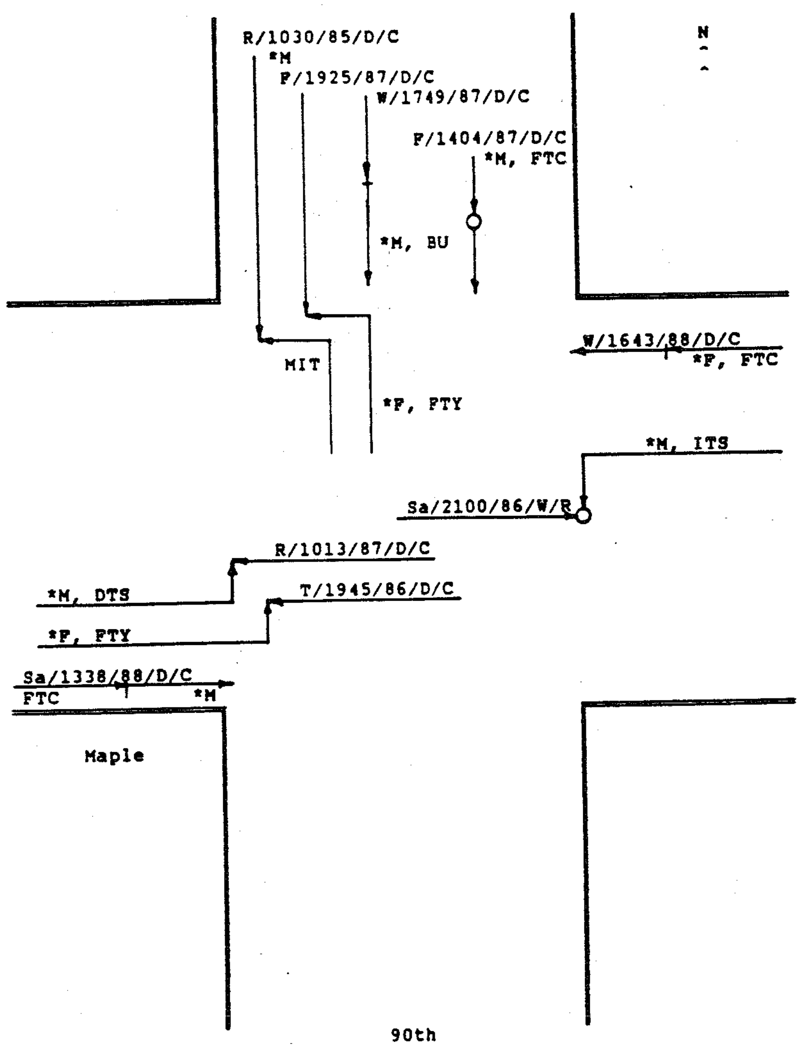


90th & Maple



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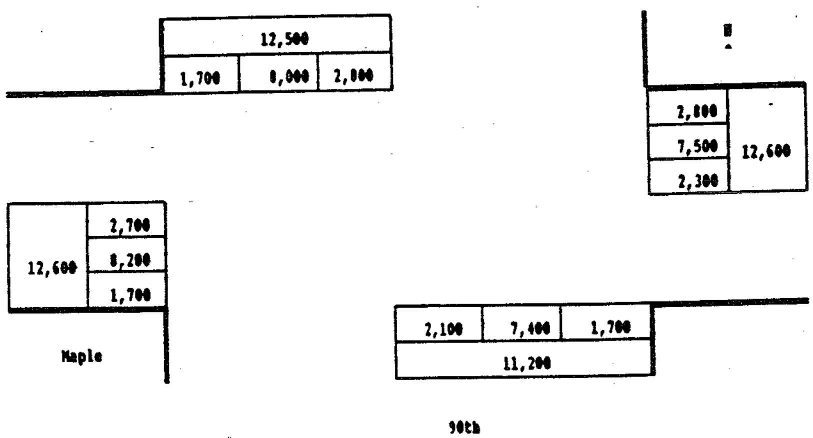

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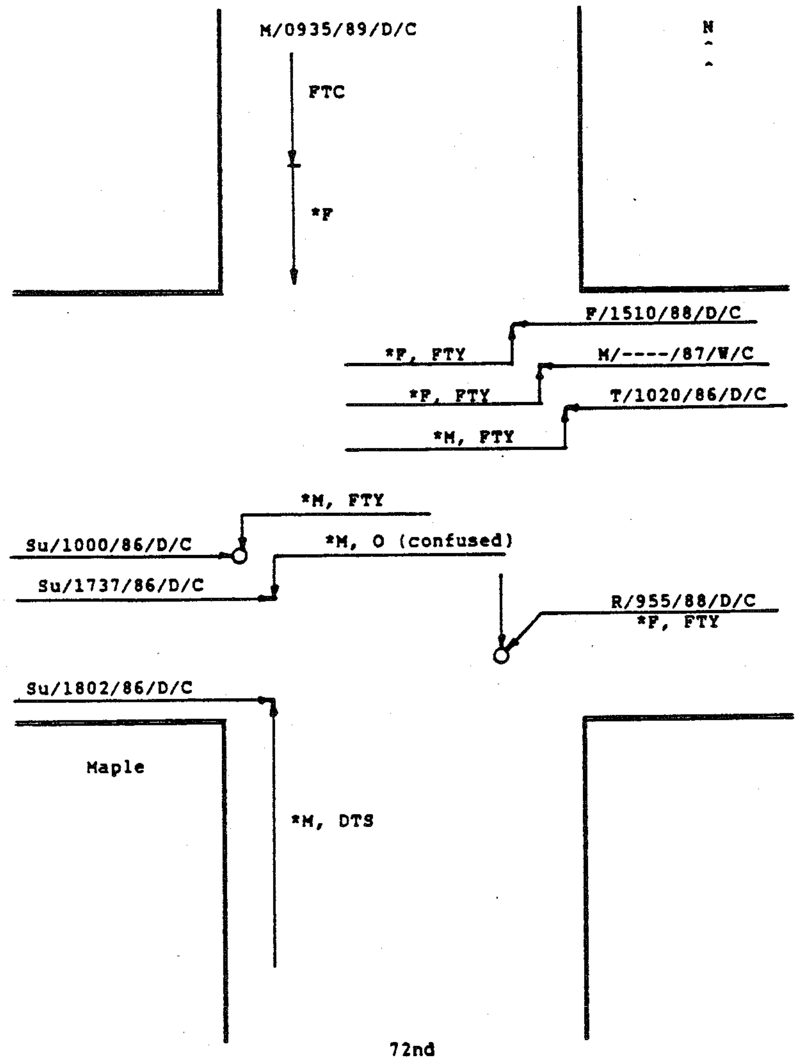

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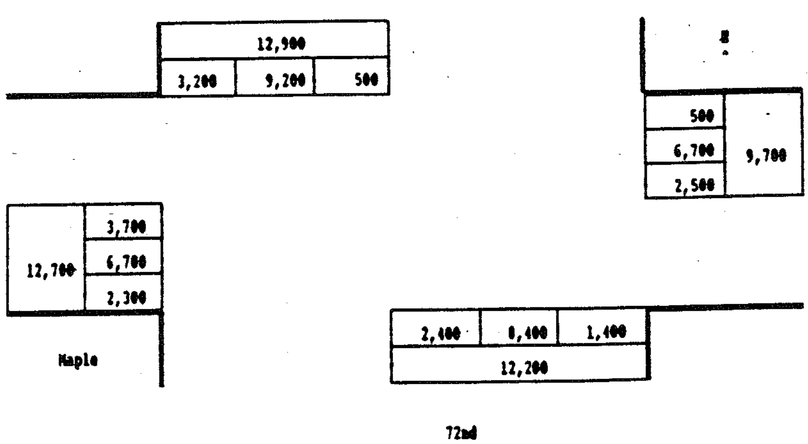
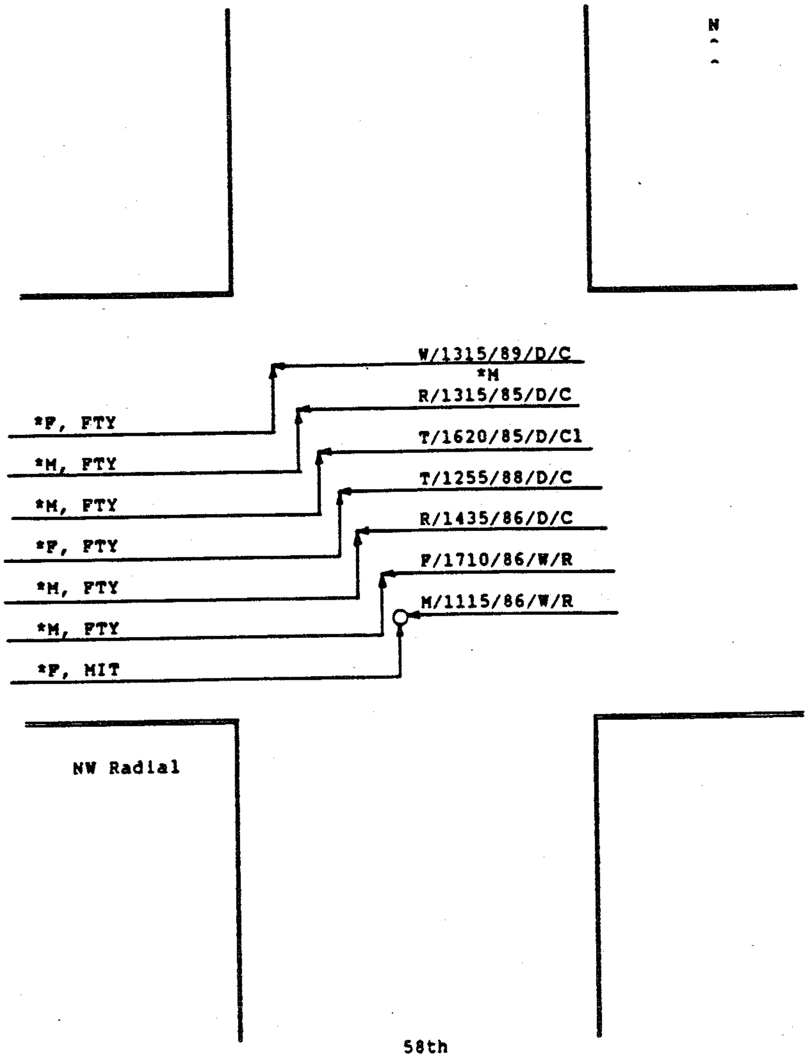


58th & NW Radial



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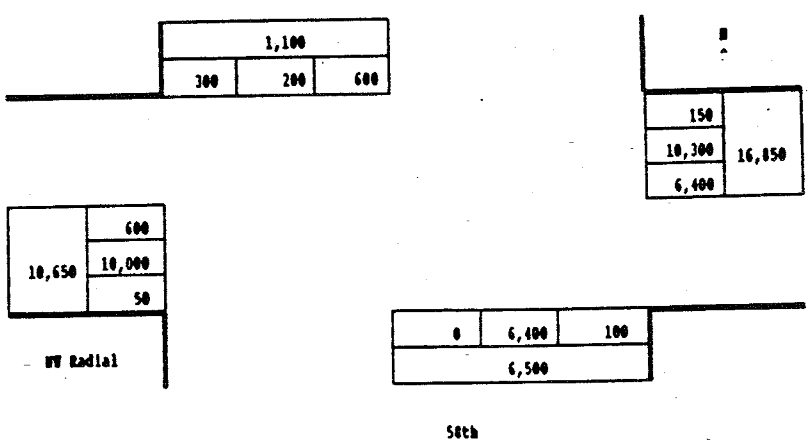
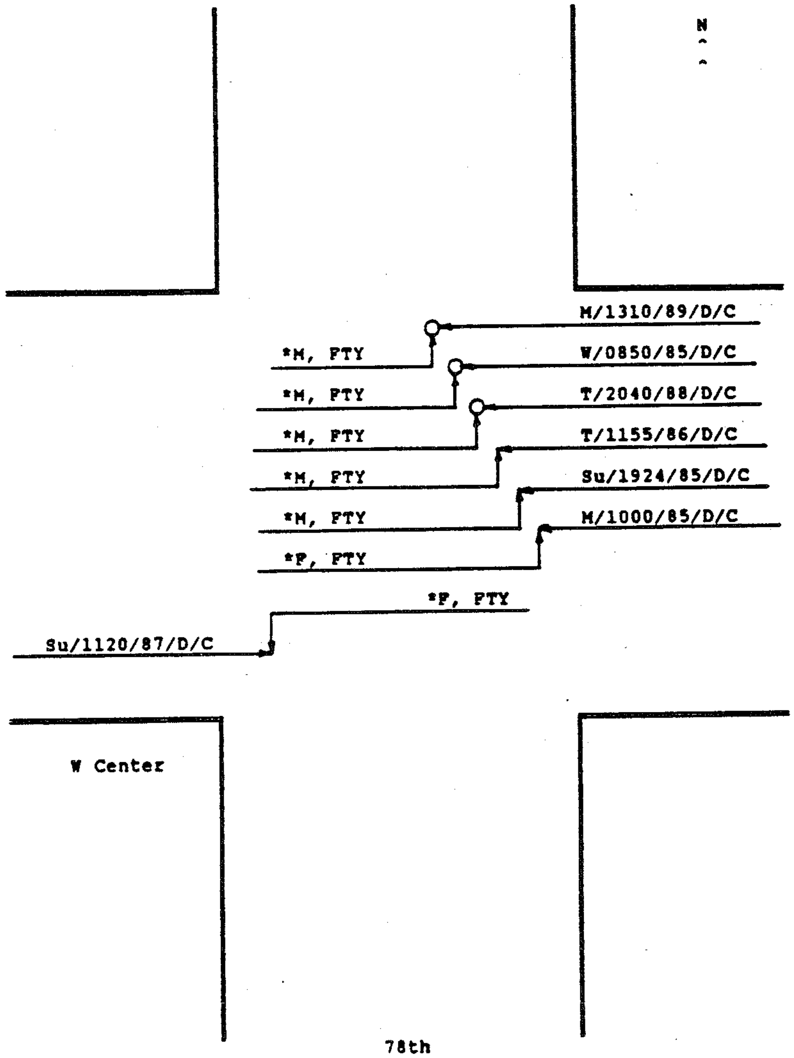


78th & W Center



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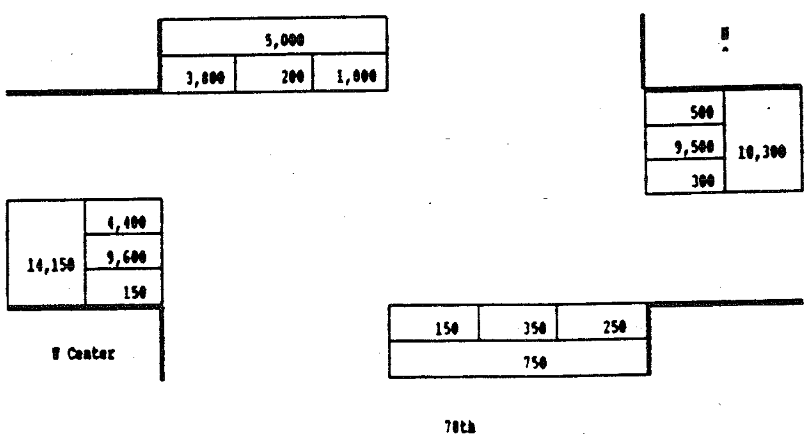
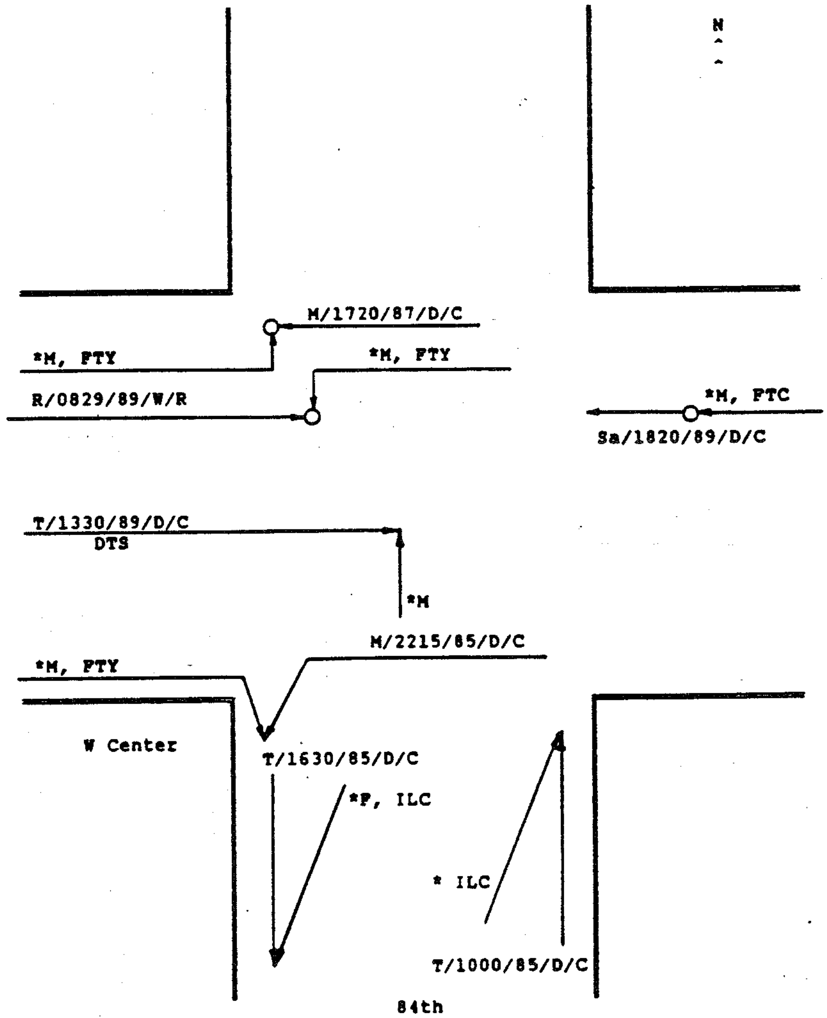
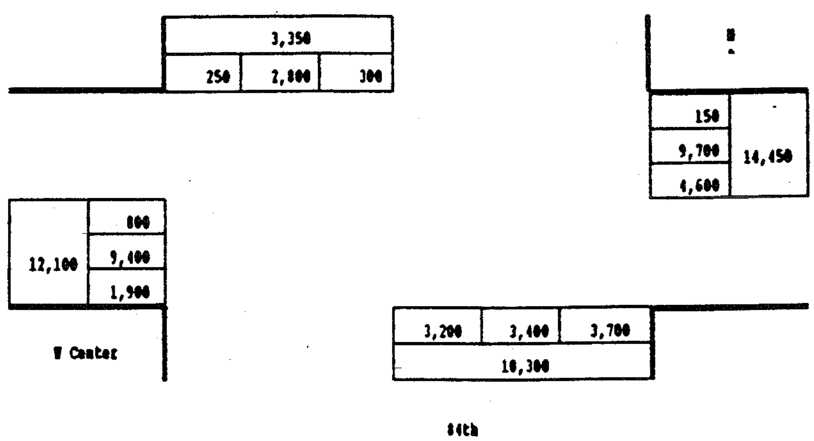


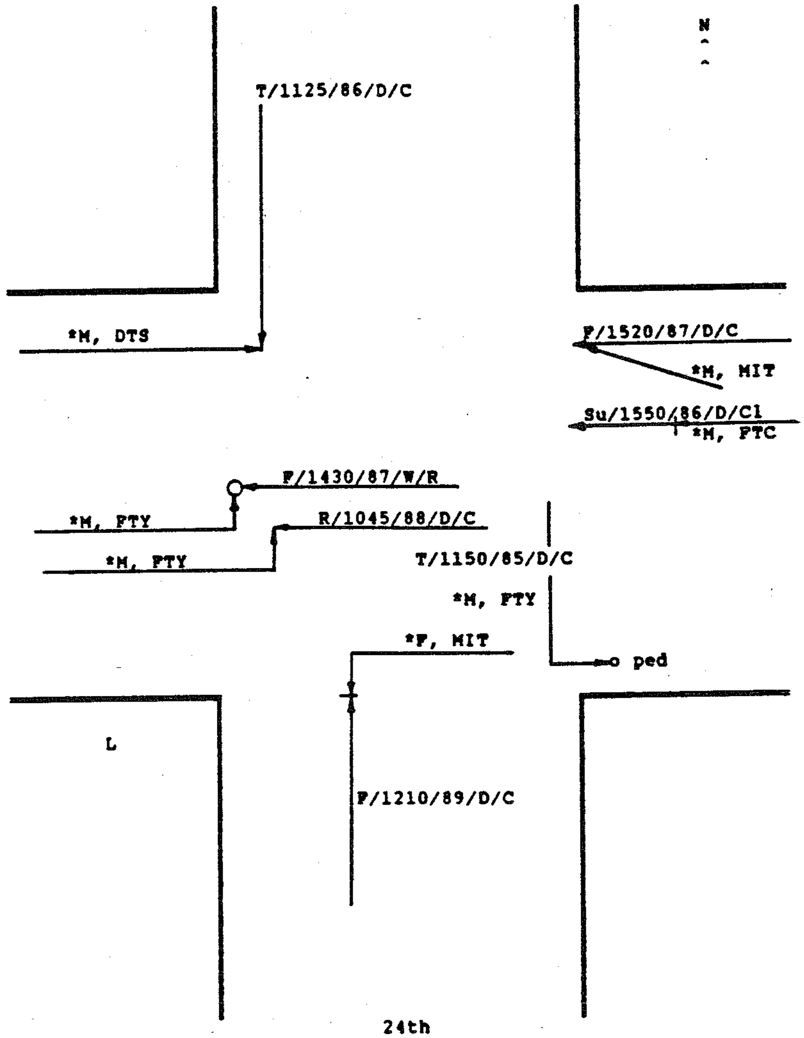
84th & W Center



Turning Movement ADT's



24th & L



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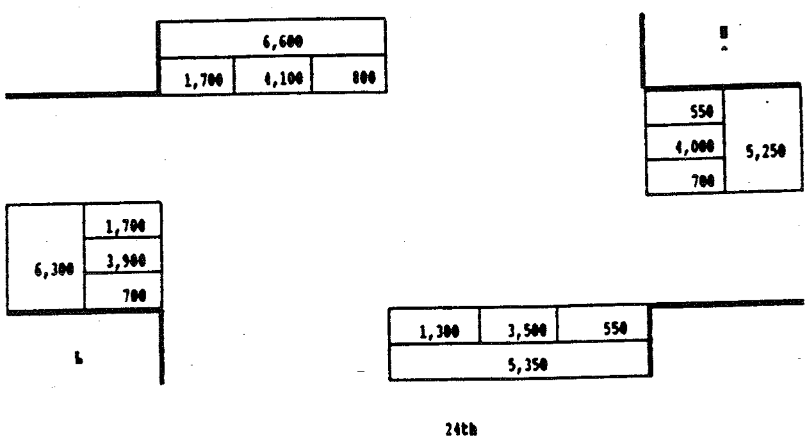
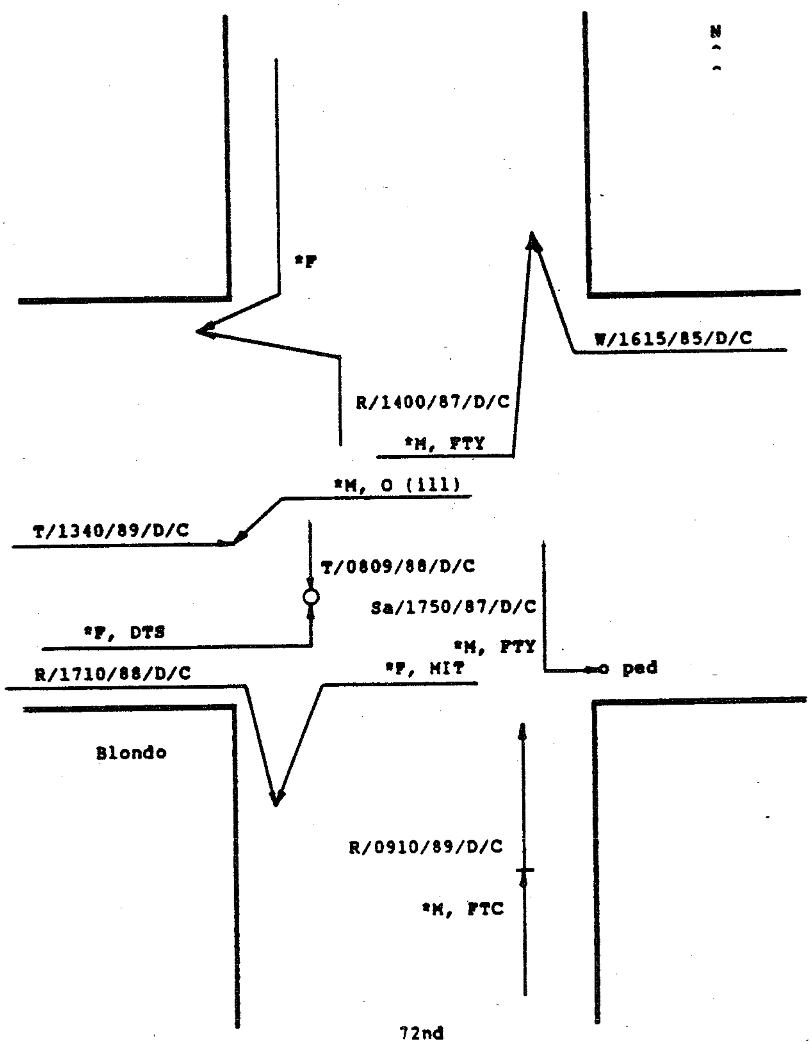
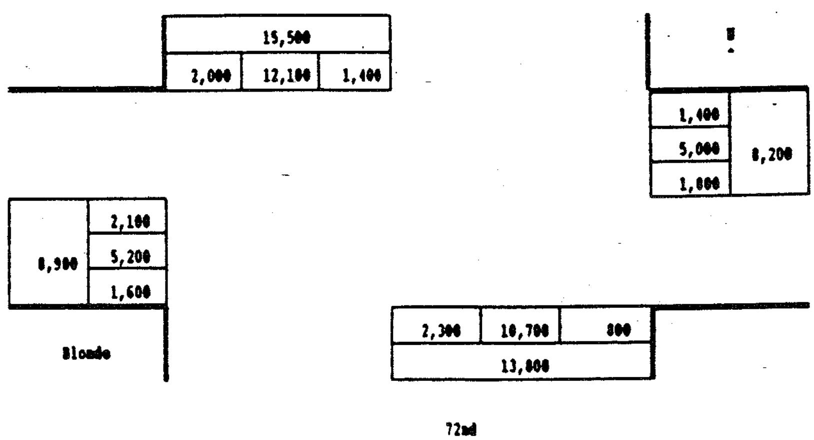


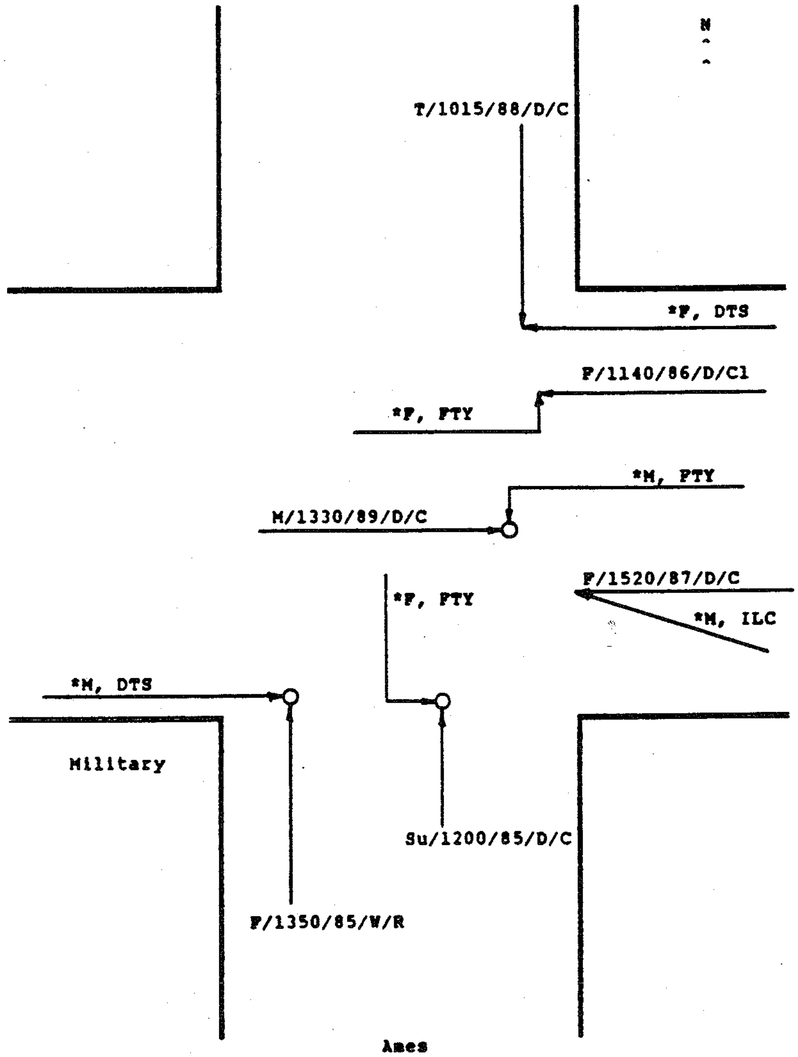
72nd & Blondo



Turning Movement ADT's



Ames & Military



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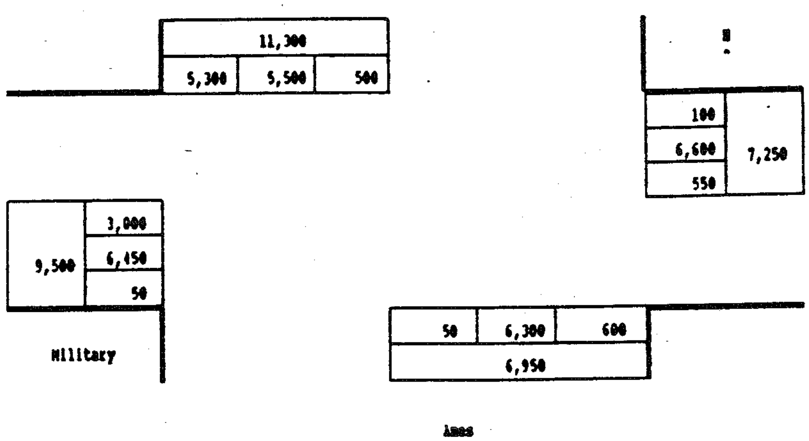
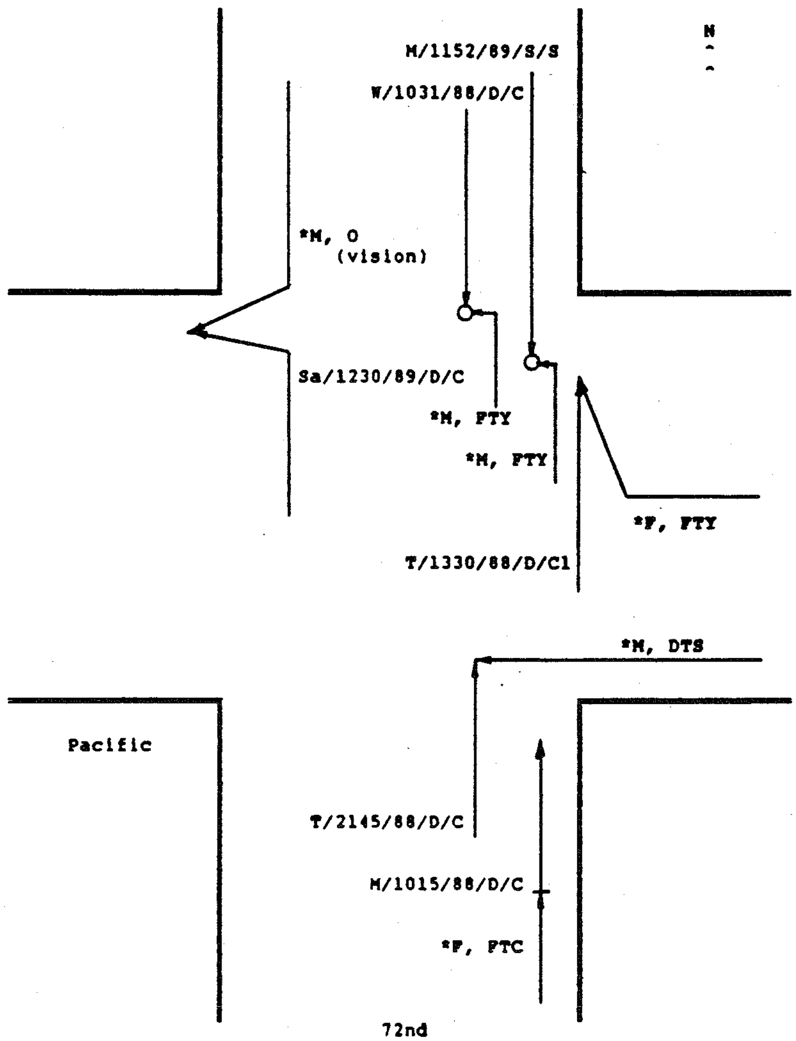


72nd & Pacific



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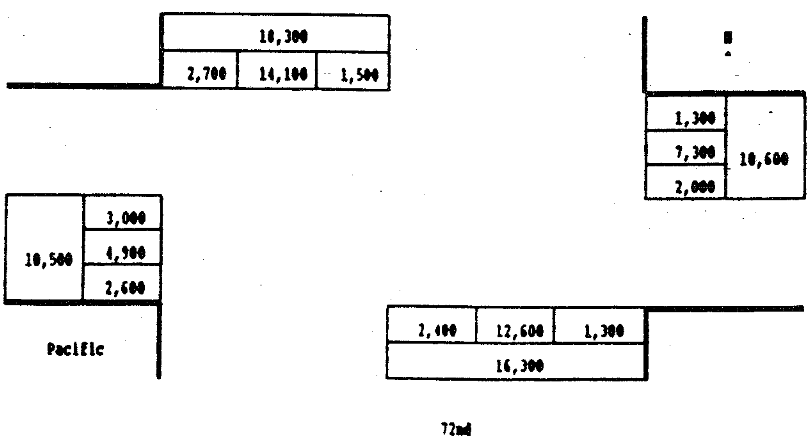
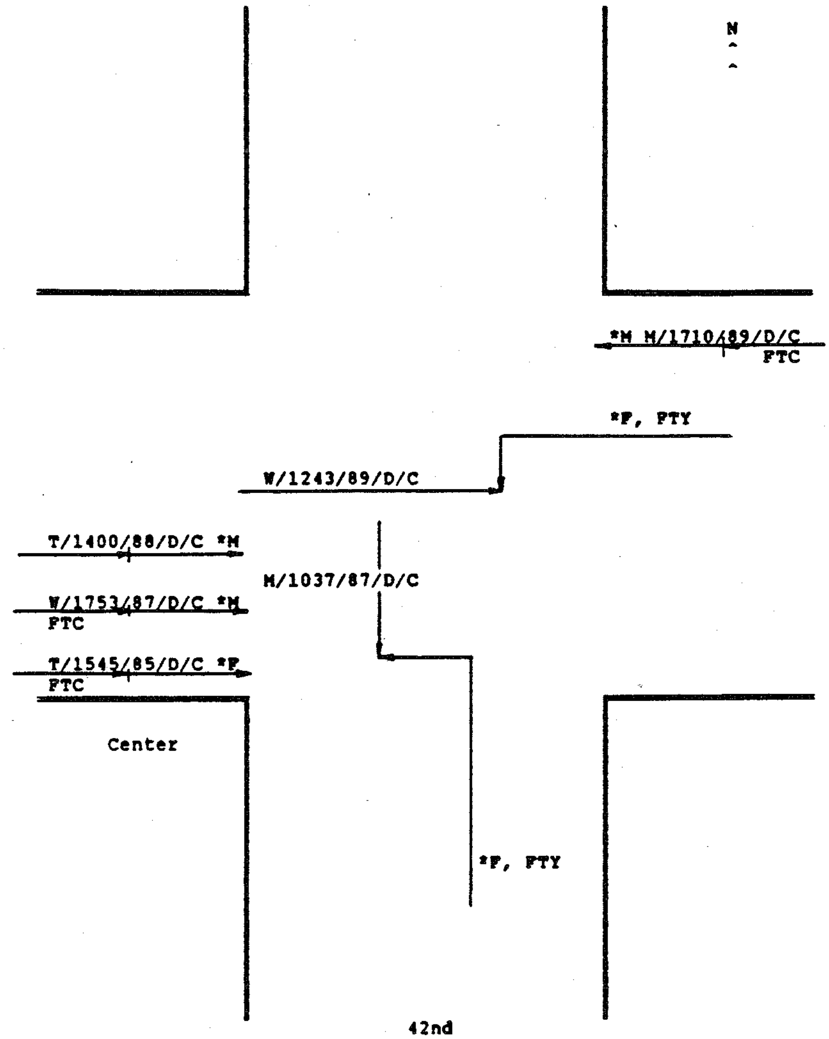


42nd & Center



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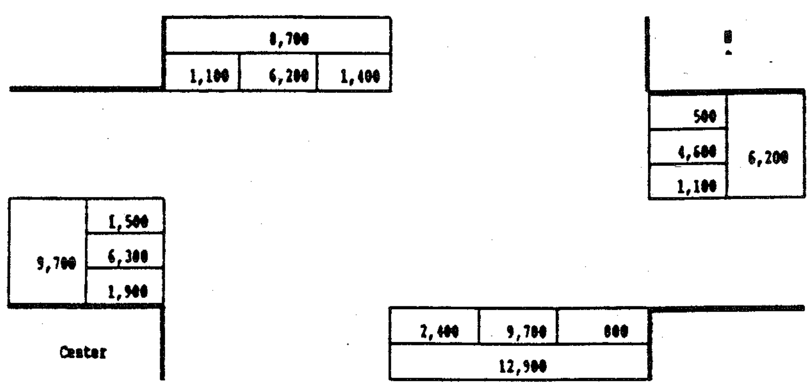
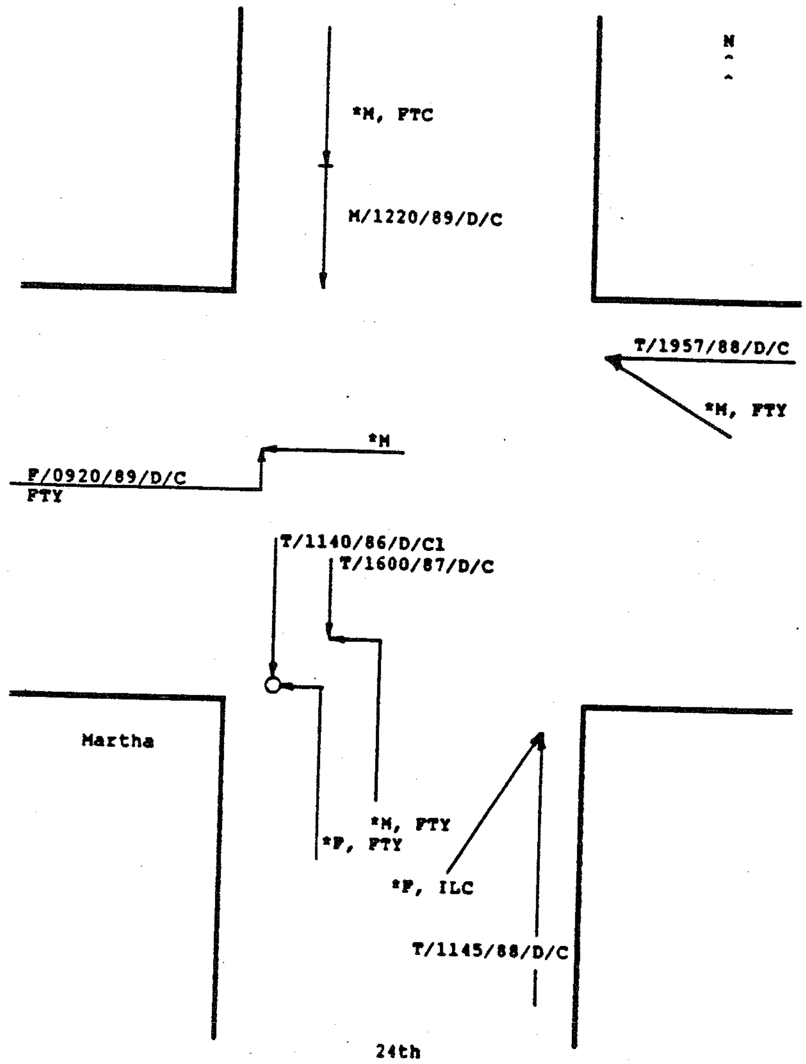


24th & Martha



Turning Movement ADT's