SPECIAL REPORT 218

TRANSPORTATION IN AN AGING SOCIETY

Improving Mobility and Safety for Older Persons

Volume 1

Transportation Research Board
National Research Council

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Volume 1
Committee Report and Recommendations

Committee for the Study on Improving Mobility and Safety for Older Persons

Transportation Research Board
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modes
1 highway transportation
2 public transit

subject areas
12 planning
51 transportation safety
52 human factors

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Study on Improving Mobility and Safety for Older Persons

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Preface

The quality of life in any society is reflected in that society's treatment of its older members. This study is about the needs and problems of older Americans in relation to our system of roadway transportation. The project was initiated in June 1986 by the Transportation Research Board (TRB), which appointed a committee of experts to review the design and operational features of that system and to recommend steps toward improving the mobility and safety of older persons—drivers, passengers, and pedestrians—all of whom are an integral part of the system.

Some months later Congress responded to the growing national concern about older drivers by including in the Surface Transportation Assistance Act of 1987 a request for "a comprehensive study and investigation of (1) problems which may inhibit the safety and mobility of older drivers using the Nation's roads and (2) means of addressing these problems."

The study committee comprised authorities in gerontology, medicine, highway engineering, vehicle design, traffic operations, urban planning, public transportation, driver education, licensing, and related areas. Their intention was to

1. Evaluate available data and research on the safety needs of the older person in traffic;
2. Identify potential measures to improve highways, vehicles, driver and pedestrian performance, and alternatives to the private automobile;

3. Weigh the public policy questions about costs, trade-offs between safety and mobility objectives, and the sometimes conflicting needs of individuals, different age groups, and the public generally;
4. Recommend improvements in highway conditions, vehicle design, licensing, testing, educational activities, and transportation alternatives; and
5. Identify promising areas for further research.

In short, this was probably one of the most ambitious programs ever undertaken on behalf of elderly drivers, riders, and pedestrians. Financial support was obtained from government agencies, private industry, and the National Research Council.

After hearing the opinions and suggestions of the committee members; consulting with professionals from relevant outside organizations, public and private; and making an intensive search of the appropriate literature, the TRB staff produced preliminary background papers and an annotated bibliography to help identify the issues.

On the basis of their expertise and interests, committee members were assigned to one or more of four subcommittees: Driver and Pedestrian, Environment, Vehicle Design, and Mobility. The subcommittees identified topics in need of study and recommended to the full committee those deemed most important for evaluation.

The full committee then ranked the topics and identified 12 for further exploration. Technical papers on these topics were then commissioned from 12 experts in the field. The chief criteria for selection of topics were (a) potential for a large beneficial impact on mobility or safety, or both; (b) cost-effectiveness; (c) freedom from legal or administrative barriers; (d) strong support from research data; and (e) minimum adverse effects on the younger driving population.

An international colloquium on Improving the Mobility and Safety of Older Persons was convened by TRB in October 1987. The commissioned papers were sent in advance to the 75 invited participants—committee members, allied liaison members, and recognized authorities on the topics covered. The basic purposes of the colloquium were to (a) help the authors of the technical papers clarify and modify their text and recommendations and (b) assist the committee in creating its recommendations. The colloquium was planned so that authors, moderator-facilitators, and discussants would interact toward these ends.

Deliberations were recorded in full and were useful to the committee in preparing its recommendations. The committee emphasized the idea of a *workable* plan, and concentrated on what can and should be done now. It also pointed out what still needs to be determined before a program can be implemented. Although recommendations were based on fact, when it could be found, in some cases the lack of data led the committee to rely on a consensus of the best judgments of its members for conclusions and recommendations.

The products of the study are organized into two volumes. The first contains an overview of the issues and the committee's recommendations; the second contains the technical papers prepared for the study.

Exercising what I hope is a chairman's privilege, I call special attention to the recommendation that, in my view, touches but goes beyond all others—the creation of an organization to follow up on the recommendations of this report and to encourage and guide whatever research may be required to address the transportation needs of an aging society.

Serious groups have in the past tried to deal with the mobility and safety needs of older persons, but their efforts have fallen short. Their recommendations have, even as have those in this report, cut across different federal agencies and all levels of government and national associations, but unfortunately there was no central direction to influence implementation of programs and research. The committee wishes to avoid that deplorable outcome. The recommendations in Volume 1 of this report were created only after the investment of considerable time and great effort by many authorities and organizations. They deserve a better fate than to spark briefly and then be allowed to expire. A follow-up organization would, we believe, encourage a persistent effort toward our goal of improving mobility and safety for older persons.

In all phases of this project, the TRB staff could not have been more helpful to the committee. The study was conducted under the overall supervision of Robert E. Skinner, Jr., Director of Special Projects. Stephen R. Godwin, Senior Program Officer, was responsible for day-to-day management and drafted most of Volume 1 under the guidance of the committee. Malcolm Quint, Research Associate, drafted Chapter 2. Darlene Yee was most helpful in organizing the colloquium, and Peter G. Koltnow provided valuable guidance to both staff and committee.

Special appreciation is expressed to Nancy A. Ackerman, TRB Director of Publications; to Naomi Kassabian, Associate Editor, for editing the report; and to Frances E. Holland for providing word processing support.

The liaison representatives of other organizations also made numerous contributions. Special thanks are in order for the extra efforts of Glenn Crawford, American Association of Motor Vehicle Administrators; Elaine Petrucelli, American Association of Automotive Medicine; and Michael Smith, National Highway Traffic Safety Administration.

Many other persons assisted the committee. Anthony DeLorenzo of the Oregon Department of Motor Vehicles made many thoughtful comments at the colloquium, as did Hugh McGee of the firm of Bellomo-McGee, Robert Dewar of the University of Calgary, Robert Henderson, and Frank Kenel of the American Automobile Association. Grace Hazzard of the National Highway Traffic Safety Administration provided special data on traffic injuries and fatalities.

These persons, along with friendly and spirited committee members, displayed so much interest and contributed so generously that chairing the committee turned out to be both a privilege and a pleasure.

James L. Malfetti
Columbia University
New York City

Contents

Volume 1: Committee Report and Recommendations

Volume 2: Technical Papers

Executive Summary

Automotive technology, the roadway system, and the population itself have matured since the dawn of the automobile age. After the turn of the century, Americans began buying automobiles by the millions and with this new mode of transportation began enjoying unprecedented independence and mobility. By current standards, it was a young society. In 1900 only 4 percent of the population was 65 or older; today, in 1988, 12 percent of the population is in this age group.

Although automobiles and highways have improved dramatically during this century, many design assumptions used today are based on the performance characteristics of a younger population. In the early 1940s, for example, when the research was conducted that forms the basis for current sign letter height standards, only 7 percent of the population was 65 or older. Research samples made up of young men were probably fairly representative of the drivers of the time. The current population of drivers, however, already has a large share of older persons, and during the next few decades the proportion of older drivers will increase even more. By 2020, 17 percent of the population will be 65 or older, resulting in more than 50 million older persons eligible to drive. Almost half of these older persons will be 75 or older.

The current older population is different from earlier cohorts. Increasingly large proportions of those up to about 75 are more affluent and healthier than their earlier counterparts; they are more likely to live in suburban areas and to depend on automobiles for mobility. As long as these individuals are able to use automobiles, they appear quite capable of meeting their own mobility needs. Those over 75 also tend to be more active than previous cohorts and also rely heavily on automobiles, either as drivers or as passengers.

The older persons of 2020 will have grown up during a period when use of the automobile became a normal part of everyday life; these older persons will probably have high expectations about driving, and there is every reason to believe that these expectations will be realized. Most older persons will probably be quite capable and safe drivers, but current statistics indicate that drivers 75 and over are more at risk of crash involvement than the average driver. Older vehicle occupants are much more likely to be severely injured or killed than middle-aged occupants in crashes of equal severity. These facts must be acknowledged even though there is no justification for restricting driving on the basis of age alone.

The roadway system—broadly construed to include street and highway design and operation, vehicle design, and driver licensing—can be better adjusted to the needs and abilities of older persons. Given the long lead time required to develop and phase in changes in the standards used for the roadway system, however, it is time to begin preparing for the mobility needs of a society that is already aging.

The Transportation Research Board (TRB) in 1986 initiated a study on the mobility and safety needs of older persons. It convened a panel of experts to review the design and operation of the surface transportation system and to recommend improvements that would better serve an aging population. As part of the Surface Transportation Assistance Act of 1987, Congress asked for "a comprehensive study and investigation of (1) problems which may inhibit the safety and mobility of older drivers using the Nation's roads and (2) means of addressing these problems." The response to this request, which emphasizes older drivers, is included in this report, which considers the mobility and safety needs of older drivers, passengers, and pedestrians.

SUMMARY OF FINDINGS

The committee's findings are summarized as follows:

- Mobility is essential to the quality of life of older persons, and the automobile is the primary means of meeting that mobility need. More than 80 percent of trips by those 65 and over are made in automobiles today, and this percentage is increasing.
- Most older drivers have good driving records. Up through age 75, most older drivers appear to perform as well as middle-aged ones. Although involved in a small number of crashes, after about age 75, older drivers are about twice as likely to be involved in a crash per mile driven.
- Older persons are among the most vulnerable to injury in motor vehicle crashes. Vehicle occupants 65 and older are more than three times more likely to die than a 20-year-old occupant from serious injuries of equal severity.
- In general, visual and cognitive performance on driving-related tasks diminish with age. At the same time, older people are very different from each other.
- Because, for any individual, age is a poor predictor of performance, age alone should not be the basis for restricting or withholding driver's licenses.
- Sign visibility and maintenance standards, assumptions about performance used in intersection design and traffic operations, and vehicle crashworthiness standards fail to account for the needs and capabilities of older persons using the roadway system.
- The population of older persons who are able to live in their own homes but who are unable to drive is growing. Better and more efficient specialized transportation service will be needed for this group to allow them to maintain their mobility and independence.
- Too little research is under way that could improve the mobility and safety of older persons, and research responsibilities are scattered across several different federal agencies.

SUMMARY OF RECOMMENDATIONS

Many steps can be taken today that will improve the mobility and safety of older persons now and in the next century. Some will have an immediate benefit; others are equally important but the benefits will take much longer to realize. Many of the steps that should be taken will benefit all age groups. The most important of these are briefly listed below.

A better understanding of many dimensions of transportation and aging is needed, however, before anything other than incremental improvements can be recommended. After identification of the most important research that is necessary, it is recommended that an effort be undertaken that would stimulate and facilitate the small-scale efforts under way at the national and state levels to enable them to address the mobility needs of our aging society.

Roadway Design and Operation

The assumptions about human performance used in signing, roadway marking, traffic control, and highway design are becoming increasingly inappropriate for an aging population of drivers.

Highway Signs

Current sign legibility standards assume a level of visual ability that many older persons cannot meet. The current standard—the assumption that an inch-high letter is legible at 50 ft—roughly corresponds to visual acuity of 20/25, which exceeds the visual ability of about 40 percent of drivers who are 65 to 74. Although roadway signs should be improved to benefit older drivers, all drivers will benefit.

- The *Manual on Uniform Traffic Control Devices* should adopt a performance standard for signs based on the minimum required visibility distance needed by older drivers. This performance standard could be met by bigger signs, brighter signs, and wider use of advance signing.
- State and local governments should develop systematic procedures to inspect and maintain signs to ensure optimal sign condition, mounting, contrast, and retroreflective performance.

More detail on these recommendations is provided on pages 66 and 67 and 78–80.

Roadway Markings

Roadway markings, such as painted edgelines, raised pavement markers, and post-mounted markers, provide visual cues to drivers to assist them in maintaining a safe lane position. Well-maintained markings are of special benefit to older drivers, but are important for all drivers, especially at night or at times of poor visibility such as fog, rain, snow, or glare. Provision and maintenance of highway markings, however, tend to be of low priority in some state, county, and local highway budgets.

- State, county, and local highway agencies should provide roadway markings of the highest accepted standard.
- State and local governments should place greater emphasis on routine inspection and maintenance of roadway markings.

More detail on these recommendations can be found on pages 80 to 81.

Pedestrian Signals

The *Manual on Uniform Traffic Control Devices* suggests that traffic engineers assume a walking speed of 4 ft per second to allow adequate time for pedestrians to cross a street, yet many older persons walk more slowly than that. Although a slower walking speed, perhaps 3 to 3.5 ft per second, would accommodate more older persons, a simplistic standard applied everywhere would impose large delays on motorists and would have safety benefits only under specific conditions. Intersections have too many differences in vehicular and pedestrian traffic volume, lane width, and geometric design for a single standard to meet all needs. Nonetheless, explicit attention should be paid to older pedestrians, and design features should be adopted that meet their needs (see also pages 67 and 81).

- Local and state traffic engineers should evaluate intersections with signal timing that assumes a walking speed of 4 ft per second or faster. At those intersections used regularly by older pedestrians or in areas with high concentrations of older persons, traffic engineers should either phase traffic lights to provide adequate time for older persons to cross or provide pedestrian-activated signals, refuge islands at the median, or other design improvements.

Roadway Design

Making a left turn against traffic at a busy intersection is among the more difficult tasks drivers must perform because of the need to judge gaps in oncoming traffic and to react quickly to opportunities to turn. Older drivers, in particular, have problems with left turns. Provision of dedicated left-turn lanes and left-turn signals simplifies this task and would benefit all drivers. The current design guide, however, does not provide adequate guidance for designers to determine when left-turn lanes should be provided and how they should be designed (see page 82).

• The American Association of State Highway and Transportation Officials should develop a procedure for determining the need for dedicated left-turn lanes. It should provide guidance on use of this procedure in the highway design guide.

Research Needs

Many geometric design and traffic control standards assume certain performance characteristics of drivers. Current information about driving performance is not representative of the driving population, and the safety consequences of changes in design are poorly understood.

• Estimates should be developed of performance distributions on tasks fundamental to highway design, such as perception–brake-reaction time, perception-reaction time for intersection sight distance, and the perception time for detecting and relating to objects in the road. Appropriate design standards should be developed that encompass the performance of older persons.

• Many decisions about traffic control of intersections are made without guidance regarding the safety consequences. The Department of Transportation should develop a research program on the safety consequences of alternative levels of traffic control, right-turn-on-red, pedestrian signals and crosswalks, and traffic control to protect left-turning traffic at signalized intersections.

Background on these recommendations can be found on pages 62 to 68. The recommendations are discussed in more detail on pages 83 to 84.

Vehicle Safety

Occupant Protection

Because of their susceptibility to injury, either as occupants or as pedestrians, older persons are more vulnerable to injury and fatality when crashes occur. Crash protection, therefore, will be of special benefit to older highway users (see pages 68 and 84 to 85).

- The states that have not adopted mandatory safety belt use laws (19 in 1987) should do so and should encourage the proper use of safety belts through information campaigns and vigorous enforcement.
- Automobile manufacturers should continue to improve the accessibility and ease of use of safety belts with the special needs of older persons in mind.
- Because of the special benefit to them of additional crash protection, older drivers should purchase automobiles equipped with air bags.

Consumer Information

Older motorists should be made more aware of their different performance capabilities, their lower threshold to injury, and how they could benefit from certain vehicle features and attributes. Air bags, properly designed seats, large rearview mirrors, and other vehicle features would provide special benefits to older occupants. Most older drivers, however, may not be aware of the benefits they would gain from such features (see page 86).

- The National Highway Traffic Safety Administration (NHTSA) should develop a consumer-oriented program that will raise the awareness of older consumers to their needs and to the vehicle features that may be of special benefit to them as they age.
- NHTSA should work with the public and private sectors to develop and disseminate such information.

Research Needs

Older persons have quite different biomechanical responses to injury than younger persons. In crashes of equal severity they are much more likely to experience a severe injury or fatality than a younger person. Older persons have a higher fatality rate per capita as pedestrians than any other age group.

- NHTSA should support biomechanical studies to delineate the differences in vulnerability to injury across age groups.

- Assuming that a better understanding of the vulnerability to injury that accompanies aging can be achieved, NHTSA should evaluate its occupant protection standards in light of the growing share of the population with a greater vulnerability to injury in low-speed crashes.

These research needs are discussed in more detail on pages 87 to 89.

Driver Screening and Licensing

By 2020 about 22 million people will be 75 or older and still eligible for a driver's license; 7 million will be 85 or older. The states are not prepared to handle the growing number of very old drivers or to identify those at high risk of accident involvement. States such as Washington and Oregon, however, are developing innovative pilot programs. Through these programs special training is provided to examiners in identifying persons, regardless of age, who might have impairments that would reduce their driving skills; counselors are available who are trained in working with older persons; special licenses are provided on the basis of the mobility needs of license applicants; and drivers with special licenses are carefully monitored. Such programs could also be used to experiment with informing license applicants of courses designed to help them brush up on their skills; to distribute brochures designed to help older drivers assess their own skills and learn how to assess shortcomings; and to counsel older persons about alternative modes of transportation in their community. Current state licensing practice for older drivers is reviewed on pages 69 to 72. Model pilot programs are described on pages 89 to 91.

- Innovative pilot programs being developed by the states should be further developed with support from NHTSA and should be carefully evaluated.

Vision Screening

Good vision is among the most important abilities needed for driving, and opportunities exist to improve driver vision screening. All states screen for static visual acuity, and most (41) set the standard at 20/40 for individuals who do not require optical correction. For those drivers who require optical correction, 36 states set the standard at 20/40, and the highest is 20/70. About half the states currently screen for loss of visual field.

• States should adopt uniform standards for vision screening at license renewal. Drivers should have a corrected static acuity of 20/40 obtainable with both eyes open. Drivers with static acuity between 20/40 and 20/80 should be referred to a qualified vision care specialist to be assessed for a restricted license. States should also screen for loss of visual field with the screening standard set at 70 degrees to either side of fixation. Drivers with visual field loss in the range of 45 to 70 degrees should be required to use special mirrors to correct partially for the loss of peripheral vision.

• Because of the importance of vision screening, the states should continue to require in-person renewal for licensing. The four-year cycle used by most states should be continued until research indicates whether a shorter or longer period is warranted.

These recommendations are described in more detail on page 91.

Research Needs

Age alone is a poor predictor of individual driving ability, but little systematic research has been directed at methods of identifying high-risk drivers on the basis of performance capabilities rather than age. A variety of specific efforts will assist in achieving the goal of improving driver screening (see also pages 92 to 94).

• The small-scale research on driver performance in the U.S. Department of Transportation and related research funded by the National Institute on Aging should be coordinated toward the goal of learning how to measure skills related to driving performance on the basis of functional capability.

• Research should be undertaken to develop validated tests of dynamic visual performance, glare sensitivity, contrast sensitivity, and other visual characteristics.

• The effectiveness of screening drivers for contrast sensitivity, dynamic visual performance, and static acuity at low-level illumination should be evaluated.

• A normal illumination (photopic) static acuity standard that is free from age bias (current illumination practice penalizes older drivers) should be developed.

• Better estimates are needed of the cognitive performance of the entire driving population on such tasks as attentiveness, information processing, and problem solving. Also needed is a better understanding of how performance levels are distributed across age groups.

• The cost-effectiveness of using automated microcomputer technology to screen the visual and cognitive performance of drivers should be evaluated.

Alternative Means of Transportation

Walking

Walking is second in importance to driving as a mode of transportation for older persons, yet many suburban areas where older persons live have few pedestrian amenities. Recommendations for improving alternative means of transportation are discussed on pages 95 to 99.

• Local governments should enhance the pedestrian environment by incorporating propedestrian safety features into subdivision and redevelopment site-plan approval and into zoning regulations.

Specialized Transportation

As more people live longer—demographers predict 8.5 million persons age 85 and older by 2030—provision of specialized transportation systems will become more vital. Many of these persons will be unable to drive private automobiles because of some disability, low income (not including health benefits), or a combination of factors that accompany advanced age. Except in a few major metropolitan areas, however, only small-scale (and infrequent) transportation service is available, in part because of the high cost of such service per trip.

• Communities planning to expand transportation service to older persons should consider subsidizing taxis as an alternative to expanding conventional forms of public transportation.

• The federal government, either through the Department of Transportation or Health and Human Services, should help local communities develop locally based transportation service appropriate to the needs of the local older population. Research that documents successful efforts to support volunteer and family networks, facilitate paid and unpaid carpools, and develop special paratransit systems should be supported by these agencies.

Organizing Research To Prepare for the Future

Responsibility for improving the mobility and safety of older persons cuts across different federal agencies (Health and Human Services, Transportation), different administrations within those agencies (National Highway Traffic Safety Administration, Federal Highway Administration, Urban Mass Transportation Administration, Administration on Aging, Institute on Aging), and all levels of government. In addition, many national associations directly influence the implementation of policy and research programs. Preparing for the transportation needs of an aging society is important to all these agencies, levels of government, and associations, but is not at the top of the action agenda for any of them. The recommendations of several earlier reports on the mobility and safety needs of older persons have languished for precisely this reason.

- A group should be created to follow up on the recommendations made in this report and to encourage and stimulate the research needed to address the transportation needs of an aging society. Such a group might be organized under the auspices of TRB and the National Research Council.

In conclusion, concern about the mobility and safety of older persons has increased in recent years as the awareness of the implications of the aging of our population has grown and as witnessed by the request of Congress for a study directly focused on the problems faced by older drivers. The available evidence indicates that most older persons, at least up through age 75, are quite capable of meeting their own mobility needs, largely as drivers of private automobiles. Because of their good driving records and the enormous cost of providing alternative means of transportation, these individuals should be allowed and encouraged to rely on private automobiles. After about 75, the driving records of older persons as a group begin to deteriorate. The heterogeneity of this age group, however, indicates that great care should be taken to develop licensing practices that are effective and fair. Some older persons, either for reasons of physical impairment or low income, will not be able to provide for their own mobility. Much more effective and efficient transportation service will need to be devised to meet the mobility needs of this group. Adoption of the recommendations made in this report will improve the mobility of older persons and reduce the risks they face in traffic as drivers, passengers, and pedestrians.

CHAPTER ONE

Introduction

American society is undergoing a demographic transformation that will continue into the middle of the next century. The "graying of America" has captured the attention of policy makers and researchers in such fields as health care, retirement, and housing, but to date little attention has been paid to the mobility needs of an aging society. Considerable research has focused on the importance of keeping individuals independent in their own homes as long as possible, but little systematic analysis has been conducted to determine how the older person in the future will manage the trips necessary to shop, to receive medical attention, to worship, and to associate with friends and family.

BACKGROUND PERSPECTIVES

Mobility is essential to the quality of life of older persons, and current trends suggest that in the future the majority will depend on the automobile to make most trips. Contrary to a widely held perception, most older persons retire in the communities in which they have worked and raised their families. Only a small percentage moves to retirement havens in the sun belt. In addition, most are living outside central cities; many of these parents of Baby Boomers populated the suburbs after World War II and are retiring there as well. Except in a few major metropolitan areas with extensive and reliable public transit, the automobile is the primary, and in many places the only, mode of transportation for meeting the needs of older people.

Fortunately, most older persons today are quite capable and safe drivers, but accident rates do increase for the oldest drivers (see Chapter 3). Two points are important in this connection.

First, older persons as a group show declines with advancing age in health, visual function, and speed of reaction, and declines on a limited number of laboratory-tested cognitive measures. At the same time, as individuals age they become more, not less, different from each other over a wide range of such measures. For individuals as opposed to the group as a whole, chronological age is a poor predictor of physical, mental, or social competence.

Second, the majority of those over 65 are "young-old": that is, they are relatively healthy, relatively well-off retirees and their spouses, actively engaged in the lives of their families and communities—in short, persons who are socially competent (Neugarten and Neugarten 1986). Although most persons over 65 report one or more chronic illnesses (or health conditions), they report no major limitations in their everyday activities because of health. Even among the oldest—those who are over 85—less than half report any physical or medical limitations that affect their daily activities (Soldo and Longino 1988).

The definition of "young-old" is based, then, on functional status and not on chronological age. A person may be young-old at 55 or 85. Most of the data presented in the chapters that follow (and in the technical papers in Volume 2) have been aggregated by age because they are not available on the basis of functional performance, which would be more meaningful. Although the performance of groups is differentiated by age categories in this report (which may reinforce the misuse of age as an explanatory variable), this is a result of the way the information is gathered and made available.

By a combination of skill and self-imposed restrictions, older drivers in the young-old category appear to be able to meet their own mobility needs. Because of the importance of independent mobility for maintaining a high quality of life in later years and the enormous cost of providing transportation alternatives, it is important that older persons retain access to the private automobile. At some point, of course, most of those who live long enough will pass from being relatively healthy to being relatively

Older persons who are healthy and vigorous—the "young-old"—make up the majority of the older population (*photograph from American Association of Retired Persons*).

impaired. Either through publicly imposed license revocation (which is rare) or family action, or by choice, many older persons find that they cannot rely on driving or walking to meet needs for socializing, shopping, and worshiping or for medical care. Some of their mobility needs are met by public transit, some by the help of family members, some by human service providers, and some by informal arrangements with community agencies, friends, and church or synagogue. Some mobility needs are not met, however. This raises the specter of some aged persons living out their last years in lonely isolation.

Although preserving the mobility of older persons is of primary concern, traffic safety statistics (compared on the basis of chronological age) indicate that older persons as a group experience a higher-than-average risk of injury and fatality when using the nation's roads and highways. Although they are involved in a relatively small number of crashes, this is because they drive less and because they account for only about 12 percent of the population in 1988. When involved in a crash, older persons are much more likely to be killed or severely injured. If their share of traffic fatalities per 100,000 population remains constant and if the death rate from motor vehicle accidents per 100,000 persons continues its current trend, traffic deaths of those over 65 will account for 17 percent of fatalities in 2020, about a 50 percent increase in traffic fatalities for that age group.

From the outset of this study the committee has been aware of both the importance of mobility for the quality of life of older persons and the higher safety risk older persons face in traffic, and it recognizes that the goals of mobility and safety sometimes conflict. Because the committee believes that, in general, mobility is more important, it sought to identify policies and research that would improve safety without compromising mobility. American society has sufficient time to develop these policies and conduct the needed research, but only if the process begins now. Stimulating that process is the goal of this report.

Volume 1 of this report presents a summary of the committee's work over two years. Chapters 2 through 4 provide background information on demographic trends, traffic safety, and the impact of an ever-aging society on the roadway system. Chapter 5 contains the committee's recommendations.

Throughout this report the term "roadway system" is intended to include all elements of the highway transportation system: highway design and operation (which includes marking, lighting, signing, and traffic control devices), vehicle design, driver licensing practices, and the interaction among highways, vehicles, and drivers. The roadway system and the effect of an aging society on its design and operation involve many complex dimensions. The committee exercised its judgment in focusing on those aspects of the system for which adjustments appeared warranted and existing knowledge might permit recommendations to be made. Thus, some important issues, such as the ergonomics of design for automobiles and mass transit vehicles, were not addressed.

Volume 2 of this report contains a series of technical papers commissioned by the committee, which address a selected number of issues, including the importance of mobility, current information on the travel behavior of older persons, intersection design and operation, sign legibility and conspicuity, roadway markings, vehicle design for occupant and pedestrian safety, headlights, consumer information, driver licensing, and driver retraining.

Because most older persons use automobiles and will rely on them more heavily in the future, most of the report addresses highways, automobiles, and driver licensing. For many older persons, especially those living in densely populated urban areas, public transit systems are critical to their mobility. Although alternatives to the automobile are discussed in one technical paper and briefly in Chapters 2 and 5, this report emphasizes the mode that the majority of older persons use the most—the private automobile.

OUTLINE OF REPORT

Demographics and Travel Trends

In Chapter 2, the aging of the population is described, and the implications of this aging on travel trends are explored. Beginning with the recognition of the importance of mobility for older persons, which is detailed in a paper by Carp in Volume 2, the discussion continues with an outline of population trends. A review of travel trends points up the reliance of older persons on the automobile. The use of other modes—walking, taxi, public transit, and specialized transportation—is described using the paper by Rosenbloom in Volume 2.

Traffic Safety

The risks older persons face in traffic as drivers, vehicle occupants, and pedestrians are reviewed in Chapter 3. The sparsity of data aggregated by age groups for accidents, injuries, and travel makes conclusions about differences among age groups difficult to draw. The available information suggests that driving-related skills diminish for drivers in the oldest age groups, which is reflected by a gradual increase in driver involvement in crashes after about age 75. Because of the greater susceptibility of older persons to injury and fatality, the effects of these crashes on them are more serious.

After about 75, older persons are as likely to be passengers as drivers. As vehicle occupants, and apparently because of their frailty, occupants over 75 have a fatality rate that rivals that of the most crash-prone drivers—those in the youngest driving age groups. Older persons are especially vulnerable to injuries from pedestrian accidents; the pedestrian fatality rate of those over 65 is the highest of any age group.

Aging and Performance

What in the aging process contributes to the increased risk for older persons when using the highway system? After a brief discussion of functional dependency, Chapter 4 continues with a review of cognitive and physiological performance necessary for safe driving, some of which changes with age. This section of the chapter draws on literature surveys on aging, vision, and cognitive performance included in the technical papers prepared for this study by Bailey and Sheedy, Schieber, and McKnight, which are found in Volume 2, and on a paper prepared by Kline for the Committee on Vision of the National Research Council (1986).

In the next section, the performance levels assumed in highway design, licensing, and vehicle design are reviewed and compared with the capabilities of older persons. The human factors literature indicates that the level of performance varies more among older persons than it does among younger persons. Much of the research on human performance related to highway design and operations fails to include the performance of older persons, and even when it does, the samples are often too small to be representative. Some of the mismatches between performance assumptions and what is known about the abilities of older persons are highlighted.

The discussion of highway design and operation draws on several of the papers in Volume 2. In his paper on the design and operation of intersections, Hauer provides information regarding highway design and operation. Mace reviews the mismatch between the visual performance of older persons and current sign standards. Waller reviews current licensing practices for older persons. Vehicle design issues for crash protection are addressed by Mackay, and Mortimer reviews potential improvements in vehicle headlamp design and maintenance.

Summary and Recommendations

Recommendations made in the technical papers prepared for this study, modified by the committee's deliberations, analysis, and judgment, were used in preparing the final recommendations. Suggested improvement in roadway design and operation draws on the papers by Hauer, Mace, and Deacon. Recommendations are also made to improve the crashworthiness of vehicles on the basis of the paper prepared by Mackay and to improve vehicle headlighting on the basis of the paper by Mortimer. In order to improve safety, suggestions are made that will affect drivers through improved license renewal procedures and vision-screening standards; these are based on the papers by Bailey and Sheedy, Schieber, Waller, and McKnight. In order to improve mobility options beyond the use of private automobiles, recommendations based on the papers by Rosenbloom and Carp are made to improve pedestrian movement in suburban and growing urban areas and to facilitate improvements in paratransit and specialized transportation services intended for the frail elderly (or older persons without access to automobiles).

Developing comprehensive policies to improve the mobility and safety of older persons is stymied almost at the outset by the lack of knowledge about the potential outcomes of these policies. Research needs are identified in Chapter 5 in experimental psychology and human factors engineering (visual and cognitive performance), optometry (visual testing), biomechanics (physiological reasons for the differences in vulnerability to injury across age groups), engineering (design standards), transportation planning, and human service delivery. The importance of collecting better information on the needs and abilities of older persons that reflects the heterogeneity of this population is emphasized.

The report concludes with a recommendation to create an organization charged with the task of following up on these recommendations and stimulating the necessary research.

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CHAPTER TWO

Demographics and Travel Trends

American society is growing older. The aging of the Baby Boom generation will hasten this trend. Stereotypes of the older person conceal their diversity in terms of health, income, and activity patterns. Older persons who are healthy and vigorous are often referred to as the "young-old," regardless of their chronological age. The majority of the young-old drive automobiles extensively, partly because of their preference for a suburban life-style. Whereas older persons who are frail also rely heavily on automobiles for mobility, they are more likely to have physical limitations that restrict their driving and thus to depend more on others for transportation. Both groups of older people, however, depend on cars; they make more than 80 percent of all their trips by car either as drivers or as passengers.

This chapter contains a review of population trends pertaining to older Americans and an outline of the increasing importance of the automobile as the dominant mode of travel for older persons.

POPULATION TRENDS

In 1900, 4 percent, or only 1 in 25 persons, in the United States lived to be 65 years old or more. In 1984 approximately 12 percent, or about one in nine people, was 65 or older.

Older persons make more than 80 percent of all trips by car, either as drivers or passengers (*photograph by Herbert A. Pennock, TRB*).

Two major influences account for the increasing proportion of older persons in the population. The first of these was the high birth rate from 1945 to 1970. Second, improvements in health care and medicine have allowed more people to live to old age.

Demographers refer to these changes in the age structure of our population as the "squaring of the pyramid" (Figure 2-1). The population structure was once pyramidal: there were many young people at the base

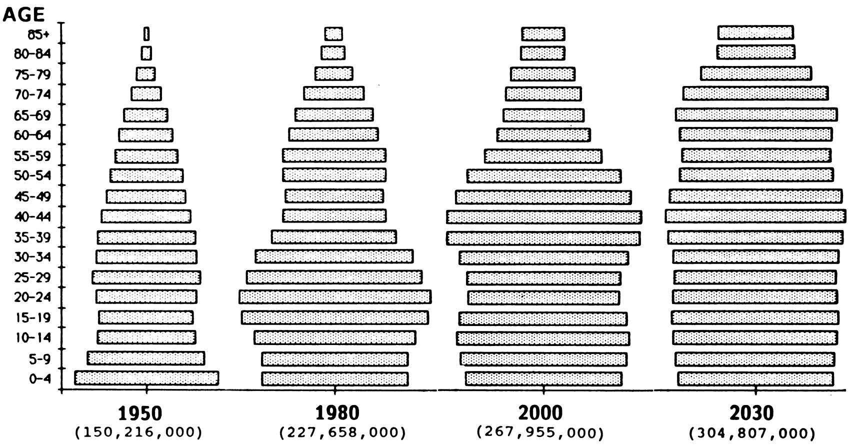

FIGURE 2-1 Squaring the U.S. population pyramid, 1950–2030.

and a few very old people at the pinnacle. The "Baby Boom and then bust" cycle plus the increase in average life expectancy changed the shape of the structure. It is fast becoming a rectangle with an equivalent number of people in each age group.

By the year 2000, 13 percent of the population in the United States will be over 65 (Census Bureau 1984, Table 6). Between 2020 and 2030—even if birth rates stay low, as most demographers believe they will—20 percent of the population will be 65 or older.

Diversity of the Older Population

Characteristics of older people reflect the diversity of the general population. A broad range of social characteristics is presented in Table 2-1. The young-old have the time and, in most cases, the income to pursue a wide range of activities. Older persons have more in common with their younger neighbors in terms of life-style than with others in their own age group of different socioeconomic status (Wachs 1979). For example, older central city residents in Los Angeles use city buses twice as often as the county average, whereas older residents of newer suburban areas have travel patterns characteristic of their neighborhood: they rely on driving and rarely use the bus. The relationship between housing and mobility in old age can be examined more completely by viewing it as a life-style concept that incorporates attitudes and social dimensions as well as physical and economic characteristics.

The absolute number of persons over 75 is growing rapidly. Currently, there are twice as many persons 65 to 74 years old as persons 75 and over. However, as an age group the number of those over 75 is growing more rapidly than those between 65 and 74 (Table 2-2). The group 85 and older accounted for about 1 percent of the total population in 1980. It is the fastest-growing of all age groups and is expected to triple in size between 1980 and 2010.

Marital Status

Marital status differs greatly between men and women over 65: less than 10 percent of men between 65 and 74 were widowers in 1986, whereas close to 40 percent of women in this age group were widows (Special Committee on Aging 1987). Women have a longer life expectancy than

TABLE 2-1 SOCIAL CHARACTERISTICS (Special Committee on Aging 1987)

	Age				
Characteristic	65–74	75–84	85+	All 65+	All 75+
Total population, 1986 (millions)					
Men	7.21	3.26	0.746	–	–
Women	9.39	5.53	1.849	–	–
Total population projected, year 2000 (millions)	17.677	12.318	4.926	34.921	17.244
In labor force, 1986, (%)					
Men	25.0[a]	–	–	–	10.4[b]
Women	14.3[a]	–	–	–	4.1[b]
Median cash income, 1985 ($)					
Head of family	20,354	16,412	15,111	19,117	–
Unrelated individual	8,160	7,186	6,400	7,476	–
Under poverty level, 1986 (%)					
Men	7.0	10.7	13.3	8.5	–
Women	13.0	18.1	19.7	15.2	–
Both	10.3	15.3	17.6	12.4	–
Married, spouse present, 1986 (%)					
Men	79.2	–	–	75.3	67.9
Women	49.2	–	–	38.3	22.8
Widowed, 1986 (%)					
Men	9.1	–	–	13.7	22.5
Women	38.8	–	–	50.5	67.0
Living alone (%)					
Men	12.7	–	–	14.9	19.2
Women	34.6	–	–	41.3	51.0
Living in nursing home, 1985 (%)	1	6	22	–	–
Median years of schooling, 1986	12.1	–	–	11.8	10.1

NOTE: Dashes indicate data not available.

[a] Data are for those 65 to 69.

[b] Data are for those 70 and over.

TABLE 2-2 ACTUAL AND PROJECTED GROWTH OF THE OLDER POPULATION, 1950–2030 (Special Committee on Aging 1987)

	Size by Age Group					
	65 to 74		75 to 84		85 and Over	
Year	Number (millions)	Percent	Number (millions)	Percent	Number (millions)	Percent
1950	8.42	5.6	3.28	2.2	0.58	0.4
1960	11.00	6.1	4.63	2.6	0.93	0.5
1970	12.45	6.1	6.12	3.0	1.41	0.7
1980	15.58	6.9	7.73	3.4	2.24	1.0
1990	18.04	7.2	10.35	4.1	3.31	1.3
2000	17.68	6.6	12.32	4.6	4.93	1.8
2010	20.32	7.2	12.33	4.4	6.55	2.3
2020	29.86	10.1	14.49	4.9	7.08	2.4
2030	34.54	11.3	21.43	7.0	8.61	2.8

men and tend to marry men older than themselves. Men who lose a spouse through divorce or death are more likely to remarry than are women. This difference in marital status becomes even more exaggerated for persons over 75. Approximately 7 of 10 men over 75 have spouses who are living, whereas 7 of 10 women are widows.

Financial Status

Loss of a spouse usually lowers the income of the remaining person. Those over 65 who live alone have 40 percent as much income as families whose chief earner is over 65. Those from 65 to 74 who are married have incomes that are on average three times the poverty level, which for couples over 65 was $6,630 in 1986; the median income for families in which the head of household is between 65 and 74 was $20,354 in 1985 (Special Committee on Aging 1987).

Persons over 75 have fewer financial resources than those 65 to 74 for a variety of reasons: lower earned income, death of a spouse, or medical expenses resulting from declines in health. Households in which the head is over 75 have a median income that is 75 percent of that for families whose head is between 64 and 74. Individuals over 75 are more likely to be poor than those between 65 and 75. About 10 percent of those who are 65 to 74 had incomes (not including health benefits) below the established poverty level in 1987 compared with 15 percent of those who are 75 to 84 and 18 percent of those over 85. Members of younger cohorts tend to have higher education levels and better incomes than members of older cohorts. Effects of aging, such as health decrements and widowhood, lower a person's income. In 1988, those over 75, compared with all those over 65, are more likely to be women, in poverty, living alone or in a nursing home, and requiring health care services. With diminished financial resources, those over 75 have less access to a private vehicle and may become dependent on others.

Only 5 percent of those over 65 are currently in a nursing home. Women are more likely than men to enter a nursing home at comparable ages, not that they are less healthy than men, but they live longer on average and are more likely to be unmarried or widowed. Unmarried persons and widowers over 85 are three times more likely to be institutionalized than those whose spouses are living (Butler and Newacheck 1981). Forty-five percent of the nursing home population is made up of persons over 85 (Special Committee on Aging 1987). The death of a spouse or absence of other family members who can provide support are the most important factors in the institutionalization of an older person.

Older women are more likely to be dependent on others for transportation than older men. As the previous sections indicate, women tend to outlive their husbands, with a subsequent loss of income and mobility. Many older women currently do not drive or have relied on their husbands to drive. Some of these women become licensed for the first time or have to drive more regularly when their husbands die. Future cohorts of older women, however, will be more experienced as drivers and the impact of the death of a spouse may lessen.

Access to transportation is more difficult for older persons who face a decline in both their financial status and their personal mobility due to chronic health conditions. Three percent of those 65 to 74 have chronic conditions that restrict them to traveling within their own neighborhood (Table 2-3). Over 24 percent of those 85 or older are limited in this way.

The young-old have the physical capabilities to drive and most have the financial resources to maintain and use a car. Most older persons are both healthy and financially secure enough to rely on a private vehicle for mobility. The decline in visual abilities, reaction time, and coordination skills with age may not limit older persons' self-care but diminishes their

TABLE 2-3 MOBILITY LIMITATIONS DUE TO CHRONIC CONDITIONS AMONG NONINSTITUTIONALIZED OLDER PERSONS, 1977 (OTA 1985, 42)

	Percentage by Age			
Place of Limitation	All 65+	65–74	75–84	85+
Outside neighborhood	8.4	4.6	12.0	30.6
Within neighborhood	6.0	3.1	8.3	24.4
Within house	2.6	1.4	3.5	10.8

NOTE: Each row is inclusive of row below; that is, "within neighborhood" includes percentage from "within house."

confidence and ability to drive. Older persons with serious physical limitations use automobiles for transportation but are more likely to depend on others for driving.

TRAVEL TRENDS

The automobile is the dominant mode of travel for older persons, as it is for the entire U.S. population. Older people drive fewer miles than do the rest of the population, but their mileage will likely increase in the future. There are two reasons for this trend. First, the number and proportion of older people with driver's licenses are rising, especially among women. Second, more older people reside in the suburbs, generally in locations where reliance on the automobile is a necessity. Few suburban residents are currently served by public transit, and the tightening of public spending gives scant hope that conventional forms of publicly provided transit will increase their service in the near future.

The percentage of older men and women holding driver's licenses has been steadily increasing for the past 15 years (FHWA 1986, 4-3). Forty-three percent of those over 65 had a driver's license in 1969, 55 percent in 1977, and 62 percent in 1983. The increase in licensure for older women is particularly striking—from 26 percent in 1969 to 49 percent in 1983 (Figures 2-2 and 2-3).

Residential Location

A growing percentage of older persons reside in the suburbs. After World War II, many people moved from rural to urban areas and at the same time, many moved from central cities to suburbs within metropolitan areas.

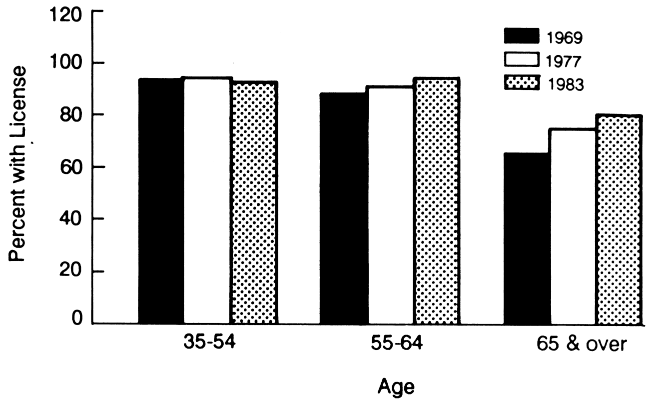

FIGURE 2-2 Male licensed drivers by age, 1969, 1977, and 1983.

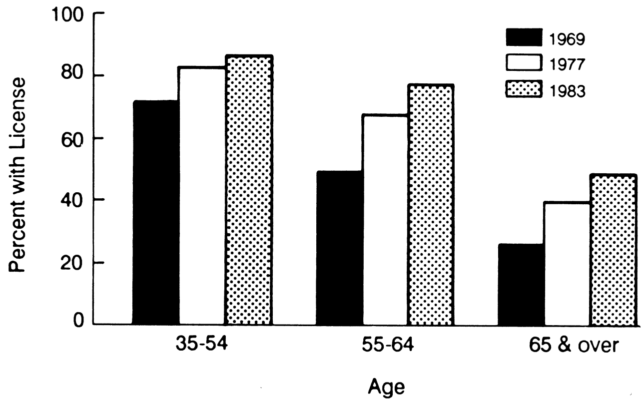

FIGURE 2-3 Female licensed drivers by age, 1969, 1977, and 1983.

Census figures from 1970 and 1980 show that the number of persons over 65 in the suburbs increased by 70 percent. This aging of the suburban population results largely from those "aging in place."

As people age they are less likely to change residential location. For example, of those over 65 in 1983, only about 5 percent moved compared with the national average of 17 percent (Special Committee on Aging 1987). The majority of older persons who own homes in the suburbs bought them many years ago and do not plan to move. Of suburban residents over 75, 40 percent moved into their homes more than 25 years ago compared with 14 percent of those between 55 and 64 (Gutowski and Field 1979). When older persons do move, more than half stay in the same county; only 20 percent move to another state.

The graying of the suburbs is likely to continue well into the next century. From 1960 to 1980 there was a steady growth rate for those over 65 in the suburbs and declining percentages for the same group in the central cities (Table 2-4). Many factors continue to push people away from cities, including the cost of housing and rapid, unexpected changes in neighborhoods. The suburbs continue to attract new residents for reasons such as newer and more available housing, the perception of low crime rates, and less traffic congestion (Gutowski and Field 1979).

TABLE 2-4 DISTRIBUTION OF THE OLDER POPULATION, 1970 AND 1980 (Census Bureau 1984)

		Percentage of Population by Location			
Age	Year	Rural	Central City	Suburb[a]	Other Urban[b]
All	1970	26.5	31.5	26.8	15.2
	1980	26.3	29.6	31.8	12.3
65–74	1970	27.34	34.34	21.54	16.79
	1980	26.50	30.62	28.59	14.29
75–84	1970	26.6	33.9	20.9	18.6
	1980	24.1	32.5	27.5	15.9
85+	1970	26.8	32.8	20.4	20.0
	1980	23.0	32.4	26.8	17.8

[a]Suburban = urban fringe.
[b]Other urban = outside urbanized area, places of 2,500 or more population.

The growth in suburban population is not uniform for all sectors of the population. Blacks are more concentrated in central cities than are whites. More than three-fourths of older blacks in metropolitan areas live in the central cities compared with one-third of older whites.

As younger people continue to move to metropolitan areas, rural areas are left with higher concentrations of older persons. This trend is strongest in the nation's agricultural heartland. Five of the 10 states with the highest percentage of older people are agricultural midwestern states (Arkansas, Iowa, Missouri, Nebraska, and South Dakota). Older persons who are isolated in rural locations must depend on their own driving abilities to meet their mobility needs.

Contrary to the stereotypes of the young-old as living in retirement communities and as frail older persons living in nursing homes, most older people live in the same house from middle age to their older years. These homes are increasingly located in the suburbs of metropolitan areas.

Travel Patterns

The majority of trips by older persons are not into or out of the city but rather between two suburban locations (Pisarsky 1988). Transit systems that serve the suburbs generally carry passengers toward the central city and not to other suburban locations. Though transit planners recognize the changing origin-destination patterns of the population, the population density in the suburbs is generally too low for transit systems to serve these areas at the current cost per trip.

Data from the Nationwide Personal Transportation Study on travel behavior between 1977 and 1983 confirm this trend of increasing reliance on the automobile and less dependence on public transit. Aggregate data on travel behavior from this survey, such as average annual mileage driven by age group, show that those over 65 use the private automobile more often, both as driver and as passenger, whereas they use public transit less frequently (Table 2-5). The average length of a walking trip is less than one-third of a mile. This reflects further dependence on the automobile and migration out of the central city, where walking is practical. Reliance on the automobile by older persons is highest in rural areas where travel options are the fewest.

TABLE 2-5 DISTRIBUTION OF PERSON TRIPS BY AGE AND MODE OF TRANSPORTATION (FHWA 1986)

		Percentage by Age			
Year	Mode	65–74	75–84	85+	All Ages
1977	Private vehicle	83.1	75.8	70.1	83.8
	Public transportation	3.2	3.4	3.3	2.5
	Taxi	0.3	0.2	0.7	0.2
	Walk	12.2	20.7	25.9	9.3
	Other	1.2	0.5	0.0	4.2
1983	Private vehicle	86.4	84.0	78.8	84.7
	Public transportation	2.8	2.0	3.7	2.4
	Taxi	0.1	0.7	0.0	0.2
	Walk	9.8	12.6	13.7	8.9
	Other	0.9	0.7	3.8	3.8

Older people tend to drive when conditions are the safest. They drive less frequently at night than do those under 65. Thirteen percent of vehicle trips by those over 65 are made at night compared with 25 percent of the trips made by younger drivers (Liss 1985).

People drive fewer miles as they age, and in very old age they become more reliant on others to drive for them. On average, men drive more annual miles than women (Figure 2-4). Both show a steady decline in mileage after 50, mostly because of declines in work-related travel; nonetheless reliance on the private vehicle remains high. Those over 75, however, are more likely to be passengers than drivers of a car (Figure 2-5). Though older people drive fewer miles, they still depend on the car for most trips.

Walking accounted for less than 9 percent of all trips in 1983; however, this mode accounts for a higher proportion of trips by older persons than by younger persons. The percentage of total trips by walking increases with age. Whether this increase is a cohort difference is still unknown; that is, it may be that persons born at an earlier point in history may have depended more on walking to get around than persons born at a later point. Aging often diminishes capabilities associated with driving, such as vision, and so older persons may walk more often. Older generations tend to live closer to a central city, where walking is practical. According to the 1983–1984 Nationwide Personal Transportation Study, walking accounts

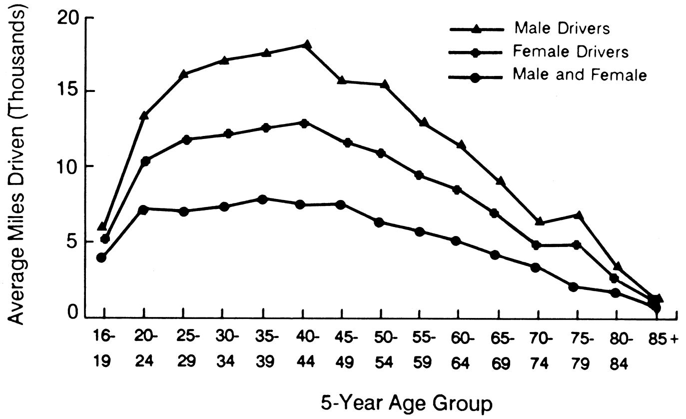

FIGURE 2-4 Average miles driven by age, 1983 (Appendix A provides sources for estimates).

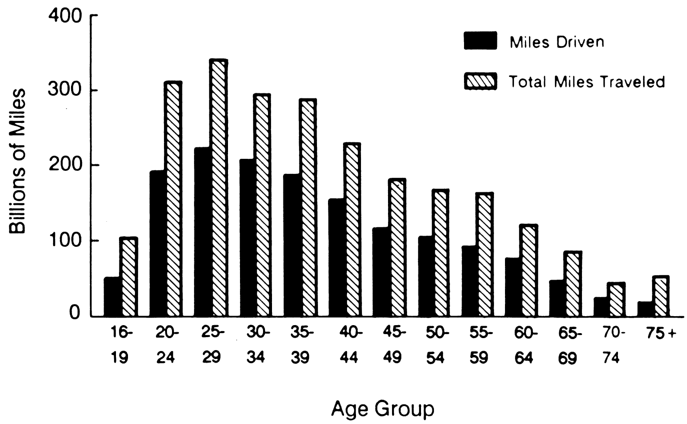

FIGURE 2-5 Total highway miles traveled by age, 1983 (Appendix A provides sources for estimates).

for one-fifth of all trips by urban residents over 80. Though this is an important mode, the percentage of trips made by walking decreased substantially from 1977 to 1983 for those 75 and older. Less dramatic reductions occurred for the age group between 65 and 74. Many areas are not designed for, or conducive to, pedestrian travel or pedestrian safety. Most trip lengths are too long to be accommodated solely by walking, especially for residents outside urban centers.

Older persons infrequently use mass transit and taxis, even when they lack other options. Those over 65 make less than 6 percent of their trips by mass transit in urban areas and less than 1 percent by taxi. Those over 65 are somewhat more likely than those under 65 to use mass transit, but the difference is quite small—less than one percentage point. Mass transit and taxis combined accounted for a smaller percentage of trips in 1983 than in 1977. Those over 65 are less likely to use taxis than younger persons because of the high cost per trip. Concerns for safety and security as well as convenience constrain transit use by older persons (Carp, Vol. 2, p. 10; Rosenbloom, Vol. 2, p. 45).

Though national averages of transit and taxi use are low, figures are higher in certain areas. Transit use by older persons is more common in older urban centers, such as Chicago and New York City, which have extensive mass transit networks. These systems serve more than rush-hour commuters and include routes to convenient retail and service centers.

Most of the country, however, does not have such extensive mass transit systems. Older persons use taxis more frequently in low-density communities and places with few or no transit options (Rosenbloom, Vol. 2, p. 49). Though the national trend for taxi and transit use is decreasing, these two modes remain important alternatives in major metropolitan areas like New York, Boston, and Chicago.

An older person who can no longer drive requires assistance from others in meeting mobility needs. Relatives, friends, and human service agencies partially meet these needs, often requiring special equipment to assist the older person. Volunteers provide invaluable transport services to older people.

Socially provided transportation that is subsidized by federal agencies is sometimes portrayed as the mode of choice for older people who are unable to drive. Surveys of these special service programs show these elderly riders as usually very poor, living alone, and without access to a car. The following data on special transportation service are taken from the paper by Rosenbloom (Volume 2). Data from 1983 showed that less than 15 percent of those 65 to 74 and 7 percent of those over 75 used special transportation services.

These special services are an important supplement for financially disadvantaged older persons but do not take the place of other travel modes. Even under the best of conditions, these formal systems of transportation for older persons are relatively costly. Costs for systems that only transport older persons are between $5 and $14 per one-way trip. Greatly expanding such services would be quite expensive. Rosenbloom estimates that providing specialized transportation for older persons without driver's licenses so that they make as many trips as older persons with driver's licenses would cost $1.75 trillion annually.

Systems that include all ages of handicapped persons have expenses ranging from $4 to $31 for individual trips. These services are restrictive by their definition. Users are required to make significant advance reservations and may feel a need to justify the purpose of their trip. Even severely physically limited older persons want to keep a variety of options open, using each mode according to how they feel, weather conditions, and its availability. Nonetheless, greatly expanding special services for those who have severe physical limitations could cost hundreds of billions of dollars each year.

SUMMARY

A growing percentage of the U.S. population is over 65 years old. Improvements in health care and medicine have extended life expectancy. More people live past the age of 85, and only about one-third of them are severely limited in their daily activities. Most older persons are among the "young-old"; they usually have greater financial resources than previous cohorts of older persons.

An increasing number of older persons live in the suburbs and are likely to remain there, or in another suburban area, for the remainder of their lives. Public transit accounts for a small share of trips in urban areas but is a very important mode for some older persons. Those located outside the central city rely on private vehicles even when traditional public transit alternatives are available.

Vehicle miles traveled annually by older people in automobiles will continue to increase. More than 80 percent of trips by all persons 65 and over are currently made in automobiles, and reliance on the private vehicle is growing. Because more persons over 75 live in the suburbs, their ability to lead independent lives will largely depend on their access to an automobile. Measures that promote older persons' abilities to drive and access to their own automobiles will assist the greatest number of older people.

The population of physically impaired elderly persons who are able to live in their own homes but who are unable to drive is growing rapidly. The cost of specialized transportation services for these individuals indicates that more productive and efficient alternatives need to be developed for this group.

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CHAPTER THREE

Safety of Older Persons in Traffic

In 1986, about 5,900 persons 65 and older were killed in motor vehicle crashes, half of whom were 75 or over. Most victims 65 and over were vehicle occupants, but more than one-fourth were pedestrians. Traffic deaths of those 65 and older accounted for about 13 percent of all traffic fatalities in 1986. Although this percentage of traffic deaths among older persons is roughly in proportion to their share of the population (13 percent of deaths compared with 12 percent of the population), older persons are less likely to be involved in traffic accidents than the average person because they travel less. As society ages during the next few decades, older persons will make up a larger share of the driving population, and the older driver of the future will have grown up in an era when the automobile became a pervasive and essential part of daily life. That future cohorts of older drivers will curtail their driving as much as their earlier counterparts have appears unlikely; the average miles driven by those 65 and over has increased with each new major travel survey taken, from 1969 through 1983 (FHWA 1985, 20). On the basis of the trends presented in the previous chapter, this growth in travel should continue, which will increase the amount of exposure to risk faced by older persons.

A broad overview of the crash risk faced by older persons is presented in this chapter. As will be shown, older persons are more at risk than the average person when using the roadway system as drivers, vehicle occupants, and pedestrians. As the number and proportion of older persons in the population increase, the number of traffic fatalities among this group could grow. For example, if the share of traffic deaths among older persons remains constant, by 2020 older persons might account for 17 percent of all traffic deaths simply because of the increasing size of this age group. Because older persons in the future will travel more than their earlier cohorts did, their percentage of traffic deaths could be even larger than their share of the population.

The growth in traffic deaths and injuries among older persons could be avoided by identifying how the current roadway system fails to meet the needs of older persons. This can be done by identifying the existing problems (crashes, injuries, and fatalities) and then proposing measures to reduce the risk that older persons face in traffic. This chapter draws on existing data to identify these problems. Potential solutions are proposed in Chapter 5.

DATA SOURCES

The data relied on in this chapter came from numerous sources. Accident data, with estimates of accidents by age, were provided by the National Highway Traffic Safety Administration (NHTSA) from the National Accident Sampling System (NASS). NASS is the only data base that provides estimates of total accidents and injury accidents at the national level, but because the sample size used is below that needed to be nationally representative, it is difficult to estimate driver involvement in crashes precisely from this source. Estimates of fatal crashes by age were provided by NHTSA from the Fatal Accident Reporting System (FARS). The FARS file, a census of fatalities in the nation, is used to estimate traffic fatalities among age groups. It is by far the most accurate national traffic safety data base available.

The exposure of different age groups to risk was compared by using two different data sources. Comparison of involvement in traffic crashes on the basis of population was made per 10,000 or 100,000 persons in each age group. Population estimates came from the Bureau of the Census mid-range estimates. When possible, comparison of involvements of different age groups in crashes was made per 100 million mi driven (or per 100 million mi traveled when passenger trips were included). Travel estimates were made based on data from the Nationwide Personal Transportation Study (FHWA 1985). Estimates of miles driven and total travel by age groups were made from the NPTS data tapes, which were provided by FHWA. Derivation of the estimates is described in Appendix A. The most recent NPTS data were collected in 1983 and early 1984 (FHWA 1986). Whenever comparisons of age groups were made on the basis of travel, estimates of accidents, injuries, and fatalities for 1983 were used so that these estimates would be consistent with the travel estimates. Otherwise, the most recent accident data were reported.

CRASH RISK

More than 46,000 Americans were killed in traffic crashes in 1986 (Table 3-1). About 13 percent were 65 or older. Although this report examines the crash risk faced by older persons, comparison of the crash experience across age groups indicates that the youngest drivers are most at risk (Figure 3-1). Teenagers and those in their twenties have the highest traffic

TABLE 3-1 TRAFFIC FATALITIES BY AGE, 1986

	Fatalities		
Age Group	No.	Percent	Population (%)
0–4	954	2.07	7.75
5–9	1,005	2.18	7.10
10–14	1,201	2.61	6.74
15–19	6,839	14.85	7.65
20–24	7,970	17.31	8.55
25–29	5,932	12.88	9.2
30–34	4,215	9.15	8.45
35–39	3,203	6.95	7.83
40–44	2,186	4.75	5.99
45–49	1,700	3.69	4.96
50–54	1,575	3.42	4.47
55–59	1,563	3.39	4.61
60–64	1,564	3.40	4.54
65–69	1,458	3.17	3.91
70–74	1,468	3.19	3.20
75–79	1,373	2.98	3.27
80–84	974	2.11	1.50
85+	622	1.35	1.17

NOTE: Involvement ratio is calculated by dividing the percentage of fatalities in each age group by the percentage of the population in each age group.

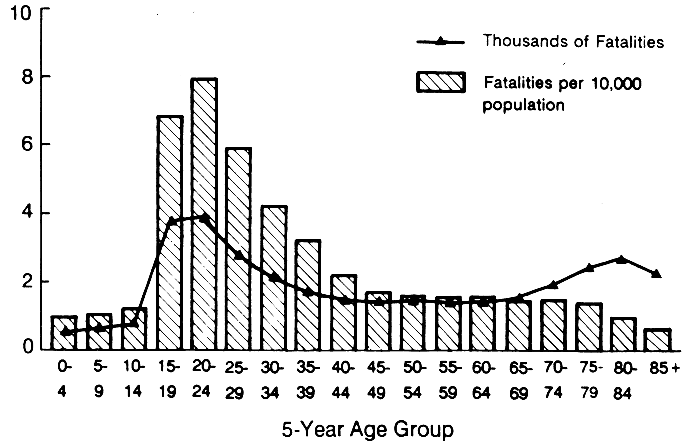

FIGURE 3-1 Traffic fatalities and fatality rates by age, 1986 (NHTSA data).

fatality rate per 10,000 persons in each age group, about 4 deaths per 10,000 population. Between 35 and 69 the fatality rate remains fairly stable between 1.4 and 1.7 deaths per 10,000 population. Between 70 and 74 the rate increases to 1.9 deaths per 10,000 and between 80 and 84 the rate reaches 2.7 deaths per 10,000. The traffic fatality rate declines somewhat after 85, presumably because other causes of death—heart disease, cancer, and stroke—are more likely than accidents to claim the lives of individuals near the end of the expected life span.

As shown in Figure 3-1, the largest total number of fatalities occurs between the ages of 16 and 24. Although the fatality rate increases after 65, the total number of fatalities is relatively small because of the correspondingly small size of the current older population and their relatively small amount of travel.

The advantage to making comparisons of age groups on the basis of population is that population estimates have a well-established reliability, and the Bureau of the Census updates its estimates regularly. The disadvantage is that different population groups have different rates of exposure to risk. Older persons travel about half as many miles as the national average for all age groups; as a result they should have a lower accident involvement rate when compared on a per-capita basis. The miles driven by each age group is a better basis for comparing actual exposure to risk than population size, but even miles driven is an imperfect measure of exposure; not all miles driven, for example, are of equal risk. Travel on Interstate highways is much safer than travel on two-lane rural arterials, and travel during the day is safer than travel at night. Though imperfect for making comparisons across age groups, miles driven is the best indicator of exposure to risk available. In the next section risk of crash involvement is compared on the basis of travel and other measures of exposure.

For Drivers

In examining the risk in traffic faced by different age groups, it is important to separate the propensity of drivers to be involved from the propensity of individuals to be involved as victims of a crash (as drivers, occupants, or pedestrians). Driver involvement in all crashes is difficult to estimate from the NASS data base, as mentioned earlier. The standard errors in the data can be estimated from the sample size, but whether the data are systematically biased on the basis of age because of an unrepresentative sample is not known. In addition, when driver involvement across age groups is compared on the basis of miles driven, the roughness of these estimates may further distort the results. The estimates of miles driven by older drivers are based on a relatively small sample (1,900 older persons out of 17,400 interviewed) in the Nationwide Personal Transportation Study of 1983. Because of the roughness of these estimates, the data presented in this section should be viewed as indicators of approximate differences in risk across age groups rather than as precise measures of risk.

Driver records can also be compared on the basis of involvements per driver. When reasonably good state accident data bases are used, some of the sample size problems associated with the NASS data can be avoided. California data, for example, indicate that driver involvements in crashes decrease throughout the life cycle until about age 75, when they increase modestly to a rate equivalent to that of 40- to 44-year-olds (Huston and Janke 1986). Although estimates of crashes in a single state are fairly reliable and the number of drivers in each age group is known, a rate based on licensed drivers fails to account for the risk that an individual faces per mile driven.

When driver involvement in crashes by age is compared on the basis of the estimates of miles driven presented in the previous chapter (Figure 2-4), the youngest drivers are by far the most prone to crash involvement

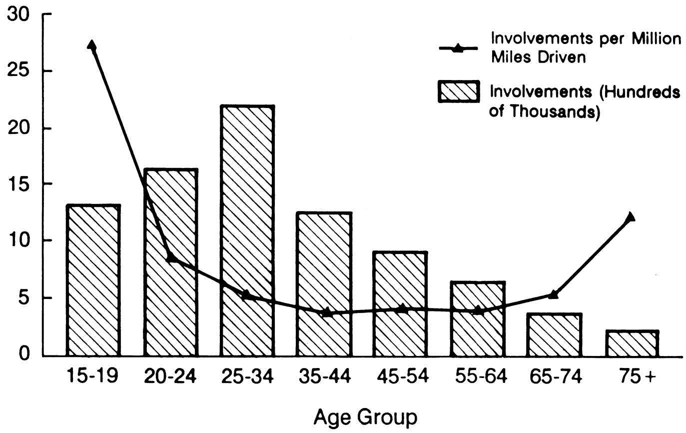

FIGURE 3-2 Driver involvements in crashes and involvement rates by age, 1983 (NHTSA and FHWA data).

(Figure 3-2). The involvement rate declines dramatically after 25 and then increases slightly between 35 and 74, after which it increases again. The roughness of the NASS data and the large standard errors associated with the estimates cast some doubt on the exact shape of the curve shown in Figure 3-2. The same basic U-shaped curve, however, has been shown with state accident data. For example, the California data discussed in the previous paragraph show a sharply rising accident rate after about age 75 when the rate is calculated per miles driven (Huston and Janke 1986). Although the rate increases in Figure 3-2, the absolute number of driver involvements declines because older drivers drive many fewer miles and there are fewer older drivers.

If the health of the older population continues to improve as it has in the past, and with a more experienced driving population, future cohorts of older drivers may perform better as drivers per mile driven. Future cohorts are also likely to drive more than current older drivers. Whether the improved performance of future older persons will be sufficient to offset the increased exposure to risk due to more driving is worthy of concern.

Fatal Crashes

As with other comparisons of crashes by age group, the youngest drivers have by far the worst record when involvement in fatal crashes is examined.

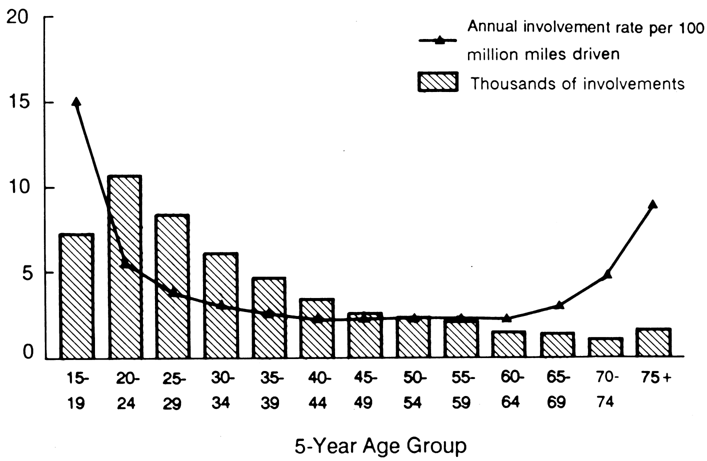

FIGURE 3-3 Driver involvements in fatal crashes and fatal involvement rates by age, 1983 (NHTSA and FHWA data).

They have an involvement rate that is more than three times greater than that of other age groups. The driver involvement rate in fatal crashes increases again after about 69 (Figure 3-3): drivers over 69 are more than twice as likely as middle-aged drivers to be involved in a fatal crash, and their rate of fatal involvement increases more sharply than their rate of involvement in all crashes. This reflects the greater vulnerability to injury of older persons. When crash severity is controlled for statistically—that is, when the severity of crash involvement is held constant—the same basic pattern appears, but the rate for older drivers does not increase as sharply (Evans 1987).

Across all age groups, 3.5 times more male drivers are involved in fatal crashes than female drivers (NHTSA 1988, 1-8). Men, however, drive more miles each year than women do. When driver fatalities by age are compared on the basis of miles driven, men and women have the same fatality rates after about age 50 (Evans 1987).

Other Comparisons

Comparisons of exposure to risk across age groups on the basis of travel estimates are only as reliable as the crash and travel data themselves. Travel estimates are based on self-reports from relatively small samples (especially in the older age groups) and are collected infrequently.

Another way to compare risk is to use a method called "induced exposure." Induced exposure is estimated by calculating an "involvement ratio," which is the number of crashes attributed to drivers in an age group divided by the number of crashes not attributed to drivers in the same age group (van der Zwaag 1971). If the ratio of attributed to unattributed crashes were equal to unity for all age groups, age-based differences in crash involvement would not exist; that is, within each age group, an equal proportion of drivers would cause crashes and an equal proportion would be the victim of crashes. As reported in the studies reviewed in the following paragraphs, however, both younger and older drivers tend to be overinvolved in crashes involving two drivers. These studies, however, must be interpreted with caution, because they depend on how the investigating police officer assigns responsibility for the crash. Such responsibility is rarely unambiguous, and the expectation that very young and very old drivers are more accident prone may distort the officer's assignment of responsibility, leading to overinvolvement of drivers in these age groups.

In an early comparison of crash rates across age groups, all the crash reports involving two drivers for Oakland County, Michigan, were collected for 1968 and 1969. This resulted in a total sample of 12,232 passenger-car crashes (van der Zwaag 1971). When the involvement ratios for these crashes were compared across age groups, 16-year-old drivers had an involvement ratio of 1.72; thus they were judged responsible for a disproportionate number of the crashes in which they were involved. Drivers between 20 and 54 had involvement ratios of less than 1; these drivers were more likely to be crash victims. Drivers 64 and over had an involvement ratio of 1.84, the highest of any age group. Thus, they were the most likely to be involved in crashes in which they were the driver at fault. This study, however, is almost 20 years old and relies on data from only one county. In support of these findings, more recent state-level data, discussed below, demonstrate the same pattern of overinvolvement by younger and older drivers.

A recent study of more than 160,000 traffic crashes in Michigan showed a greater responsibility for crashes by drivers under 25 and drivers over 69 (McKelvey et al. 1987). The curve in Figure 3-4 shows the ratio of the percentage of drivers in each age group judged by the investigating officer to be responsible for a multivehicle crash to the percentage of drivers

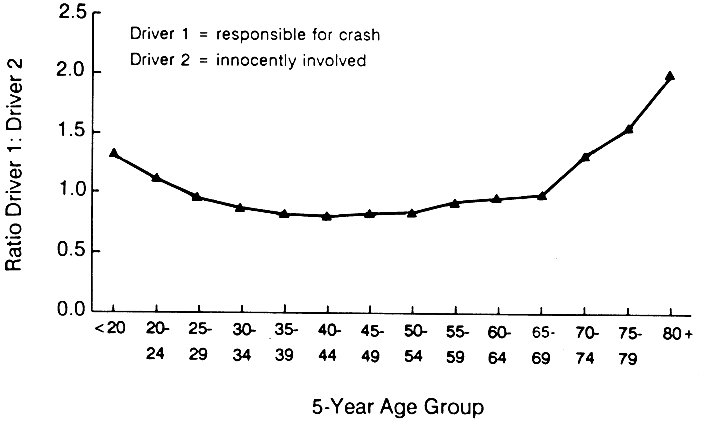

FIGURE 3-4 Driver responsibility for multivehicle accidents, 1983 (McKelvey et al. 1987).

innocently involved. A similar study of 50,000 reported crashes occurring in 1982 on major highways in Michigan showed the same basic pattern of overinvolvement in crashes by younger and older drivers (Maleck and Hummer 1986). In the latter study, drivers under 24 had an overinvolvement ratio of 1.18. Drivers between 25 and 54 were responsible for fewer crashes than the total number in which they were involved. Drivers over 65 had an overinvolvement ratio of 1.24. The pattern is the same both for crashes in which an injury occurred and for all crashes.

The possible bias in the method of induced exposure, noted earlier, was tested for by McKelvey et al. (1987) by comparing the results from right-angle crashes (where responsibility is less ambiguous) with those from all crashes. In this comparison, involvement ratios were quite similar, which suggests that bias on the part of the officer does not explain all the differences across age groups. Despite the potential weaknesses of the induced-exposure method, its use results in a U-shaped curve for crash involvement across age groups that is similar to the curve obtained when crashes are compared across age groups on the basis of miles driven.

Although older drivers appear more likely to be involved in crashes, they are still involved in a relatively small total number of crashes. In the study by McKelvey et al., for example, drivers over 65 (an age group that spans more than 25 years) were involved in 6.7 percent of all crashes in the study sample. In comparison, drivers 16 to 20 (an age group that spans 4 years) were involved in 14 percent of total crashes in the study sample.

For Occupants

Although as drivers those 70 and over are involved in a relatively small number of crashes compared with the total number of crashes, older persons are exposed to risk as passengers as well, and older persons are more likely to accumulate vehicle miles as passengers than are younger adults. Once in a crash, as driver or as passenger, an older person is more likely to suffer an injury or a fatality than a younger vehicle occupant.

The injury rate per million passenger miles traveled is highest among those 15 to 24 (Figure 3-5). After reaching its lowest point among those 35 to 44, the rate increases with each succeeding age group. The total number of injuries, however, declines with increasing age.

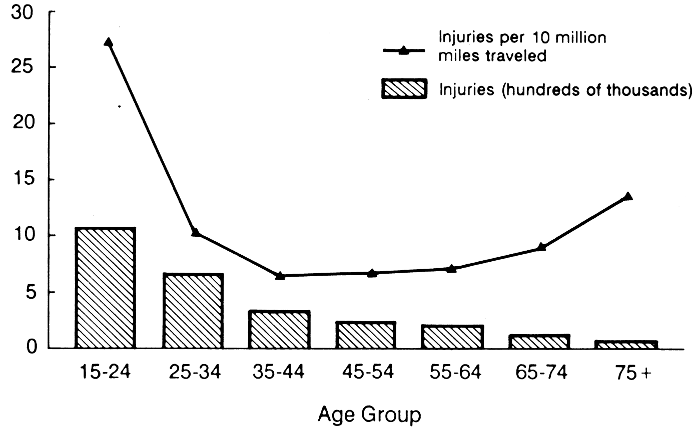

FIGURE 3-5 Occupant injuries and injury rates by age, 1983.

The serious-injury rate (in this case those classified by the Abbreviated Injury Scale of the American Association for Automotive Medicine as AIS 3 or greater) increases more sharply after age 44 (Figure 3-6), presumably because of the increasing vulnerability that accompanies aging. Crash tests using cadavers have demonstrated that in crashes of equal severity, injury severity increases with age (Neathery et al. 1975, Eppinger et al. 1984). The absolute number of serious injuries is highest among the youngest drivers and lowest among the oldest.

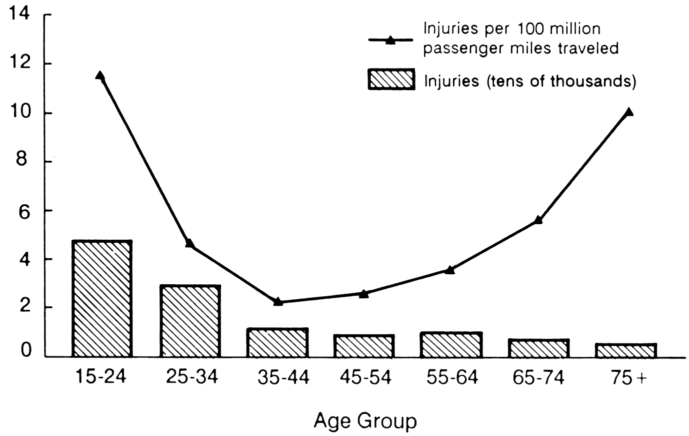

FIGURE 3-6 Serious occupant injuries and injury rates by age, 1983.

As occupants of passenger vehicles, those 16 to 19 and 75 and older have the highest levels of risk per 100 million passenger-mi of travel (Figure 3-7). Although the somewhat higher probability of being involved in a crash as driver plays a part in the increased risk of fatality, the increase appears to be caused largely by the physical vulnerability of older persons. In fatal crashes between drivers 20 or younger and drivers over 65, the older driver is four times more likely to be the victim than the younger driver (Partyka 1983). Drivers over 75 are twice as likely to be involved in a crash as middle-aged drivers but have a total involvement rate four times as high as middle-aged drivers because of their vulnerability. This same point can be made by examining the different consequences across age groups when an older driver receives the same injury as a younger one. Roughly 20 percent of the 20-year-old vehicle occupants are likely to die as a result of serious injury compared with 70 percent of the 65-year-old occupants (Mackay, Vol. 2, Figure 1). In absolute terms, the largest number of occupant fatalities occurs among the youngest age groups.

Although the occupant fatality rate begins increasing after 69, the occupant fatality rate for all age groups has declined in recent years after increasing between 1950 and 1970 (Whitfield and Fife 1987). This improvement could be explained by recent improvements in the crashworthiness of vehicles (Crandall 1986, Graham and Garber 1984). Whitfield and Fife, using data from the National Center for Health Statistics, estimate

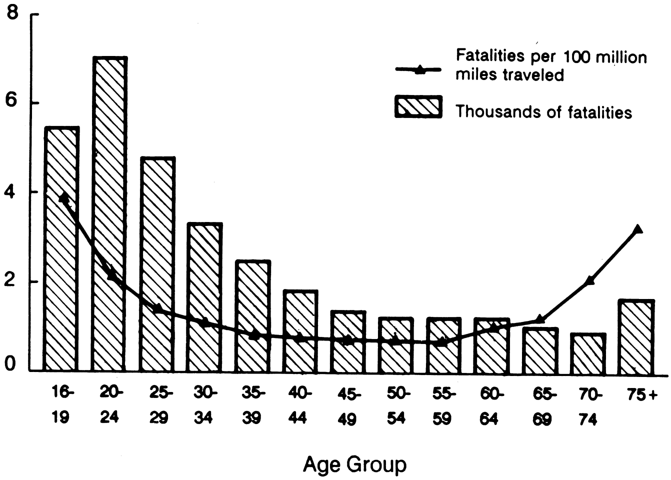

FIGURE 3-7 Occupant fatalities and fatality rates by age, 1983.

that between 1970 and 1980 the greatest improvement in the occupant fatality rate occurred among men 70 to 79. Analysis of FARS data—a better source for traffic fatalities that only became available in 1975—also indicates that occupant fatalities per million population for all groups decreased modestly between 1976 and 1986 (Figure 3-8).

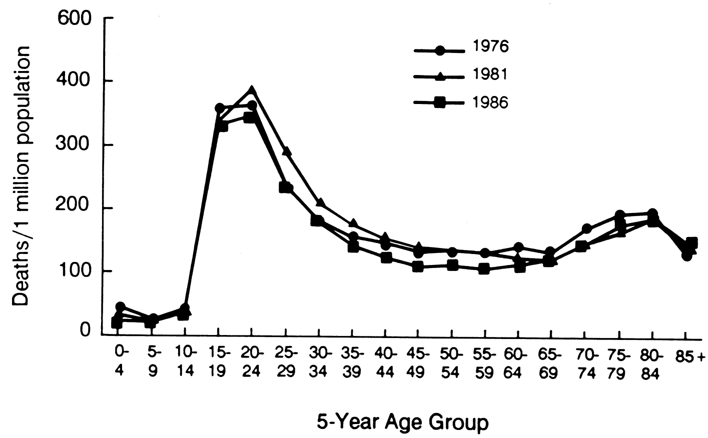

FIGURE 3-8 Motor vehicle occupant fatalities per 1 million population.

For Pedestrians

Older persons have the highest pedestrian fatality rate of any age group (Figure 3-9). The lack of an accepted way to measure the exposure of pedestrians to crash risk has long made it difficult to determine whether older persons are more likely than younger persons to be killed as a result of injuries received in a pedestrian accident or whether they are more likely to be involved in pedestrian accidents. Some have argued that the high fatality rate for aged pedestrians is simply due to their greater reliance on walking for mobility and therefore their greater exposure to risk. A recent study of pedestrian behavior, however, suggests that older persons are actually less likely to be pedestrians than those in other age groups (Tobey et al. 1983). On the basis of observations of 61,000 pedestrians at 1,350 sites in 5 Standard Metropolitan Statistical Areas (SMSAs), older persons were actually underrepresented as pedestrians compared with their proportion of the population in the sampled areas. Although they accounted for 16 percent of the population, those 60 and over made up only 7.7 percent of pedestrians observed during the course of this study.

This same study reports that older pedestrians are somewhat more likely to disregard pedestrian signals. About 13 percent of men over 60 "walked against the red" compared with about 11 percent of all men (Tobey et al. 1983). At the same time, male and female pedestrians over age 60 waited

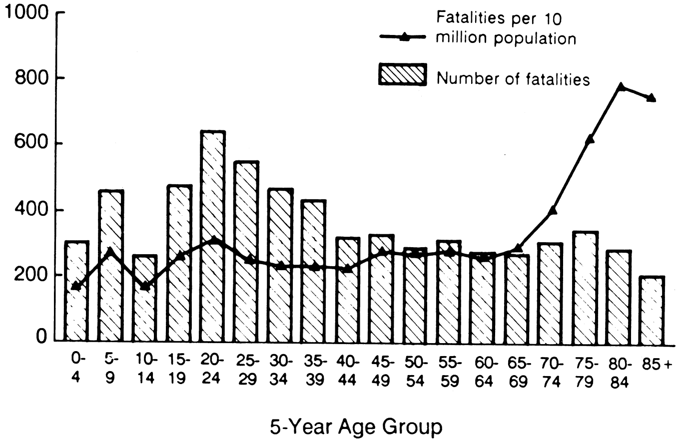

FIGURE 3-9 Pedestrian fatalities and fatality rates by age, 1986 (NHTSA data).

for the longest gaps between vehicles when crossing. For example, 85 percent of older persons waited for a gap of 9 sec or more before crossing against the red, whereas 63 percent of the total population waited for a gap of 9 sec or more. Given their tendency to wait for longer gaps, it could be that older persons are more likely to be involved in pedestrian crashes in situations where they have to share the right-of-way with a vehicle, for example, at an intersection permitting right-turn-on-red. In these cases the reduced nimbleness of older persons may lessen their ability to avoid being struck by an automobile even if they detect it. In general, however, the overrepresentation of older pedestrians in fatality statistics appears to be largely a function of their physical vulnerability (Hauer, Vol. 2, p. 197).

In contrast to the death rate for motor vehicle occupants shown in Figure 3-8, which has remained fairly static for older persons during the last decade, the death rate for older pedestrians declined by one-third between 1977 and 1986 (NHTSA 1988, 8-3). Although older persons continue to have the highest pedestrian fatality rate of any age group, the rate is steadily declining. As noted in Chapter 2, walking trips by older persons appear to be declining. Whether the decline in the pedestrian fatality rate can be explained by reduced exposure to risk or improved traffic safety or some combination of the two is not known.

CRASH PATTERNS

Older drivers tend to make mistakes somewhat more frequently than younger drivers when turning, either when merging into a lane or turning across a lane of traffic. This pattern appears consistently in studies of traffic violations, crashes, and fatal crashes (Waller, Vol. 2). Not surprisingly, this problem tends to be most pronounced in urban areas. This is partly a function of exposure to risk (most driving occurs in urban areas), but it may also be due to the much greater complexity of the urban driving environment. Older drivers recognize that they have problems with left turns and merging, along with failing to respond to road signs and signals (Malfetti and Winter 1987).

Fatal Crashes

Drivers over 65 are involved in a disproportionate number of fatal crashes in which they fail to yield the right-of-way (Partyka 1983). In comparisons based on violations charged against surviving drivers (because fatally injured drivers are rarely charged), surviving drivers under 65 failed to yield the right-of-way in 7 percent of the fatal crashes in which they were involved, whereas surviving drivers over 65 failed to yield the right-of-way in 24 percent of the fatal crashes in which they were involved. These findings result from comparing overinvolvement ratios across age groups for more than 18,000 drivers in fatal crashes involving two vehicles in which the driver was charged with a violation. These figures come from FARS data for 1979–1981.

The youngest drivers are vastly overrepresented in fatal crashes in which speeding is charged. Drivers over 65 are slightly more likely to be charged with inattention (in 4 percent of fatal crashes compared with between 2 and 3 percent for other age groups) and, as with drivers under 25, are more likely to be charged with failure to observe signs than drivers between 35 and 49 (6 percent of surviving older drivers are charged with this violation compared with 3 percent of surviving drivers 35 to 49). Drivers 65 and over are the least likely to be charged with driving recklessly or too fast, or to be reported drinking and driving.

All Crashes

Maleck and Hummer also demonstrated the propensity for older drivers to be involved in turning crashes. Drivers over 65 and drivers under 21 are both overrepresented in right-turn crashes (Maleck and Hummer 1987). Relative involvement in left-turn crashes (those in which turning across a lane of traffic is often required) increases sharply for drivers over 54 (Figure 3-10). Such crashes are frequently more severe because of the driver's exposure to being hit by a vehicle approaching from his left side. Maleck and Hummer also showed that older drivers were overinvolved in backing and parking crashes and in head-on collisions.

Maleck and Hummer made a unique contribution by finding that the overinvolvement ratio for older drivers disappears in rural areas. Because it appears that older drivers are no more likely to cause crashes on rural roads than are drivers in any other age group, measures directed at reducing the risk of crash involvement for older drivers in rural areas may have fewer benefits than those in urban areas.

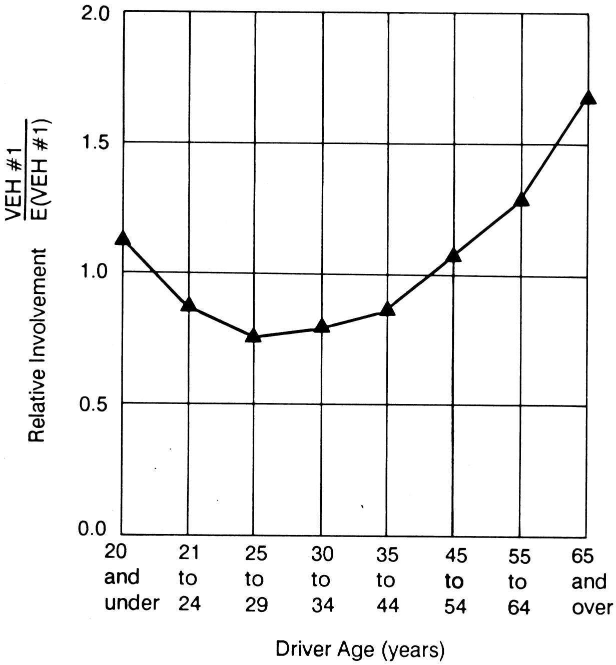

FIGURE 3-10 Relative accident involvement by driver age for left-turn accidents (Maleck and Hummer 1986).

SUMMARY

Older drivers show an involvement in crashes that is more extensive than that of middle-aged drivers though not as bad as that of drivers in their teens and early twenties. The statistics suggest that after about age 75, the accumulated skill and judgment gained over a lifetime of driving tend to be offset by other factors (the physiological and cognitive changes that accompany aging, which are discussed in Chapter 4). Although the involvement rate in all crashes of drivers over 75 is about twice that of middle-aged drivers, their fatal crash involvement rate is about four times as great as that of those 35 to 64 because of the older person's greater susceptibility to injury. The broadest possible picture of the transportation safety problem faced by older persons has been given here. A more detailed examination of this problem is presented by Hauer (Volume 2).

Older persons are not the only group at risk when using the roadway system. Indeed, when examined in terms of incidence, the problem that older persons represent to overall traffic safety is small relative to that of the youngest drivers, but the problem is nevertheless real. As vehicle occupants, both drivers and passengers, older persons have higher injury rates than middle-aged drivers and share with young drivers the highest occupant fatality rate. In short, the consequences of traffic crashes increase with age. Nowhere is this more telling than in pedestrian crashes.

Older persons have a much higher pedestrian fatality rate than any other age group. The concern at this stage is the extent to which traffic crashes, injuries, and fatalities among older persons will increase as society ages. Currently the total numbers are small relative to other age groups. Whether the higher rates of involvement and the severity of outcome of those involvements will translate into higher numbers of deaths and injuries in the future is worthy of concern. The sharp decline in the pedestrian death rate per 100,000 population for older persons during the last decade is more encouraging than the modest decline in the death rate for motor vehicle occupants. If the trend in increased driving (and therefore increased exposure to risk) among older drivers continues, the traffic safety picture for older persons could worsen.

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CHAPTER FOUR

Aging and Performance

To allow the growing number and proportion of older drivers to meet their basic mobility needs more safely, the roadway system—street and highway design and operation, vehicle design, and driver licensing—will need to be adjusted to better accord with the needs and abilities of older persons. Physiological and cognitive changes that occur with age and affect driving performance are examined in this chapter. The discussion highlights areas of roadway design and operation and vehicle design in which the capabilities and needs of older persons are not adequately addressed. The chapter begins with a description of the driving task and a review of the basic elements of driving that change with age. Assumptions about human performance that are built into the roadway system and that are increasingly incompatible with an aging population of drivers are identified. Design changes to the system alone, however, cannot accommodate all drivers, especially those with sharply declining skills. The ability of driver-licensing agencies to identify drivers with declining skills is also discussed.

SELF-DESCRIBED LIMITATIONS OF ACTIVITY

Before specific changes in driving performance that accompany aging are discussed, it is useful to have an overall picture of the functional dependency of older persons. Functional dependency for the activities of daily

TABLE 4-1 SELF-REPORTED FUNCTIONAL DEPENDENCY OF THOSE OVER 65 (Soldo and Longino 1988)

	Activity Limitation[a] (%)		
Age	Total	Men	Women
65–74	12.6	11.7	13.3
75–84	25.0	20.9	27.6
85+	45.8	40.8	48.2
Total (65+)	18.9	16.0	20.9

[a]Activities of daily living include bathing, dressing, using toilet, mobility, continence, and eating.

living can be defined as the need for help with such basic functions as eating, bathing, dressing, continence, using the toilet, and indoor and outdoor mobility (Soldo and Longino 1988). As shown by the data in Table 4-1, only 12.6 percent of those 65 to 74 and only 25 percent of those between 75 and 84 report any limitations on their activities for daily living. About 46 percent of those over 85 report some limits. These self-reports reveal that the majority—more than 85 percent of those between 65 and 74 and just over half of those 85 and older—report themselves unrestricted in the normal activities necessary for living.

There are no similar sample data on self-reported limitations on driving, but some research has been conducted to determine whether older persons perceive problems with driving or reading traffic signs (Yee 1985; Kosnik et al. 1986). Drivers 55 and over report more problems reading traffic signs, seeing clearly at night, turning their heads while backing, reaching safety belts, reading instrument panels, and merging into high-speed traffic than do drivers 35 to 44 (Table 4-2). Although reports of driving difficulty appear to increase with age, most older drivers do not report such difficulties.

THE DRIVING TASK

Driving a modern passenger vehicle on a clear day in light traffic does not overtax any dimension of performance (perceptual, cognitive, or physical). However, in heavy traffic at high speed, at night on poorly marked roads, at a complex intersection, or in a potential accident situation, the demands placed on drivers can exceed their abilities. Driving can be described as consisting of four discrete phases (Smith 1968). A driver must (1) see, or

TABLE 4-2 SELF-REPORTED DRIVING DIFFICULTIES OF OLDER AND YOUNGER DRIVERS (Yee 1985)

	Percentage by Driver's Age (N = 446)	
Reported Difficulty	55+	35–44
Reading traffic signs	27	12
Seeing while driving at night	40	32
Turning head while backing	23	5
Reading instrument panel	9	3
Reaching seat belt	22	10
Merging and exiting in high-speed traffic	32	15

hear, a situation developing (stimulus registered and sampled at the perceptual—visual or auditory—level) and (2) recognize it (stimulus recognition at the cognitive level). The driver must then (3) decide how to respond (cognitive level) and then (4) execute the physical maneuver (motor level). This same model applies to walking, but a formal task analysis of walking in a complex urban environment has not been examined in empirical research.

The cognitive and physiological changes that accompany aging raise questions about how well older drivers perform in all four phases. Critical to the first phase is the attentiveness of the driver to the driving environment. Do decrements in the ability to concentrate on a task occur with aging? The attentive driver must be able to accurately discern visual or auditory stimuli. What changes in the visual or auditory system that accompany aging might affect the ability simply to see or hear a potentially hazardous situation developing? Having perceived, the driver must decide how to respond, often within a fraction of a second. Are older drivers slower to respond? Finally, the driver must perform the physical tasks of braking and steering. Are older drivers less able to perform these tasks?

Vision

The ability to see, one of the most important functional abilities for driving, declines with age. Though human beings age at different rates, and generalizations about the abilities of older persons are fraught with caveats, older persons commonly experience loss of visual function. Most notably, the lens of the eye yellows and hardens with age, which reduces the amount of light reaching the retina and contributes to diminished ability to focus on near objects (Bailey and Sheedy, Vol. 2, p. 295). In addition, less light reaches the aging eye because the pupil tends to become smaller with age and loses some of its ability to dilate in dim light (Bailey and Sheedy, Vol. 2, p. 295). For those over 65, cataracts and glaucoma are roughly eight times more common than in the general population (Sekuler et al. 1982). Loss of the ability to focus on static and moving objects is more common among older persons (Weale 1963), as is sensitivity to glare (Wolfe 1960). The decline of these and other visual abilities has been well established in the laboratory. Several studies have attempted to link age-related decline in visual ability to traffic accidents; Kline's 1986 review of the literature indicates that there is such a link. The following discussion is based on his paper.

Static Visual Acuity

The ability to discriminate fine, stationary, high-contrast details (static acuity) declines with age. This visual function tends to remain fairly constant up to about age 50, after which it declines rapidly (Bailey and Sheedy, Vol. 2, p. 295). Although eyeglasses compensate for much of the loss, frequently it is impossible to correct the static acuity of older persons to the same level as that of younger persons. Roughly two-thirds of those 65 to 75 have a corrected static acuity worse than 20/20 compared with 13 percent of those 18 to 24 (Bailey and Sheedy, Vol. 2, Table 1).

Despite the obvious importance of clear vision to driving, past studies, such as Burg's major effort in the late 1960s, showed very low (but statistically significant) correlations between static acuity and accident rates (Burg 1967). In a reanalysis of Burg's data, researchers did not find any relationship between static acuity and accidents for drivers under 54, but did find small but statistically significant relationships between static acuity and accidents for drivers over 54 (Hills and Burg 1977). Although static acuity is the only visual ability measured for driver licensing in all states, it is only one of several visual abilities important for driving.

As already mentioned, the yellowing of the lens that accompanies aging combined with the decline in pupil size reduce the amount of light reaching the retina. The hardening of the lens and reduced ability to focus that begin about age 45 also reduce near static acuity (Koretz and Handelman 1988). Because of the reduced light reaching the retina and reduced accommodative power of the older eye, the acuity of older drivers deteriorates markedly at night. Shinar's (1977) study indicated small but significant correlations between either static or dynamic visual acuity (discussed next) and accidents. Under low illumination, however, static acuity proved to be the best predictor of overall accident involvement (Shinar 1977).

Dynamic Visual Acuity

Dynamic visual acuity, the ability to distinguish detail in moving objects, also declines with age (Reading 1968). The motion component of dynamic visual acuity suggests that it would be more directly related to driving than static acuity. Of the many visual abilities measured in Burg's research and the later work of Shinar (1977), dynamic visual acuity was among a handful of visual abilities to show a significant correlation with accidents (although the correlations were quite small, explaining less than 10 percent of the variance).

Visual Field

Older persons tend to experience a contraction in their field of view. Although Burg did not show a correlation between reduced visual field and accidents, more recent research by Johnson and Keltner (1983) did. The rate of convictions and accidents for drivers with loss of visual field in both eyes was twice as high as that for individuals with normal vision who were matched on the basis of age and sex (Johnson and Keltner 1983). The drivers in their 10,000-driver survey who were over 65 were more likely to have a reduced field of view than those under 60 (13 percent versus 3.5 percent). Almost half of the older drivers with reduced visual field were unaware of their impairment.

Other Visual Changes

Other visual abilities important to driving decline through the aging process. Studies have not yet established a link between frequency of accidents and age-related reductions in visual abilities such as contrast sensitivity, glare recovery, distance perception, and visual search (Kline 1986). These visual abilities are discussed in more detail by Bailey and Sheedy and by Schieber in Volume 2. In some respects the failure to link visual performance with accidents is not surprising. Accidents have many causes, few of which are ever measured. Statistically significant findings and large correlations are rare in cross-sectional accident research. Nonetheless, despite the difficulty of establishing any relationship between the many contributing factors in crashes and driver physical abilities, significant relationships have been observed between accidents and static acuity under normal and low illumination, dynamic visual acuity, and reduced field of view. Performance of these visual funtions declines with age.

Hearing

The prevalence of hearing impairment (deafness and hardness of hearing) rises sharply with age from less than 2 percent of those under 17, to 24 percent of those between 65 and 74, and to 39 percent of those over 74 (OTA 1985). Little research, however, has been conducted to examine the relationship between hearing loss and safe driving. The consequences of hearing loss with age may not be important in driving. The ambient noise level inside automobiles traveling faster than 35 mph provides a level of masking similar to a very severe hearing loss; this tends to minimize the role of hearing (for all ages) in driving. The ability to hear warning sirens and train whistles at railroad crossings and to respond to horns of other drivers is obviously related to safety; yet the connection between hearing loss and safe driving has not been established (Henderson and Burg 1974).

Cognitive Performance

Driving requires a combination of perceptual skills in which cognitive performance plays a major part. In terms of the four-phase model described earlier in this chapter, cognitive performance is fundamental to attentiveness to the driving task, recognition of a stimulus, and choice of the appropriate way to respond.

Attentiveness

Review of in-depth accident examination studies indicates that driver inattention contributes to 25 to 50 percent of motor vehicle crashes (Shinar et al. 1978). The ability to focus attention on a task is widely perceived to diminish with age (Botwinick 1978). Some evidence suggests that older persons are more easily distracted by irrelevant stimuli (Kausler 1982). Staplin's review of the literature concludes that older persons have more difficulty than younger adults in selectively attending to the most important stimuli (Staplin et al. 1987). The magnitude of the differences and their importance to driving, however, have not been adequately determined.

Information Processing

In addition to perceiving salient information, a critical element of cognitive performance is perceiving it accurately. For example, laboratory tests of the ability to judge the distance between objects accurately show that older persons (over 60) are much more likely to underestimate the relative depth separating visual targets than are persons between the ages of 18 and 45 (Hill and Mershon 1985). A recent simulation study by Kline et al. (1986) indicated that older persons overestimated the velocity of oncoming vehicles, but not enough to compensate for their underestimation of the distance between themselves and the vehicles. Kline suggests that such misperceptions in real life would make older drivers or pedestrians more likely to encroach on the lane of an oncoming vehicle than younger persons (Kline 1986). Although this hypothesis has not been tested in accident research, it may contribute to an explanation of the turning accidents characteristic of older drivers.

A recent and extensive review of the literature reports a general consensus among researchers that older persons process information more slowly than younger ones (Staplin et al. 1987, 85). Earlier researchers arrived at the same conclusion (Panek et al. 1977, 423; IOM 1981). When older persons are required to solve complex problems, an example of which in traffic might be negotiating a busy, complex intersection, "the general findings across a wide variety of problem solving tasks are that older people experience declines in their performance of complex, multifactor tasks" (Staplin 1987, 93). The slower speed with which older persons can process information, particularly when required to make complex decisions, suggests that they require more time than younger drivers to complete the cognitive component of the four-phase driving model.

Forgetfulness and Dementia

Slower information processing and mild memory loss appear to be a normal part of aging (Katzman 1985). Some losses in cognitive ability, however, are caused by diseases more common with advanced age; these losses, when severe enough to interfere with social or occupational functioning, are referred to as dementia. Because of the many causes of dementia, it is difficult to diagnose. Katzman (1985) estimates from various sources that about 4 to 5 percent of individuals over 65 have dementia severe enough to prevent them from living independently. The rate of severe dementia increases with advanced age. Up to 20 percent of those over 85 are estimated to have severe dementia. Katzman estimates that about 55 percent of dementia cases are the result of Alzheimer's disease.

Although severe dementia is debilitating to individuals and increases with advanced age, the overall prevalence among individuals over 65 is fairly low (4 to 5 percent). Mild to moderate dementia, characterized by forgetfulness, however, is more common, perhaps affecting 30 to 35 percent of the individuals over 85 (Katzman 1985). The prevalence of forgetfulness as an early stage of dementia coupled with normal memory loss associated with aging probably affect the cognitive processes necessary for safe driving, but this has not been examined. Research on this topic is recommended in Chapter 5.

In addition to normal memory loss and the effects of disease, the cognitive process can be disrupted by prescription drugs. McKnight's review (Vol. 2) indicates that this issue has been identified as a potential problem, but research has not been conducted to determine its magnitude.

Motor Skills

A fairly wide body of evidence indicates that the speed of simple motor response diminishes with age (IOM 1981, 116; Staplin et al. 1987, 101). The decreases in speed of response, such as those needed to operate a modern automobile, however, are small, and can be compensated for with practice (Welford 1977). Welford's (1977) review indicates that the motor responses needed for driving a car are not limited by muscular changes that accompany aging; hence any slower reaction time among older drivers is probably a result of a slower decision-making process.

Although the decrease in motor skills needed for driving modern vehicles appears to be small, studies of walking speeds indicate that older pedestrians walk more slowly than younger ones (McGee et al. 1983, 47–48). As discussed in the next section, this slower walking speed has some consequences for assumptions used in the operation of traffic signals.

Physical well-being also affects physical performance. Self-reports of the 10 most prevalent chronic conditions for all persons over age 45 increase with age (Special Committee on Aging 1985, 13, Table 4). The prevalence of these conditions shows a gradual increase with age, however, without any evidence of a threshold after which there is a dramatic increase. For example, about 40 percent of those between 65 and 74 have arthritis compared with 30 percent of those between 55 and 64 and 20 percent of those 45 to 54.

The effect of health on performance has been treated extensively in a report examining the federal policy of requiring airline pilots to retire at age 60 (IOM 1981). In this report the medical and behavioral research was surveyed to determine whether the incidence of medical impairment that accompanied aging could impair the function of older pilots. Although the percentage of individuals in each age group with physical impairments increases across the age span, after a thorough review of the relevant biomedical and behavioral research, the IOM study concluded that "variability within an age group is often nearly as great as variability among age groups, and that *usually no single age emerges as a point of sharp decline in function*" (IOM 1981, 144).

Physical Vulnerability

In addition to the increased risk of crash involvement for older drivers identified in Chapter 3, the outcomes of crashes are more severe. Physiological changes contribute to the vulnerability of older people. Mackay's paper in Volume 2 of this report reviews the biomechanical changes that accompany aging and contribute to this vulnerability. Bones become more brittle because of a decline in mineral content. Joint function is diminished and resilience is lessened by a loss in the extensibility of collagen fibers. Atheroma of the arteries, common among older persons, increases the probability of blood loss. All these changes result in a lower tolerance to injury in the event of a crash.

Summary

Most persons between 65 and 85 and more than half of those over 85 report that their health is quite good and that they do not experience any limitations in pursuing their daily lives. Nonetheless, the research on human performance indicates that, in general, some visual abilities (static and dynamic visual acuity, visual field, sensitivity to glare, and others) decline with age. The effect of these declines in visual function becomes more pronounced at night or under conditions of low illumination. Some visual abilities—static and dynamic acuity, visual field, and static acuity under low illumination—have been linked to accidents. Cognitive performance, particularly the speed of information processing, also slows with age; this effect is more pronounced in carrying out complex tasks.

The literature on performance indicates that older persons require a little more time to complete the four phases of the driving task: seeing, recognizing, deciding, and acting. As discussed in the next section, assumptions about performance of the four-phase process, referred to as perception-reaction time, are basic in highway design and traffic operations.

Although the research indicates reduced performance with age, it also points to an increasing amount of variability in performance with age (IOM 1981; Heron and Chown 1976). Age alone is a poor predictor of the performance of any individual. As discussed in the next section, the variability in performance by older persons must be taken into account when adjustments to standards in highway design and operation are considered, particularly driver licensing.

Regardless of the variability in their performance, older persons are more vulnerable to injury when a crash occurs. This changed biomechanical response to injury poses some complex problems in designing for vehicle crashworthiness, as discussed in Chapter 5.

PERFORMANCE AND THE ROADWAY SYSTEM

Highway Design

Human performance characteristics are taken into account in 13 geometric design standards and 5 traffic control devices (McGee et al. 1983). Most of these design standards relate to providing drivers with adequate clear areas to enable them to see other objects or vehicles in sufficient time to maneuver (e.g., to cross an intersection or to pass another vehicle). McGee et al. point out, however, that some design features assume visual performance and reaction times that many drivers (many of whom are older) may not be able to meet.

Stopping Sight Distance

Stopping sight distance is calculated as the sum of two distances: the distance traversed between the time an object is detected and the brakes are applied and the distance required to bring the vehicle to a full stop. In highway design, a perception-reaction time of 2.5 sec is assumed for determining the behavioral component of stopping sight distance, with 1.5 sec allowed for braking and 1 sec allowed for perception. When adopted by the American Association of State Highway and Transportation Officials, the 2.5-sec assumption was considered long enough to cover "nearly all" drivers under most driving conditions. McGee et al. (1983) reviewed the literature on field studies through 1983; these showed that the 85th-percentile performance for the brake-reaction time component of perception–brake-reaction time ranged from 0.85 to 1.88 sec (McGee et al. 1983, 34). The 95th-percentile brake-reaction time ranged from 0.88 to 2.36 sec. The lower estimates come from studies conducted between 1925 and 1953. McGee et al. estimated that the 85th-percentile perception–brake-reaction time might be as high as 3.2 sec, well above the current 2.5-sec specification.

In a 1984 study, however, Olson et al. estimated that the 95th-percentile perception–brake-reaction time for stopping sight distance was 1.6 sec. Olson's study included an element of surprise, so the driver was relatively unprepared for the test. When driving to the test site and before being notified that the experiment had begun, the subject came upon an object in the road just over the top of a hill. Perception–brake-reaction time was clocked by an instrumented vehicle. Although the 15 subjects in the sample over age 60 performed more slowly than the younger subjects, 95 percent of all subjects perceived and reacted to an object in the road in 1.6 sec, which is well within the 2.5-sec assumption.

Even though the performance of the older subjects was within the existing assumptions, this might be explained in a variety of ways. The tests were run during daylight and with good visibility, so the poorer night visual abilities common among older persons would not have had a detrimental effect on their performance. The older drivers who participated in the study may have been healthier and more vigorous than the average older person, and may have been abnormally alert because they knew they were participating in an experiment (even though they were not likely to have anticipated the surprise). Finally, because the appropriate response to the surprise was relatively unambiguous, this test may not have reflected the longer cognitive processing times common among older persons when faced with a more complex situation.

Intersection Sight Distance

The sight distance provided to drivers at intersections varies slightly depending on the type of intersection. The assumptions for perception-reaction time vary from 2.5 to 3 sec (McGee et al. 1983, 7–9). For drivers in stopped vehicles who intend to cross a major street, 2 sec is allowed for the driver to look in both directions, decide to cross, and initiate action (e.g., shift gears if necessary). The assumptions used when an intersection is designed on the basis of the performance of trucks are more accommodating for older drivers because the design allows for slower acceleration and braking. If the design vehicle is a passenger car, however, the 2 sec allowed for driver perception and decision may not be adequate for older drivers with slower head movements and longer decision times (Hauer, Vol. 2, p. 219). A research effort to address this issue is recommended in Chapter 5.

Three questions arise from this discussion of perception-reaction time for stopping sight distance and intersection sight distance, the first two of which are empirical. What is the distribution of perception–brake-reaction times across the population of drivers under the varied conditions of driving? Until research with representative samples is conducted to answer this question, the proportion of the population excluded by the current standard will not be very well known. The importance of representative samples cannot be overemphasized. Given the variability in performance of older persons, samples that represent the older driver need to be larger than samples made up of younger persons, whose abilities are more similar. These larger sample sizes (which should be random samples rather than be distorted by volunteer bias) make research more expensive, but without them the findings may exclude the performance of a large and growing share of the driving public.

The second question that arises has to do with the costs and benefits of extending the perception–brake-reaction time. Allowing more time for this process would certainly increase the cost of design, both when new roads are provided and when existing ones are reconstructed to meet the standard. The safety benefits of longer perception-reaction times, however, are not at all clear (McGee et al. 1983; Hauer, Vol. 2, p. 220).

Many design features, for example, build in other dimensions to increase the margin of safety. Stopping sight distance, for example, uses conservative assumptions for braking distance based on poor tires and a wet surface. These additional conservative assumptions compensate for the slower performance of older drivers. The actual benefits to be obtained from a more generous specification for perception-reaction time are unknown.

The third question relates to the proportion of the population that is to be covered by design standards. If standards are based on the 85th-percentile or 95th-percentile performance, some share of the population is excluded. Clearly some trade-off has to be established between the cost of design and the benefits obtained. This question is premature because the proportion of the population that is or might be excluded has not been well established nor have the benefits of extending the performance specification. Research needed to begin filling this gap is identified in Chapter 5.

Given that highway designers assume a perception-reaction time of at least 2.5 sec, it would make sense to at least screen license applicants to determine whether they can perform at this speed. Experimental psychologists have been testing such performance for some time. A relatively simple simulation, one that could be performed on a microcomputer, would probably suffice and could be incorporated into license screening. Research needs in this area are recommended in Chapter 5.

Pedestrian Design Features

Physical design improvements to accommodate older pedestrians are well known but not often enough provided. Simple improvements include widened sidewalks (Hauer, Vol. 2, p. 223); pedestrian refuge islands; curb ramps, which also benefit those in wheelchairs; removal of barriers in the sidewalk; and street lighting (Templer 1979; Zegeer 1988).

Highway Operations

Among performance characteristics, assumptions about driver visual acuity and pedestrian walking speed have the greatest influence on traffic operations standards (McGee et al. 1983, 104). Assumptions about visual acuity are used to determine the size and legibility of traffic signs, and assumptions about walking speeds influence the timing of pedestrian signals at intersections.

Traffic Signs

As pointed out in the paper by Mace in Volume 2, the letter height for signs is based on the assumption that an inch-high letter is visible from 50 ft. This standard was derived from research conducted by Forbes in the 1930s (Forbes and Holmes 1939). The size of the lettering and therefore the size of the sign are determined by the design speed of the highway, the time required to read the sign, and the time needed to make the appropriate maneuver in traffic. Providing 1 in. of legibility for every 50 ft, however, assumes a visual acuity of roughly 20/25. The estimates by Bailey and Sheedy in Volume 2 indicate that 40 percent of drivers between 65 and 74 do not see that well and that through age 75 the 95th percentile for acuity is close to 20/40.

The older driver is at more of a disadvantage reading signs at night because of poorer acuity under low illumination. Sivak et al. (1981) compared younger drivers with older drivers in the distance necessary to be able to maneuver in traffic after reading a sign. In this study, the older drivers (62 to 79) with corrected static acuity of 20/18 during the day had a static acuity of 20/42 at night. These older drivers had a legibility distance only 65 to 77 percent that of drivers 18 to 24. Given that the older drivers in this sample had excellent vision under high illumination yet had a considerable disadvantage at night, it is clear that current design does not provide enough time or distance for the average older driver to maneuver after reading a sign, especially at night.

Susceptibility to "visual clutter" also increases with age, which makes it more difficult for older drivers to detect and read traffic signs regardless of illumination (Kosnik et al. 1986; Sekuler 1986). Mace's review indicates that although older drivers do not require additional time to actually read a sign, they may need more time to detect it (Mace, Vol. 2). Recommendations to improve sign performance are made in Chapter 5.

Many older drivers compensate for poorer visual acuity by driving more slowly and by reducing their driving at night. By driving at a slower speed, the older driver provides himself with more time to maneuver in traffic even though he has to be closer to a sign before he can read it. Whereas drivers can compensate for inadequacies in design by adjusting their own performance, doing so can have adverse consequences in traffic. For traffic flow and safety, it is better to retain a uniformity of speeds (Hauer 1971). Partyka (1983), for example, found that older drivers have a higher probability of being involved in fatal crashes with very young drivers than they do with drivers of their own age group. She suggests that the different driving speeds of the oldest and youngest drivers may be the reason. The higher accident involvement rate of older drivers described in the previous chapter further indicates that older drivers are not fully able to compensate for their declining skills.

Compensation by driving less at night obviously affects older persons' mobility. It appears unlikely that future cohorts of older drivers, who will have grown up with greater expectations for personal mobility, will be equally willing to curtail their driving at night.

Pedestrian Signals and Crosswalks

The *Manual on Uniform Traffic Control Devices* suggests that a walking speed of 4 ft per second be used in signal timing. A review of the literature by McGee et al. suggests that many pedestrians—perhaps as much as 30 percent of the population, many of whom are older—do not normally walk that fast. Whether this assumption proves to be a problem depends on many site-specific conditions: the timing of signals, the number of slow walkers, the width of the lanes, and traffic at the site. As discussed in Chapter 5, traffic engineers should be more attentive to potential problems at the local level and should make site-specific adjustments when appropriate. It is recommended in Chapter 5 that signs be made bigger and brighter, which will benefit pedestrians as well as drivers.

The benefits of pedestrian crosswalks, though intuitively obvious, have been widely debated (Hauer, Vol. 2, p. 244). Crosswalks may give pedestrians a false sense of security, particularly at locations where many motorists ignore the pedestrian's right-of-way. Zegeer (1988) suggests that crosswalks are most beneficial at low-speed intersections with traffic signals and at school crossings with crossing guards. Research needs for pedestrian crosswalks are described in Chapter 5.

Vehicle Design

Designers of motor vehicle interiors begin with assumptions about human characteristics that, though complicated in execution, are intended to ensure that controls are within reach and that visual displays and mirrors are within the visual field of most drivers. The actual design that reaches the marketplace, however, is influenced by additional styling and marketing decisions. Automobile manufacturers in the United States have already recognized the aging of the automobile-purchasing market, and some models are already featuring bigger buttons, larger visual displays, and simpler operating instructions designed with the older vehicle purchaser in mind (*Business Week* 1988). Some vehicle features available as standard or optional equipment are of special benefit to older drivers and passengers. Kanouse (Vol. 2) outlines the merits of improving older persons' awareness of vehicle features that they might consider when purchasing automobiles.

In addition to the ever-evolving area of vehicle interior styling, two other aspects of vehicle design are important to older persons: crash protection and future design improvements that may simplify driving.

Crash Protection

Current occupant crash protection standards set simple pass or fail thresholds for forces applied to the head, chest, and femur in simulated crashes. These thresholds are measured in 30-mph fixed-barrier frontal crashes with anthropometric dummies. (Rulemaking to implement and improve standards for side-impact crashes was initiated by the National Highway Traffic Safety Administration in early 1988.) A single value is used for measuring the forces applied to the head, chest, and femur. As Mackay points out, the ability of different segments of the population to withstand these forces is not well known, but given their increased vulnerability to injury, older persons appear to be less well served by the existing standards than younger persons (Vol. 2, p. 189). Nonetheless, it is difficult, given current knowledge, to develop a standard for vehicle performance that effectively protects against fatalities for young drivers, which tend to occur in severe crashes, and fatalities for older drivers, which tend to occur in less severe crashes (Mackay, Vol. 2). Considerable research in biomechanics and crash protection is needed, as is recommended in Chapter 5.

Future Design Improvements

Future cohorts of older drivers may well be operating vehicles considerably more sophisticated than those in the current fleet. Technological innovations to improve visibility at night (vision enhancement through infrared cameras) and crash avoidance (radar braking) may simplify driving and reduce the risk to safety (Appendix B). These innovations will benefit all drivers, but especially those with reduced skills.

Considerable research, partly aimed at reducing traffic congestion, is under way abroad, and some in the United States, aimed at increasing the amount of information available to drivers (Appendix B). The technologies being examined range from radio or cellular phone broadcast of audio signals to digitized, electronic maps displayed on the driver's dashboard. (Although these technologies are in a very early stage of development, designers would do well to heed the ever-growing number and proportion of older drivers who will be expected to use them.)

These new technologies will be integrated into the roadway system in slow, incremental steps during the next few decades. Properly designed, they could simplify driving for all persons, especially older ones. It is premature at this stage to predict the speed with which they will be introduced or how much they will benefit older drivers. Nonetheless, these technologies may ultimately prove to be a special boon to the aging population of drivers.

Licensing

Performance standards for licensing are set by individual states, but they show a fair degree of consistency. All states screen applicants for static visual acuity, and the most common standard is 20/40, though several states deviate from this norm. (As mentioned earlier, the static acuity of the older population and the acuity assumed in sign standards are at variance.) In contrast to some highway design and operation standards, which are influenced by assumptions about human performance, licensing practices tend to be based on age, primarily the age at which it is legally possible to drive (typically 16). After an individual has a license, restriction or revocation is caused by some infraction or by a series of violations.

Some states use chronological age in part of the renewal process, but practice among the states varies widely. Most jurisdictions require drivers to renew their licenses on a 4-year cycle, and most (39) require a vision test at renewal. As noted by Waller (Vol. 2, p. 74), Maine requires vision testing at 40, Oregon at 50, and Pennsylvania requires random testing of vision and health at renewal for applicants 45 and over. Only eight jurisdictions require knowledge testing for all renewal applicants. Among those that do not test all renewal applicants, one state requires it at 89 and three at 75. One state requires a road test beginning at 69 and three require road tests beginning at 75. One state uses a discretionary policy of requiring a road test and medical report at 65 and one state requires both at 78. No state uses chronological age to arbitrarily limit or restrict the driving privilege.

Since passage of the Age Discrimination Act of 1975 and the 1978 amendment to the Age Discrimination in Employment Act, the issue of age discrimination has become an increasing concern in the conduct of public programs and in private hiring practices (Neugarten 1981). Mandatory retirement at 65 is now a thing of the past, which is an explicit recognition that individuals do not become unable to perform just because they cross an age threshold. Few states use age-based criteria for license testing or reevaluation, because they fear being charged with age discrimination (Malfetti et al. 1988).

Nonetheless, age-based criteria abound in public policies. As Neugarten (1981) points out, eligibility for Medicare, Social Security, some housing programs, and some tax benefits is based on chronological age. At the other end of the age spectrum, individuals are not legally permitted to drive until 16 and are not legally able to purchase or consume alcoholic beverages until 21. These policies recognize that 16 years of age is an arbitrary threshold and that not all drivers are ready to drive at that age. Similarly, the drinking age was raised to 21 because of the drinking and driving practices of a relatively small proportion of all 18- to 21-year-old drivers. These age-based choices, however, are made on the basis of administrative expediency; it is far more costly to make individualized assessments than to make across-the-board distinctions on the basis of age (Neugarten 1981, 823). Licensing administrators make the same choices; it would be expensive to screen all applicants extensively in order to identify those capable of driving and those who for reasons of physical health, behavior, or mental condition are not capable of driving. Nevertheless, at the other extreme, it is impossible to set a chronological age at which all drivers are incapable of driving. In the face of these extremes—the high cost of extensive screening and the inappropriateness of denying the driving privilege on the basis of age—most states do very little when it comes to regulating the aging driver (Malfetti et al. 1988).

Some research suggests that existing license renewal practices that include age as one dimension may not be fully justified (Kelsey et al. 1985). California, for example, has a program that allows drivers up to age 70 with clean driving records for the preceding four years to renew their licenses by mail. Kelsey et al. (1985) evaluated the effect of this program by randomly assigning drivers with clean records into two groups: the treatment group was allowed to renew by mail, and the control group was required to follow the normal in-person license renewal procedures. Although the group allowed to renew by mail had a slightly higher accident rate, the difference between the treatment and the control groups was not significantly different (Kelsey et al. 1985). This research suggests that for drivers who have clean driving records, in-person renewal is either not necesssary or not effective. Before California limited license renewal by mail to drivers under age 70, a pilot program allowed clean-record drivers of any age to renew their licenses by mail for two years. In this pilot program, clean-record drivers were randomly assigned to treatment and control groups, and among the two-year extended drivers, those over 70 had significantly fewer accidents than their counterparts in the control group (Janke and Kelsey 1981). Kelsey et al. (1985) offer two interpretations of this result. First, it is possible that older drivers who have clean records are aware of any limitations they might have and take corrective action. Alternatively, it could be that the in-person renewal practice (as practiced in California) is not effective in identifying problem drivers.

As Waller points out, the licensing process in general is not predictive of future individual performance (Vol. 2, p. 83). The declines in physiological and cognitive performance that accompany aging reduce the ability of some older drivers to drive safely, but these declines might only be detected by a more rigorous screening process, which has not been developed (Huston and Janke 1986). States are unwilling to require more extensive screening because of the limited ability to identify problem drivers with current methods. At the same time, the states are reluctant to require less than they already require because of fears of legal liability. As Waller points out, license administrators are finding themselves in court defending the licensing of drivers involved in serious crashes (Vol. 2, p. 83).

Until some systematic, cost-effective procedures are developed, some states will probably continue to use age to determine eligibility or as a trigger for when additional screening should begin. Some states, fearing charges of age-based discrimination, will continue to do very little to identify drivers whose performance poses a risk to themselves or others. Research that might develop improved license screening procedures is recommended in Chapter 5.

SUMMARY

Older persons generally are quite active and healthy. The majority of those aged 65 to 85 and almost half of those 85 and over do not report any limitations on their abilities to perform basic activities of daily living. Many older drivers, however, do report increasing difficulty when driving, especially when driving at night. Performance of visual, cognitive, and motor tasks does decline, on average, with age. Most older persons experience a hardening and yellowing of the crystalline lens of the eye and decreased pupil size. These contribute to a decline in static acuity and an increased sensitivity to glare. These losses in visual abilities are more pronounced in poor viewing conditions—at night, at dusk, or in fog or rain. The speed of decision making slows with age, particularly when the person is confronted with a complex problem. These declines in performance reduce driving skills, especially under poor driving conditions.

Several highway design and operation standards are sensitive to assumptions about driver performance. Perception-reaction time is the most important performance characteristic, and the literature on the adequacy of the current 2.5-sec assumption for perception-reaction time is not in agreement. The standard of visual acuity used for determining the size of signs is not consistent with the visual capability of many older drivers nor with the criteria applied for licensing. Signal timing assumes a walking speed faster than that of many older pedestrians.

Current occupant protection standards are not sensitive to the wide distribution in physical vulnerability that exists across age groups. Considerable research is needed to identify the differences in biomechanical responses to injury across age groups and to develop vehicles that better protect those in the population who are more vulnerable to injury.

State practices for driver licensing assume minimal performance criteria both for initial license applicants and for license renewal. A few states use age thresholds to determine when additional screening should occur, but practice across states is quite varied. License administrators are concerned about the growing number of very old license holders, but have little research to guide them in identifying those individuals who may be a higher risk. Many states, partly for fear of being charged with age discrimination, do not make special attempts to screen out older drivers who may be a greater danger to themselves or to others.

Recommendations are made in Chapter 5 to adjust highway design and operation to better accommodate older drivers, to develop a research program to improve occupant and pedestrian crash protection, and to improve the process of screening driver performance.

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IOM	Institute of Medicine (National Research Council)
OTA	Office of Technology Assessment

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CHAPTER FIVE

Summary and Recommendations

A variety of steps can be taken to improve the mobility and safety of older highway users. In the technical papers commissioned as part of this study and published in Volume 2, experts in several fields recommend a large number of such improvements. Their papers were presented at an international colloquium in the fall of 1987 during which an audience of invited guests commented on the authors' recommendations. After reviewing the debates that occurred during the colloquium and after further discussing the authors' recommendations, the committee selected the ones summarized in this chapter as the most promising; the committee judges these recommendations to be practical, achievable, and affordable. Actions that can be taken by individuals, voluntary associations, private organizations, and the different levels of government are identified.

Although a variety of incremental improvements are recommended at this stage, the attempt to develop comprehensive, affordable transportation policies for an aging society is immediately handicapped by the lack of knowledge about the potential outcomes—the benefits and costs—of many alternative policies. Fundamental gaps exist in our understanding of how human performance changes across the life cycle and how those changes affect the driving task and the safety of motorists and pedestrians. In addition, little systematic information is available about the travel behavior of the current older population and little attention is being paid to how the travel needs of future cohorts of older persons will differ from those of today.

A series of high-priority research needs is identified in this chapter. The different federal agencies, national associations, states, and private groups that might carry out these recommendations and support the needed research are also identified. In the last section, a proposal is made that a group be created to stimulate adoption of the recommendations made in this report and to facilitate the needed research.

The recommendations in this chapter are divided under four main headings—the roadway environment, crash protection, driver licensing and screening, and alternatives to the private automobile for enhancing mobility. The recommendations are in bold type to distinguish them from the introductory and explanatory text.

IMPROVING THE ROADWAY ENVIRONMENT

Many older drivers have more difficulty managing the demands of modern traffic than the average younger driver. Among other reasons for this difficulty, human performance assumptions underlying the design of highways and traffic operations correspond more closely to the abilities of younger drivers. For example, many older drivers do not have sufficient time or distance to respond to visual cues—particularly under conditions of low illumination—because they cannot see as well as younger drivers. In addition, the speed required to decide and act in order to merge with high-speed traffic and negotiate complicated intersections can overtax the capability of some older drivers. The walking speeds required of pedestrians at some intersections are often too fast for the older person to manage comfortably.

Many of the practices and standards used in traffic control have been developed over time from rules of thumb and professional judgment. The earliest codified practices for marking and signing rural highways are in the first manual on uniform standards, published in 1927 by the American Association of State Highway Officials. This publication was merged with a manual for urban roads to become the first *Manual on Uniform Traffic Control Devices* (MUTCD) in 1935. The MUTCD has undergone several revisions; nonetheless many standards have changed little since the 1930s. Two reviews of the research underlying the standards in the MUTCD found that many current standards were based on subjective judgments rather than specific research (McGee et al. 1983; Shapiro et al. 1987). Recommended corrections to the research inadequacies are discussed in the following sections along with identification of practices for signing, marking, and pedestrian signals that should be modified on the basis of current information.

Guidance for the physical design of highways is found in several sources, but the design guide prepared for the American Association of State Highway and Transportation Officials (AASHTO) is used by the Federal Highway Administration and the states (AASHTO 1984). After a review of the assumptions about performance underlying intersection design, recommendations are made to improve the research underlying these design assumptions.

Highway Signs

Older drivers have expressed their dissatisfaction with highway and street signs both informally and in survey research (Yee 1985). As Mace's review shows, older persons have to be much closer to a sign than younger ones before they can see the sign clearly (Mace, Vol. 2). The effects of age on visual processes and the growing number and proportion of older drivers suggest that a new approach is needed in highway signing based on the distance that a driver needs to detect a sign, read it, and make appropriate maneuvers. **The MUTCD should adopt a performance standard for highway and street signs based on the degree to which a sign ensures the minimum required visibility distance of the older population.** Although the performance of signs should be improved specifically for older drivers, all drivers will benefit. Performance could be enhanced in alternative ways: letter sizes could be increased, the conspicuity of signs could be enhanced by using higher-intensity reflective materials, and multiple signing could be used.

The current rule-of-thumb used to determine the letter size of guide signs assumes that an inch-high letter can be seen from a distance of 50 ft. (Letter sizes are even smaller on warning and regulatory signs.) One way of improving sign performance would be to increase the current design to assume that an inch-high letter can be read at 40 ft rather than 50 ft (Mace, Vol. 2, p. 29). For example, assuming a minimum visibility distance of 900 ft (commonly used in determining letter size for Interstate signs), a sign design based on 1 in. of letter height for every 50 ft would have 18-in. letters. A design based on 1 in. for every 40 ft would require 22.5-in. letters. Increasing the letter size, however, also requires the sign to be larger, and therefore increases the cost of the sign and the mounting. Some signs, however, could meet the performance standard without necessarily being larger if their conspicuity were increased, if multiple signs were used, or if there were some combination of the two.

The conspicuity of signs can be enhanced by using high-performance retroreflective sheeting. At night a driver can detect a brighter sign sooner. Better sign conspicuity is more important in urbanized areas with visual clutter. The MUTCD already requires that all signs have retroreflective backgrounds, but various grades of retroreflective sheeting are used by the states. **The Federal Highway Administration and the states should cooperate through the National Cooperative Highway Research Program (NCHRP) on a project to determine the level of retroreflective sheeting intensity needed to provide adequate conspicuity for older drivers and to identify the types of signs that would be good candidates for enhancement with high-performance retroreflective sheeting.**

Another way to provide information for the older driver is to give more advance notice through greater sign redundancy. Advance notice signs (referred to as mid-block signing in urban areas) should be used more widely by state and local traffic engineers, as they are on Interstate highways and freeways, to alert drivers to upcoming intersections, especially when the driver needs to maneuver into an exit or turn lane. Greater redundancy would improve the performance of warning and regulatory signs as well as of guide signs. The performance criteria for multiple signing should account for the potential problem of visual clutter. In some urban areas, for example, the visual scene may be too complex for multiple signing to work well. **The Federal Highway Administration should cooperate with the states through NCHRP to develop procedures and guidelines for using advance notice signs.**

Drivers can also be provided the necessary information within the minimum visibility distance through the use of symbols, which enable the driver to read the sign faster. Research by Allen et al. (1980) indicated that the current population of older drivers has some problem with symbol recognition (which was overcome with training in this study), but it appears unlikely that future cohorts of older drivers will have this problem. **The Federal Highway Administration should support research on the use of symbol signs and on optimal symbol types.**

Once adequate signs are in place, they must be inspected and maintained on a regular basis. **The states should work through NCHRP to develop procedures for sign budgeting, inspection, and maintenance to ensure that sign condition, mounting, placement, contrast, and reflectivity are maintained.** Projects are now ongoing within NCHRP and the Federal Highway Administration to develop minimum retroreflectivity standards and procedures for inspection. This research should be synthesized; the result might be a guidebook for sign inspection and maintenance that could be used by all jurisdictions.

Roadway Markings

Drivers are provided with several kinds of visual cues to enhance tracking in the lane and through curves. Centerlines, lane lines, edgelines, crosswalk lines, stop bars, and symbols are the most common markings, but other types, such as raised (or recessed) pavement markers, post-mounted delineators, and chevron signs, are widely used to supplement pavement markings. Pavement markings and other types of delineation are reflectorized to improve nighttime visibility. These devices and markings benefit all drivers but are of significant benefit to those who have reduced visual capability (Deacon, Vol. 2, p. 261).

Pavement edgelines are required by the MUTCD for Interstate highways and should also be employed on other roads in high-hazard locations or where narrow shoulders, hazardous side slopes, and road curvature might place the momentarily inattentive or errant driver at risk.

Much of the current research on delineation is focused on increasing the standard of 4-in. edgeline marking to 6 or 8 in. A recommendation regarding the benefit of wider edgelines, however, awaits the result of a major multistate study currently being conducted for the Federal Highway Administration.

The maintenance of delineation often ranks low in some highway program priorities, and roads not on the federal-aid system are frequently poorly marked. **State and local governments should place greater emphasis on the inspection and maintenance of roadway delineation (including retroreflective performance) for the benefit of all drivers.**

In addition, state, county, and local highway engineers should assess rural highways that are not part of the federal-aid system to be sure that they provide delineation treatment of the highest accepted standard.

Pedestrian Signals

The phasing of traffic lights at intersections to allow for pedestrian crossings is guided by the suggestion in the MUTCD that pedestrians be assumed to walk at 4 ft/sec. Many older persons do not walk this fast (Hauer, Vol. 2, p. 232). Traffic engineers, however, must accommodate the needs of vehicular and pedestrian traffic. The simple solution of taking a few seconds of green time in each signal cycle from the vehicle and giving it to the pedestrian would impose a large delay cost on motorists (although this large delay is made up of the sum of many small delays). As a further reason for caution, the costs and the potential safety benefits that would be achieved depend on many site-specific conditions (Hauer, Vol. 2, p. 238). Rather than adopt a new, arbitrary standard with clear costs and uncertain benefits, **local and state traffic engineers should evaluate intersections with signal timing that assumes a walking speed faster than 4 ft/sec to determine whether better solutions can be found. Conduct of these evaluations should be given priority. At those intersections adjacent to or in areas used regularly by older persons, traffic engineers should give priority to either phasing traffic lights to give adequate time for older persons to cross or providing pedestrian-activated signals, refuge islands at the median, or other improvements.** The Federal Highway Administration has recently revised the pedestrian traffic volume warrants in the MUTCD to make them more responsive to the needs of elderly and handicapped pedestrians (*Federal Register* 1988). A guide to assist in the provision of alternative site-specific improvements in pedestrian crosswalks has been developed by the Federal Highway Administration (FHWA 1987).

Pedestrian signals (Walk, Don't Walk) have not been applied consistently from city to city, and many pedestrians, not just older ones, are confused about when they have the right-of-way. As the first step in overcoming pedestrian uncertainty, **local traffic engineers should conform to the standards recently adopted by the MUTCD to ensure uniformity in pedestrian signals from community to community. In**

addition, the meaning of those standards must be communicated to the public more extensively by local traffic safety officials.

Roadway Design

One approach to simplifying the maneuver of turning against oncoming traffic is to provide separate left-turn lanes. The design guide for highways published by AASHTO recommends use of left-turn lanes when traffic volumes are high and speeds are fast but does not provide warrants or a design procedure. A large body of conflicting information exists regarding the benefits of left-turn lanes (Hauer, Vol. 2, p. 218). **AASHTO should provide a critical review of these studies through NCHRP, develop a procedure for analyzing the need for left-turn lanes, and provide design guidance in the highway design guide.**

Another approach to improving safety at intersections is to provide additional sight distance for safe crossing. When intersections are designed to be crossed by large trucks (i.e., the truck is the design vehicle), the sight distance and crossing time will be adequate for drivers of passenger vehicles; the procedure for design when the passenger car is used as the design vehicle, however, may not be adequate (Hauer, Vol. 2, p. 220). The sight distances and the decision times used in design may be too short for drivers who move their heads more slowly and who take longer to decide.

AASHTO should reevaluate the sight-distance triangles used in designs for passenger vehicles with the capability of the older driver in mind. An NCHRP project should be funded to (1) review the design procedure, (2) recommend better design assumptions in light of the capabilities of older drivers, and (3) identify alternative practices for highway engineers to employ at intersections already built that provide inadequate sight triangles.

At-grade intersections are basic points of conflict between vehicles crossing paths with each other and with pedestrians (Hauer, Vol. 2, p. 210). Motor vehicle fatality statistics indicate that intersections pose a particular risk for older persons. Hauer notes that the officials who analyze and approve the plan to have or modify intersections do so without specific knowledge about the safety merits of alternative designs. **The Federal**

Highway Administration should fund research on the safety performance of alternative street networks with a focus on the frequency of intersections and their design (three legged, four legged, etc.).

Research Needs

Traffic Operations

Once an intersection is in place, traffic control signs and devices serve as the principal means of protecting the safety of motorists and pedestrians. Most intersections with low traffic volumes have no traffic control at all, yet many pedestrian fatalities (about about half of those occurring at intersections) occur at intersections that lack traffic control (Hauer, Vol. 2). Although the costs to motorists and to the public of adding traffic control at uncontrolled intersections can be readily estimated, it is quite remarkable that current research is inadequate to predict the safety consequences of adding signs and signals to uncontrolled intersections or the consequences of upgrading the level of traffic control at controlled intersections. **The Department of Transportation should fund basic research to determine the relationships between safety and traffic control. Research projects that could specifically benefit older persons include determination of the safety consequences of**

- **Pedestrian signals and pedestrian crosswalks,**
- **Varying levels of protection for left-turning traffic at signalized intersections,**
- **Moving from no control to use of traffic signs and from use of signs to use of traffic signals, and**
- **Permitting right-turn-on-red.**

This research should go beyond the before-and-after studies in the literature (which often lack statistical controls or tests for significant effects) and should ensure that samples used are large enough to adequately reflect the variability in performance among older persons. Adequate sample sizes vary with the desired level of confidence of statistical tests, the degree of accuracy desired, and the variability in the measures of interest (Blalock 1972). Because the performance of older persons is known to be more widely varied than it is for other age groups, sample sizes for older persons must, of necessity, be larger than for younger ones in order to make valid comparisons across age groups.

Highway Design

The basic research on human performance in vision and cognition recommended in the discussion of improving license screening later in this chapter can have a significant impact on future highway design and operation. Many design standards and professional practices assume that most drivers perform perception-reaction tasks at certain speeds. A major evaluation of highway design and operations standards affected by driver and pedestrian performance characteristics identified 13 geometric design and 5 traffic control standards that explicitly consider these characteristics (McGee et al. 1983). This same report notes that the assumptions about performance used in the development of these standards were "weakly supported by empirical research, incorrectly specified, or [used] an inappropriate specification." The report was unable to estimate the proportion of the population excluded by current standards for the same reason that this study has found it difficult to recommend appropriate adjustments to current practice to account for an aging population. Although initial empirical research has been conducted to distinguish performance differences across age groups (Lindholm et al. 1986), there is insufficient reliable empirical information on the distribution of performance for the current population of drivers and pedestrians.

The Department of Transportation or the National Institute on Aging or both should act to rectify this gap in basic knowledge. **Studies should be conducted to provide information about the current performance across age groups of the driving population in perception–brake-reaction time, perception-reaction time for intersection sight distance, and the perception time for detecting and relating to objects in the road. These studies should also take account of the variability in performance among older persons and use samples large enough to represent the full range of the older-driver population.**

IMPROVING VEHICLE SAFETY

Safety Belts

Older persons are more susceptible to injury or fatality in a crash than younger persons (Mackay, Vol. 2, p. 167; Partyka 1983; Evans 1987).

Safety belts, properly worn, greatly reduce the risk of injury. Design enhancements are needed to make them easier for older persons to use (*photograph from American Association of Retired Persons*).

Improved crash protection, therefore, will be of special benefit to older highway users. Proper use of existing lap and shoulder safety belts is the most cost-effective safety measure currently widely available (Mackay, Vol. 2, p. 180). **All states should adopt mandatory safety belt use laws and encourage correct use of safety belts through information campaigns and vigorous enforcement.**

Although the restraint systems being introduced by the automobile manufacturers are making safety-belt systems easier to use, the design for the older driver can be improved (Mackay, Vol. 2, p. 184). More attention should be paid during design to the physical ability of older drivers. Use of safety belts by older persons would be facilitated by making the belts easier to reach and attach; electronic devices that place the buckle within easy reach are already being offered by Mercedes-Benz. **Automobile manufacturers should continue to improve the accessibility of safety belts and the adjustment of seats and pedals with the special needs of older persons in mind.**

Improved Consumer Information

Improved consumer information can benefit older motorists by making them more aware of the specific ways in which their performance and susceptibility to injury are likely to change as they age and of the attributes that they should look for and consider when purchasing a motor vehicle. Consumer behavior can be influenced by well-designed information campaigns, and an opportunity exists to improve the quality of consumer information that will enhance safety when older drivers make vehicle purchase decisions (Kanouse, Vol. 2).

Features such as air bags and properly designed seats provide special benefits to older occupants (States 1985). Many older purchasers, however, are not aware of the value of these features. The protection provided by safety belts is much improved by the addition of air bags; these devices utilize the entire forward surface of the chest rather than only the narrow surface under the shoulder belt. Broadened load reduction reduces the risk and severity of clavicle and rib fractures and injuries to the cardiovascular system and lungs. In addition, air bags control and cushion the head and neck, which prevents contact with the steering wheel and windshield. The air bag, however, should be viewed as an adjunct to the safety belt, not as a substitute. It is designed for protection in frontal crashes, and safety belts are essential for protection in other types of crashes. In the event of a crash, the air bag may pose some hazard to unrestrained children sitting (or standing) immediately adjacent to the driver (Viano 1987), which further emphasizes the importance of proper use of safety belts and child safety seats.

The National Highway Traffic Safety Administration (NHTSA) should develop a consumer-oriented program that will raise the awareness of older consumers to the vehicle features that are of special benefit to them as they age. NHTSA should also work with other organizations in the public and private sectors to develop and disseminate such information.

Improved Headlight Performance

Because of the declining ability to see well under low illumination that accompanies aging, headlight illumination is potentially of special benefit to older persons. During daylight (photopic conditions), the eye of the typical older driver receives one-third the illumination received by the eye of the typical teenager. At night (scotopic conditions) the retina of the eye of the typical older person can receive 16 times less light than the retina of the typical teenager. Increased illumination to compensate for this loss is desirable. Older persons, however, are also more sensitive to glare, which increases with illumination. Safer driving at night requires adoption of policies and practices that provide as much illumination as possible without increasing glare (Mortimer, Vol. 2). The following steps are recommended:

1. The glare caused by high-mounted headlights on light trucks and vans should be ameliorated by a federal standard reducing the mounting height on light trucks and vans to the range of 22 to 30 in.

2. Better illumination could be maintained if automobile manufacturers provided wider availability of headlight washers as vehicle options.

3. Individual older drivers can maximize the performance of their headlights by ensuring that they are kept clean and correctly aimed, and should be made aware of the need to do so.

Research Needs

Older persons have quite different biomechanical responses to crash trauma, and these differences across age groups are not fully understood (Mackay, Vol. 2, p. 189). Current policy for occupant protection, however, may not be appropriate for an aging population (Mackay, Vol. 2, p. 189). Federal occupant protection standards require vehicles to pass crash tests at an impact speed of 30 mph. However, deceleration of an occupant from an impact speed of 30 mph to zero in a fraction of a second is a severe event, and can still result in severe injury or fatality, especially if the occupant is unrestrained or older. In other words, current policy is designed to protect against fatality in the case of a severe crash. Older persons, however, tend to be involved in relatively less severe crashes at lower impact speeds, yet still have a high probability of severe injury or fatality. Thus the design that may be appropriate for protecting younger persons may not be adequate for older ones or for the types of crashes in which they are involved.

As noted in Chapter 3, older drivers have more problems than average when crossing traffic and have a tendency to be involved in turning crashes, especially left turns against oncoming traffic. Better crash protection in the side panels, therefore, will be of special benefit to older drivers. The committee supports the Department of Transportation's recent decision to develop a side-impact performance standard. (One alternative to strengthening side panels would be to lower vehicle bumpers to reduce vehicular intrusion in side impacts. This concept was raised too late in the course of this study to be evaluated but might merit additional study.)

Additional research will be needed, however, to better simulate the benefits of side-impact protection for older occupants. The crash dummies currently in use represent many years of development and are a significant improvement over earlier versions; nevertheless they are fairly crude. Although current dummies can simulate head and thorax damage from direct frontal impacts, they cannot simulate soft tissue damage or injuries caused in side impacts (Viano et al. 1987). Even though further refinements to crash dummies will take many years, such refinements are needed to guide vehicle design for occupant protection.

NHTSA should develop and fund a research program that would (1) conduct biomechanical studies to delineate the differences in the vulnerability to injury across age groups, (2) develop crash dummies to be used in crash tests that are more representative of the impact response of the various segments of the motoring public, (3) examine crash protection for older persons in lower-speed crashes, and (4) collect control data on driving exposure and crash exposure representive of the age distribution of the driving population.

Assuming that improved understanding about biomechanical differences results from the previous research, **NHTSA should reevaluate the adequacy of the Federal Motor Vehicle Safety Standard 200 series for protecting a growing population of older persons more vulnerable to injury.**

The Department of Transportation should also expand its pedestrian safety research program. This should begin with exposure and field accident studies to investigate the risks, causes, and consequences of pedestrian accidents across age groups. NHTSA should also emphasize its research program to encourage the production of vehicles less hostile to older pedestrians. This effort should be the first step in

developing a propedestrian crashworthiness standard. Some protection to pedestrians can be offered by softer and more uniform vehicle fronts and by softer hoods (in the region where the pedestrian's head is likely to strike the vehicle during impact). These improvements, however, will only be realized in the long term. For the short term, environmental and behavioral interventions should be encouraged.

IMPROVING DRIVER LICENSING AND SCREENING

Model Programs

The practice of licensing drivers has changed little since all states adopted the same minimum standards in the mid-1950s. Most driver-licensing programs were developed to introduce drivers to using the highway system by requiring knowledge of traffic laws, basic driving skills, and minimum visual acuity levels. Few states are prepared for the growing need to screen older drivers to identify those whose declining skills increase the risk of accident involvement. By 2020 about 22 million people over 75 will be eligible for a driver's license and 7 million of these individuals will be 85 or older (Special Committee on Aging 1987, Table 1-2). In contrast to the growing need to improve licensing practices in anticipation of an aging population, states are beginning to reduce the requirements for driver screening at license renewal. States are experimenting with mail-in renewals and longer periods between renewals as cost-saving measures (Waller, Vol. 2, p. 81).

Driver-licensing programs now have a limited capability to screen out drivers who are at a higher risk of accident involvement. Increased accident risk can result from many performance characteristics for which valid, cost-effective tests have not been developed. In part because of the inability to predict driving performance on the basis of tests of skill and knowledge (such tests do not yet exist), state licensing procedures have long relied on specific points to demarcate the age at which a person can become a driver but not the age at which a person is too old to drive. As noted in Chapter 4, age is not a good predictor of ability when individual older persons are considered. Although performance decrements are more common in later years, little research and experience with screening older drivers is available to guide the states in developing sensible programs.

A few states have begun to pay more attention to practices for licensing older persons. Oregon and Washington, in particular, are in the process of developing programs that may well prove quite beneficial (Malfetti et al. 1988). Oregon, for example, has begun providing special training for license examiners on identification of license applicants of any age who might have an impairment that would affect their driving. In addition to routine screening, these individuals may be asked to take a driving test to allow the examiner to determine their driving ability more precisely. Special counseling is also available to these drivers. Counselors trained in working with older persons arrange visits to homes, assess the mobility needs of the older person, and even offer coaching on how to improve shortcomings identified on the road test. The program is geared to maintaining the privilege to drive based on the needs of the older person. Nonetheless, some restrictions may be imposed as to when and where the person may drive, and drivers who have received restricted licenses are also closely monitored.

State programs such as these should experiment with other ideas that may improve the driving skills of older adults. For example, information about driver retraining programs offered to older adults could be provided as part of the license renewal process. These programs are available through organizations such as the American Automobile Association, American Association of Retired Persons, and the National Safety Council. In many states older persons are eligible for an insurance discount upon completing such a program (McKnight, Vol. 2). License renewal applicants could also be given a driver self-assessment inventory. This inexpensive learning device is presented as a short questionnaire designed to encourage drivers to rate their own performance, assess their ability to perform certain tasks, and learn how to reduce shortcomings (Malfetti and Winter 1986). Persons with declining skills could also be given information about alternatives to driving such as the specialized transportation services available in many communities.

NHTSA should support the further development of these pilot programs and support careful evaluations of how well they work.

To allow examiners to assess functional impairment, **the states should continue to require periodic in-person license renewal for all drivers. A four-year cycle is the most common period for renewal and should**

be continued until evaluation research indicates that a longer or shorter period between renewals is warranted.

Vision Screening

Vision provides the primary sensory input for driving. All states screen for static visual acuity (the ability to see stationary fine high-contrast details) at initial licensure, but only 41 states screen vision at renewal (Bailey and Sheedy, Vol. 2, p. 296). The most common standard for static acuity is 20/40, but 16 states deviate from this norm. Just over one-half of states screen for visual field.

On the basis of the recommendations made by Bailey and Sheedy and the similar recommendation made by the American Optometric Association in 1986, **all states should adhere to a static acuity screening standard of 20/40 for drivers with corrected vision with both eyes open. Drivers with static acuity between 20/40 and 20/80 should be referred for a vision test and, on the basis of the report by a qualified optometrist or opthalmologist, should be considered for a restricted license. License bureaus should also screen for loss of visual field. Drivers with a field of view in the range of 45 to 70 degrees to either side of fixation should be required to install special mirrors to partially compensate for the loss of peripheral vision. Drivers should be screened for static acuity and visual field both at initial licensure and upon renewal.**

The cost of visual field screening for all drivers, however, could be high. For example, assuming that each year one-fourth of the 162 million licensed drivers would be screened for visual field loss with a procedure requiring 2 min per eye, a total of 2.7 million personnel hours would be added at an annual cost of roughly $45 million a year. A simpler, and quicker, screening procedure could be developed, however, that would require less time. In addition, because the incidence of visual field loss is four to five times greater in the population over 60, most of the benefits would result from screening older drivers only (Johnson and Keltner 1983). For this reason, states might choose to screen drivers 60 and over for visual field loss at the license-renewal stage (every four years). The components of a visual field screening test are outlined by Bailey and Sheedy in Volume 2. The higher cost of more extensive screening could be recovered through license fees.

Medical Advisory Boards

Medical Advisory Boards, made up of specialists in fields such as neurology, cardiology, and vision care, assist driver-licensing bureaus in identifying individuals with impairments that adversely affect their driving. Although all states once had Medical Advisory Boards, many have dropped them or allowed them to cease functioning. As was pointed out in Chapter 4, individuals age differently, and driving skills may diminish because of a broad array of cognitive and physiological changes. Individual license examiners are not prepared to assess whether the health of an individual warrants a restriction on his or her license, but they can be trained to refer drivers for this kind of assessment.

Medical Advisory Boards could play an important role in preparing for an aging driving population. They could cooperate with NHTSA and the American Association of Motor Vehicle Administrators in developing better criteria for assessing functional performance and assist in the development of a review process that protects individual older drivers and the public. Before taking on this task, Medical Advisory Boards should augment their expertise by adding geriatricians and gerontologists. **An evaluation should be conducted by NHTSA to assess the causes for the decline of Medical Advisory Boards, to recommend steps to reinstitute and reinvigorate them, and to evaluate their potential for assisting in licensing procedures for older drivers.**

Research Needs

Vision

Burg's major research effort on vision and driving in the 1960s identified a wide variety of visual skills that potentially relate to driving performance. Static and dynamic visual acuity were shown to have small but statistically significant correlations with accident involvement. Static acuity is screened by all states in licensure, but research in two specific areas is needed to improve current practice. First, the illumination level used in screening devices is well below the illumination typical of daytime and is frequently well below the level at which acuity improves with illumination. Because of the diminished amount of light reaching the retina of the older eye, older drivers show a deficit in tested acuity that underrepresents their actual daytime acuity (Schieber, Vol. 2, p. 371). **A research project**

should be funded to establish a normal illumination (photopic) acuity standard for screening devices that is free of such age bias. This research would help establish a screening standard more appropriate for daytime driving.

Second, Shinar's follow-up research on Burg's work showed that static acuity under low illumination was the measure most related to accident involvement (Kline 1986). Screening for acuity under low illumination, therefore, would help identify drivers (both young and old) with problems driving at night. **A specific research project should be funded by either NHTSA or the National Institute on Aging to develop an appropriate illumination level and screening procedure.**

Bailey and Sheedy also note the early research correlating dynamic visual acuity (the ability to discriminate detail in moving objects) with accidents (Vol. 2, p. 301). Because a driver needs to detect and identify moving objects—often large, low-contrast targets—visual abilities that are dynamic in character appear to be more closely related to safe driving than static acuity. In dynamic visual acuity, however, the actual level of acuity measured depends on smooth pursuit eye movements in relation to target speed. Thus it may not prove to be the best measure of the dynamic visual skill needed for driving. Dynamic contrast sensitivity appears to provide more information about an individual's dynamic visual performance than does dynamic visual acuity because it assesses the ability to detect objects of all possible sizes and can be assessed with and without pursuit eye movements. **A research project is needed to develop (1) a standardized test for dynamic visual tasks (dynamic visual acuity and dynamic contrast sensitivity), (2) a validated procedure suitable for screening on a mass scale, and (3) normalized data on a large population.**

Measures of contrast sensitivity—the ability to distinguish differences in contrast at a given distance—might serve as a useful screen to identify individuals who have difficulty detecting low-contrast targets (pedestrians at night, for example) and those with visual disorders more common among older persons (cataract and glaucoma), which are unlikely to be detected in static acuity screening (Schieber, Vol. 2; Committee on Vision 1985). **Specific research on contrast sensitivity is needed, however, to assess the accuracy of the tests, to select the appropriate test to use in mass screening, and to develop normalized measures for the population.**

Sensitivity to glare is another visual function that changes with age. Mortimer's analysis of headlight design in the United States shows that some designs currently permitted on vehicles cause high levels of glare due to reflected light in rearview mirrors (Vol. 2, p. 386). Bailey and Sheedy, along with Schieber, recommend development of measures of glare sensitivity (Vol. 2, p. 322). **A specific research project to develop a standardized test of glare sensitivity and normalized data for the population should be conducted.** This research would aid in design of headlights and day-night mirrors, and in screening drivers.

State-of-the-Art Technology

Microcomputers and videodisk technology have advanced to the point where they could be used to conduct both knowledge tests and vision screening (Schieber, Vol. 2, p. 361). Microcomputers could also be used to screen drivers to ensure that their perception-reaction times are within the 2.5 sec assumed in highway design. **Development of the necessary software and hardware should be encouraged by NHTSA and the cost-effectiveness of this technology should be evaluated.** These technologies could also be used to collect the data needed to develop validated tests for visual characteristics related to safe driving.

Cognitive Performance

Visual performance is only part of driving. Cognitive performance is critical for the recognition and decision phases of driving. Older persons tend to process information and solve complex problems more slowly than younger ones, but at this time there are no valid tests for screening drivers with slow cognitive performance and little evidence that training can help these drivers compensate (McKnight, Vol. 2, p. 106).

Basic research is needed in the cognitive area, in large part because many elements of highway design and operation are based on the assumption that most individuals can perform the perception-reaction task at a given speed. Much of the research done in the past and in recent years used small samples that included few older persons, if any. Those selected were readily available volunteers, who may not be representative of the older population. If a large and growing share of the population is unable to perform at the levels assumed in design, then the design or operation of the system has to be changed. Unfortunately, at this time it is not known how well current design assumptions fit the population of current or future drivers.

The National Institute on Aging or the Department of Transportation, or both, should fund more basic research on how performance related to driving, such as attentiveness, information processing, and problem solving, is distributed across the population of drivers. The consequences of mild memory losses and dementia for safe driving should also be examined, and a study should be conducted to determine the potential hazards caused by the use of multiple prescription drugs by older drivers. Research in this area should pay special attention to the heterogeneity of the older population and should design sampling procedures to obtain representative samples of the older population of drivers.

IMPROVING ALTERNATIVES TO THE AUTOMOBILE

Some older people are unable to rely on private automobiles because of some disability, income, or a combination of physical factors that accompany advanced age. Because of the aging of the population, the number of such persons is growing. Aside from the private automobile, other modes account for a small but important share of all trips by persons over 60 (Rosenbloom, Vol. 2, p. 48). For example, for those aged 80 in rural and urban areas, the most frequently used mode of travel after the automobile is walking.

Walking

Walking is as important to older persons as a means of exercise as it is a means to visit friends or to shop. Demographic trends indicate that the proportion of older persons residing in suburbs and exurbs has exceeded 50 percent and is still growing. Walking is more difficult outside urban areas for a variety of reasons. In low-density residential areas, trip lengths are obviously much longer. Many suburbs and exurban residential areas do not have sidewalks. Design for shopping centers frequently assumes that all shoppers will drive to them rather than walk. Pedestrian crossings are frequently not available on suburban arterials, and signals are set to maintain a high volume of through vehicular traffic. The pedestrian environment should be enhanced to permit safer walking. **Communities should begin incorporating propedestrian features into site plans and zoning regulations. Land use planners, transportation planners, and traffic engineers should work cooperatively at the local level to evaluate and improve the pedestrian environment, especially in neighborhoods with high or growing concentrations of older persons.** Reports to guide planning for enhancing pedestrian facilities in suburban and developing rural areas have been published recently by NCHRP (NCHRP 1987a, 1987b).

After walking, three other alternatives are relied on by older persons in declining frequency of use: transit, taxis, and specialized transportation. Steps to enhance these modes in the short term are discussed below.

Public Transit

In many major metropolitan areas extensive public transportation systems provide alternatives to automobile travel. Although these systems are geared toward serving the journey-to-work trip, many older persons can and do use them to meet their mobility needs. Even so, only a relatively small share of urban trips by older persons are made on public transit (less than 9 percent of trips by persons over 60).

Physical disabilities are not the primary reason for low utilization of transit (Rosenbloom, Vol. 2, p. 50). The problem seems to stem from the orientation of large public transportation agencies, which is to serve the commuter. Wachs (1988) suggests that one disincentive to the provision of more service of special benefit to older persons by transit agencies is the half-fare policy required to receive federal funds. Because the agency can only earn half a fare for special service to the elderly, expansion of service to the elderly, even to those who could afford a full fare, returns less revenue than services to full-fare patrons. Even full fares only cover a portion of total operating costs; hence if an agency increases services for older persons, it may only increase its deficit.

A long-standing debate has raged over provision of service to the elderly and handicapped, the unsuccessful resolution of which also affects transit service for older persons (Wachs 1988). In the 1970 amendments to the Urban Mass Transportation Act of 1968, Congress declared that the elderly and handicapped had the same right to mass transportation service as other persons and that special efforts should be made to make service available. Heated arguments have taken place since that time over whether buses should be equipped with wheelchair lifts, how much such equipment costs, and whether the benefits are worth the costs. As Wachs (1988) points out, most older persons are not handicapped and therefore do not benefit from expenditures on wheelchair-equipped buses.

Taxis

Taxis account for an even smaller share of total trips (less than 2 percent for those over 60) than transit. Nevertheless, taxis provide an important option for many older persons and are often relied on for trips to receive medical care. The biggest barrier to more reliance on taxis by older persons is the expense. To expand service to older persons, however, subsidizing rides in taxis is far less expensive than expanding public transportation service (Rosenbloom, Vol. 2, p. 51). **Communities considering expansion of alternative modes of transportation for older persons should consider subsidizing private taxi operators as an alternative to expanding conventional transit service.**

Outside major metropolitan areas, transit and taxi service are not widely available. In these areas, the primary alternative to the private automobile is small-scale (and infrequent) forms of specialized transportation.

Socially Provided Transportation

As more people reach advanced age—demographers predict 8.5 million persons 85 and over within 4 decades—provision of transportation services for this group will become more important. Three different types of socially provided transportation are currently provided to older persons: (1) informal arrangements between private individuals, (2) formal service by public and private human service agencies, and (3) formal service provided by transit agencies. Information about the first type is lacking, but, given the large share of total trips by older persons made as passengers in private automobiles, it probably constitutes a major transportation option available to older persons. The latter two forms of socially provided transportation are often referred to as specialized transportation.

Specialized transportation is provided by myriad providers in myriad forms. The complexity of specialized transportation results partly from the many federal and state programs that support such services. The General Accounting Office has estimated that 114 different federal programs help to provide transportation service to disadvantaged and vulnerable persons (Rosenbloom, Vol. 2, p. 53). More than half of these programs are funded by the Department of Health and Human Services and three are funded by the Urban Mass Transportation Administration.

Less than 16 percent of those over 65 used specialized transportation services in 1983 (Rosenbloom, Vol. 2, p. 59). The users of these services tend to be individuals without driver's licenses, living alone, without regular access to an automobile as a passenger, and with very low incomes. Many of the users of these services, however, have other options and rely on specialized transportation for very specific trips.

Because many providers of specialized transportation are not in the transportation business, their service tends to be irregular and inefficiently provided. These trips are expensive: a one-way trip ranges from $4 to $18 for ambulatory elderly persons; the cost for nonambulatory older persons is twice as high (Rosenbloom, Vol. 2, p. 58).

Federal policy in recent years has focused on improving coordination in the delivery of services to reduce the duplication across programs. In 1986, the Secretaries of Transportation and Health and Human Services signed a letter of agreement to coordinate services funded by the two agencies. Part of the agreement calls for research and monitoring of coordination at the local level by a coordinating council. This cooperation is important to encourage more efficient and better services. **The Secretaries of Health and Human Services and of the Department of Transportation of the incoming administration should renew and reemphasize their agreement to coordinate transportation services and to monitor this coordination at the local level.**

Given the extensive amount of experimentation with specialized transportation under way, more systematic evaluation should be taking place to improve services and to transfer information about successful practices and models to other providers. The cooperative agreement between the Department of Health and Human Services and the Department of Transportation is but a first step in this direction.

Nontraditional means of enhancing specialized transportation should be experimented with and evaluated. For example, trips provided through volunteer and family networks (which might be supported through subsidies at a lower cost than those for expanding public transportation), carpooling among older persons, and greater use of private providers (e.g., taxi operators) should be encouraged. **The needs of the older population vary from place to place, and regional planning organizations should be developing plans specific to their communities. In addition, the Administration on Aging, together with the Department of Transportation, should fund research that documents exemplary practices to help local governments develop services appropriate for the older persons in their communities.**

Research on Mobility and Aging

Older persons' well-being in later years depends on their ability to meet their own needs (Carp, Vol. 2, p. 16). Mobility is essential to such self-sufficiency, but in our complex and decentralized society mobility can be difficult to maintain. Research is needed to better understand the extent and nature of the problems older persons face: how many older people live independently but are stranded in their homes because they lack adequate access to automobiles? How does the size and nature of the problem differ across urban, suburban, and rural communities? What are the most effective transportation alternatives for those unable to rely on private automobiles?

Threats to independence of older persons exist for other reasons than lack of access to an automobile. Research on transit crime, for example, indicates that the fear of being mugged on the way to the bus stop (often quite justified) directly affects the ability of older persons to maintain mobility (Levine and Wachs 1986). Carp's early survey research of older pedestrians indicated that they dreaded aggressive motorist behavior (Carp 1971). Retirees had high levels of fear when crossing busy intersections and high levels of hostility toward motorists who encroached on pedestrian crossings.

Research on the travel behavior (and barriers to travel) and the perceptions of older persons is essential to better understanding the diversity of their mobility needs. Wachs (1979) has shown, for example, that in Los Angeles the travel behavior of older persons is better explained by lifestyle characteristics than by age; **this case study should be replicated in other urban areas to explore these concepts further.** These areas call

Retirees have high levels of fear when crossing busy intersections and high levels of hostility toward motorists who encroach on pedestrian crossings (*photograph by Herbert A. Pennock, TRB*).

for interdisciplinary research among gerontologists, psychologists, and transportation specialists.

ORGANIZING RESEARCH TO PREPARE FOR THE FUTURE

Review of the many agencies, levels of government, and other groups responsible for implementing the recommendations made in this chapter highlights one of the basic problems impeding progress. Responsibility for improving the mobility and safety of older persons cuts across different federal agencies (Health and Human Services, Transportation), different administrations within those agencies (National Highway Traffic Safety Administration, Federal Highway Administration, Urban Mass Transportation Administration, Administration on Aging, National Institute on Aging), and all levels of government.

In the three agencies supporting research most directly related to safety and mobility for older persons—the Federal Highway Administration, the National Highway Traffic Safety Administration, and the Administration on Aging—research funds directly addressing the transportation needs of older persons amounted to but $700,000 annually in recent years (Appendix C). These projects are vital and will prove very useful, but are, nonetheless, on a small scale.

Several foundations, such as the American Automobile Association Foundation for Traffic Safety and the American Association of Retired

Persons Andrus Foundation, are and have been quite active in supporting research related to the mobility and safety of older persons, but relatively little discussion about research priorities appears to be occurring among governmental and private sponsors of research.

In addition to the scattered responsibilities for research at the national level, major associations such as the American Association of State Highway and Transportation Officials, Motor Vehicle Manufacturers Association, the American Association of Motor Vehicle Administrators, Highway Users Federation, and other organizations representing older persons directly influence the implementation of policy and research programs through the activities of their members. Preparing for the transportation needs of an aging society is important to all these agencies, levels of government, and associations, but is not at the top of their agendas for action. The recommendations of earlier reports on the mobility and safety needs of older persons have languished for precisely this reason.

A group should be formed to follow up on the recommendations made in this report and to identify and stimulate the research needed to address the transportation needs of an aging society. Such a group might take the form of a committee operating under the auspices of the Transportation Research Board. Its mission would consist of

- Bringing together high-level officials and professionals involved in the different dimensions of implementation to discuss progress on an annual or semiannual basis,
- Sharing information about ongoing research by sponsoring meetings of agencies funding the various aspects of the demonstration and research programs,
- Raising awareness by providing presentations for meetings of professional and consumer organizations,
- Issuing reports or articles on an occasional basis to keep the issue in the public eye, and
- Serving as a center of information on reports, applied research, data, and resources for meeting the mobility and safety needs of an aging society.

This continuing presence need not be expensive or permanent. Having the many agencies involved provide modest grants to support a small staff would cover the cost. Probable sponsors include the Department of Transportation, Department of Health and Human Services, Veterans Administration, American Association of Retired Persons, various private organizations, and foundations concerned about the implications of an aging society. The role of the group might evolve over time to address a broader range of transportation issues than could be addressed in this study.

Concern about the mobility and safety of older persons has increased in recent years, as witnessed by the growing awareness of the implications to society of our aging population and the request by Congress for a study directly focused on the transportation problems faced by the older members of society. Adoption of the recommendations made in this report by the various federal, state, and local agencies; private organizations; and national associations that directly influence the mobility and safety of older persons will be a major step toward improving the quality of life of older citizens.

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APPENDIX A

Estimated Travel by Age Groups

The total miles driven and the total miles traveled by different age groups can be used to compare exposure to risk in highway travel. Estimates of travel by age group, however, are not collected frequently. The Nationwide Personal Transportation Study (NPTS), conducted for the Department of Transportation by the Bureau of the Census in 1969, 1977, and 1983–1984, is the only national source for estimating travel by age group. The study is a home interview survey of 6,400 households. Among other questions, household members 16 or older were asked about daily trips as drivers and passengers and annual miles driven. There were 17,400 individuals interviewed in 1983 and 1984, 1,900 of whom were 65 or over.

In order to calculate total miles driven by each age group, the percentage of the total population in each age group that has a driver's license is multiplied by the average miles driven by each age group (Table A-1). The population estimates in Column 2 of Table A-1 are from the Census Bureau [1984, Table 6 (mid-range estimates)].

The percentage of each age group with a driver's license is derived from the weighted results of the NPTS as calculated from the data tapes. These data correspond fairly closely with state reports submitted to FHWA (1983) (Table A-2). The NPTS estimates are 4 to 6 percentage points below those of FHWA, except for drivers 16 to 19 and drivers over 70. For

TABLE A-1 ESTIMATED MILES DRIVEN BY AGE FOR 1983

Age Group	Population (thousands)	Percent Licensed, 1983	Average Miles Driven (thousands)	Total Miles Driven (millions)
16–19	15,624	62	4,985	48,445
20–24	21,871	85	10,339	191,527
25–29	21,170	89	11,810	221,566
30–34	19,070	89	12,126	206,592
35–39	16,278	90	12,662	186,243
40–44	13,171	89	13,015	152,444
45–49	11,175	88	11,805	115,932
50–54	11,144	84	10,936	102,432
55–59	11,463	85	9,443	91,803
60–64	10,734	84	8,568	77,281
65–69	9,005	75	6,804	45,738
70–74	7,352	68	4,750	23,586
75–79	5,263	54	4,821	13,679
80–84	3,264	43	2,615	3,668
85+	2,512	22	1,053	578
				1,481,516

SOURCE: NPTS data tapes and Census Bureau (1984, Table 6).

TABLE A-2 COMPARATIVE ESTIMATES OF LICENSED DRIVERS

Age Group	NPTS Estimate (%)	FHWA Estimate (%)
16–19	62	59
20–24	85	92
25–29	89	96
30–34	88	96
35–39	84	95
40–44	89	93
45–49	88	93
50–54	84	91
55–59	85	88
60–64	84	84
65–69	75	79
70+	54	55
70–74	68	
75–79	54	
80–84	43	
85+	22	

SOURCE: NPTS data tapes and FHWA (1983, Table DL-20).

TABLE A-3 ESTIMATED TOTAL MILES TRAVELED AS DRIVERS AND AS PASSENGERS

Age Group	Miles Traveled (millions)
16–19	101.3
20–24	312.2
25–29	341.9
30–34	295.4
35–39	288.7
40–44	228.7
45–49	180.8
50–54	168.0
55–59	163.5
60–64	120.6
65–69	84.6
70–74	44.3
75+	51.8

SOURCE: NPTS data tapes and FHWA (1986, Table E-100).

younger drivers the NPTS estimates are slightly higher. If the FHWA data are better estimates, use of the NPTS estimates may slightly overrepresent the amount of travel by this age group. For drivers 70 and over the estimates are within a single percentage point. FHWA, however, does not have estimates broken out separately for age groups over 70. For this reason the NPTS data are used in deriving total travel estimates.

The average miles driven by each age group (Column 4 in Table A-1) is estimated from the answers given in the NPTS and is taken directly from the NPTS data tapes. The total miles driven is simply the product of Columns 2, 3, and 4, which is expressed here in millions of miles.

The estimate of total miles is 1.48 trillion. This corresponds well with the FHWA estimate of total passenger-vehicle miles for passenger cars and single-unit trucks for 1983, which is 1.57 trillion (FHWA 1983, Table VM-1). Given that the FHWA estimate is derived in a totally different manner (based on registered vehicles, fuel sales, and estimated fuel efficiency), the correspondence between the two estimates is quite reasonable.

In order to calculate total highway miles traveled by age groups as drivers and as passengers (Table A-3), the NPTS data (FHWA 1986, Table E-100) on percentage of trips as drivers and as passengers were used. These tabulations, however, end at age 65 and above. Data to calculate travel by older age groups were extracted from the NPTS data tapes. The total highway miles traveled was calculated by multiplying Column 5 in Table A-1 by the ratio of miles traveled as a driver to total miles traveled as estimated in the NPTS.

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APPENDIX B

Technology Development

This appendix presents a brief overview of potential new technology that may aid future older persons in their vehicle and on the roadway.

New technology has improved vehicle safety and increased individual mobility. During the past 50 years engineers have continually improved the automobile's engine, transmission, suspension, and crashworthiness. Occupant protection has increased with the universal installation of safety belts and safety windshields. Improved braking and handling abilities have improved driver performance. In the coming years, installation of air bags will further reduce injuries and fatalities.

Technological improvements will continue. The automated highway, where the occupant is chauffeured by vehicle technology, is receiving renewed interest, although it remains a distant vision (MVA Systematica 1987). In coming years drivers will have better information on route conditions and new techniques for displaying this information. On-board computers will monitor driver and vehicle performance. Technology may also play an active role in controlling the vehicle in an emergency situation.

In the near future, electronics may provide new types of assistance to drivers. Ambitious European and Japanese projects have been launched to develop route guidance systems. In one scenario, drivers will receive up-to-date information on traffic conditions, construction delays, parking availability, and weather. This information will assist the driver in route choice and other decisions. The 14 major European automotive companies are behind a European project called Prometheus. "The aim of Prometheus is to increase the efficiency and safety of traffic by utilizing computer assisted driving and traffic management without going for the automatic highway," according to Karlsson (1988, 4). Demonstration projects in Berlin and London will apply guidance technologies to a limited number of cars. Infrared beacons will track vehicle location while drivers transmit destinations and receive route information. A Japanese project called AMTICS uses radio transmissions to relay current information to the driver.

American research in this area is not yet on the scale of the European or the Japanese research, but U.S. manufacturers have pursued these technologies in the past. Automobile manufacturers have been involved in developing driver information systems and route guidance systems since the early 1950s. Companies experimented with AM radios for transmitting messages on emergency road conditions (FHWA 1987). Researchers were also developing sensors to warn drivers when their vehicle deviated from the highway lane. The first comprehensive motorist information system, developed in the 1960s, used polarized magnets embedded in the roadway to advise motorists of speed limits, unusual geometric features, and static routing requirements. In 1985 General Motors investigated the use of an on-board mapping system.

Though the research projects mentioned earlier aim to provide drivers with better information, a major safety issue is the driver's ability to cope with this information while driving. Video screens used to display route information may interfere with the driver's concentration on the road, increasing the possibility of an accident (MVA Systematica 1987). Because of this safety problem, researchers are developing technology to give vehicle information in new formats. A "heads-up display" will project essential operating information, such as vehicle speed, onto the car's windshield using holographic techniques (Rivard 1987). In place of a visual display of information, a voice synthesizer could bring the driver's attention to problems with vital vehicle components. These techniques allow the driver's complete concentration to remain on the road while he receives important information on the car's performance.

Research has extended beyond guidance systems and into methods for actively controlling the vehicle. For many years researchers experimented with radar technology to detect oncoming collisions, but the results have yet to be encouraging (Jurgen 1986). Systems regularly warn of nonexistent dangers and fail to warn of actual threats.

Technology can enhance even the most basic information source for the driver, his vision. For example, under adverse conditions an infrared camera can project a picture unobscured by headlight glare, dense fog, or low lighting. This technology will help the driver to see far beyond the range of his headlights (Holusha 1987). Even at night the driver will be able to see distant curves, pedestrians, or animals in the roadway hidden by fog or rain. Automotive companies are testing this technology with various display techniques. For example, using a hologram embedded in the windshield glass, drivers can see an enhanced frontal view of the roadway. In this approach, however, the driver must restrict his head movement to 1 or 2 in. for clear resolution, which is too limiting for most drivers. A video screen mounted in the instrument display panel is favored by GM researchers for displaying the infrared picture. The driver refers to this picture when his forward vision is obscured.

In the near future, older drivers will benefit from other vehicle modifications that improve driver vision, especially at night when glare is a major problem for older drivers. Automobile designers are developing a day-night rearview mirror for the driver's door to enhance the view of following traffic and reduce glare. Switching headlights from high to low beams dramatically reduces the distance illuminated. Researchers are working on a mid-range beam that illuminates farther than the low beam without creating excessive glare. Other technology, such as headlamp washers developed and used in other countries, awaits introduction in the United States (Mortimer, Vol. 2).

The aging of the population is fast becoming widely recognized. Automobile manufacturers are already responding to these changes. For example, American manufacturers have arranged for older persons to meet with design engineers to discuss potential design changes and to test prototypes.

Technological improvements in the future will place less of a burden on the driver for safe operation of his vehicle. Research efforts on highway automation continue to take incremental steps both in the United States and abroad. Implementation, however, remains in the distant future. The vehicle and highway in the year 2020 will be different in ways that can only be speculated about now. For the upcoming decades, however, the highway system and automobiles will not be radically different from what exists today. Research will continue to be critical for identifying cost-effective adaptations to the current system to meet the changing needs of an aging society.

Automotive designers and engineers are recognizing the importance of accommodating the needs of older persons. Efforts to reduce glare for the driver or improve lighting at night will especially assist older drivers. Long-range research efforts may automate components of driving such as emergency braking. Electronic vehicle guidance systems may be developed to increase highway capacity but will also improve mobility and safety for drivers with diminished capabilities. Information technology may add dramatic improvements to the highway system. These improvements, however, will occur in small, incremental steps over many decades. As described in Chapter 5, many steps can be taken today that will benefit older people in the near term.

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APPENDIX C

Research Activities

Research on the transportation needs of older persons is a new area of inquiry, but interest increases with each new population forecast. Nonetheless, research publications and funds are still quite limited.

This appendix examines research activities and expenditures by the federal government and by private foundations. In the first section six federal agencies are described that work either to improve the transportation system for older people or to improve the ability of older people to use this system. In the second section are listed private, nonprofit foundations that support programs aimed at helping older persons lead active, independent lives.

PUBLIC AGENCIES

Research related to the mobility and safety of older persons is scattered across several federal agencies. Agencies within the U.S. Department of Transportation support research to improve the safety of all highway users. Agencies within the U.S. Department of Health and Human Services support activities specific to older people but usually examine mobility in terms of activity within the home. The Veterans Administration conducts research aimed at disabled veterans, which of course includes many older persons. Some research projects are cosponsored by several agencies, but in general the agencies do not coordinate their activities with one another.

The Federal Highway Administration (FHWA) had a total research and development budget of $45.5 million in 1986 (Table C-1). Of these funds, $14.7 million were for highway safety research, divided into three general categories: safety design, traffic safety research, and traffic systems (NSF 1988). The Safety Design Division supports research on geometric design, roadside hardware, large-truck safety, and the cost-effectiveness of safety programs. The Traffic Safety Research Division funds research to evaluate and improve traffic control devices and addresses the needs of special highway users. The Traffic Systems Division is responsible for human factors research. This division conducts safety research on night driving, methods for improving driver guidance information and communication systems, and the concept of the automated highway.

FHWA is currently sponsoring two studies that review the adequacy of design standards as they relate to the needs of older persons. The project, titled Traffic Control Design Elements for Accommodating Drivers with Diminished Capability, will determine whether the older driver is being

TABLE C-1 FEDERAL RESEARCH AND DEVELOPMENT, 1986 (NSF 1988; OMB 1987)

		Research and Development ($ thousands)			
		Research			
Agency[a]	Total Budget[b] ($ thousands)	Applied	Basic	Development	Total
Federal Highway Administration	14,379,900	14,700	–	30,800	45,500
National Highway Traffic Safety Administration	219,100	16,100	–	6,300	22,400
Urban Mass Transportation Administration	4,159,600	–	–	8,200	8,200
Veterans Administration	27,075,100	155,100	14,800	16,300	186,200

[a]Information on research and development spending by category is not available for the National Institute on Aging and the Administration on Aging. The total budget for the National Institute on Aging is $149.8 million and for the Administration on Aging, $671.3 million.

[b]Program level.

adequately accommodated by current traffic control design criteria (*Public Roads* 1987). The estimated cost of this project is $285,000 and is supported for about 2 years. A second project has produced an updated manual to improve pedestrian access to the transportation network for the elderly and disabled user. This project received $72,000. FHWA also provided technical assistance to the American Association of Retired Persons in the development of a safety program for older pedestrians.

The National Highway Traffic Safety Administration (NHTSA) spent $16.1 million on applied research and analysis in 1986 (Table C-1). NHTSA's research focuses on improving vehicle crashworthiness, accident avoidance characteristics of motor vehicles, safety belt use, and alcohol countermeasures. Other activities include the collection and analysis of data on highway safety problems. The Office of Driver and Pedestrian Research has two divisions: Driver/Passenger Systems Research and Problem-Behavior Research. The annual research budget of this office is about $2.7 million, divided evenly between the two divisions. The Driver/Passenger Systems Research Division plans and conducts research programs aimed at improving driver and passenger safety through education, training, and licensing and postlicensing control techniques. The Problem-Behavior Research Division emphasizes driver-pedestrian-bicyclist behavior as it relates to traffic safety. This division's multidisciplinary approach incorporates knowledge from the fields of experimental and social psychology, human factors research, traffic safety law, education, and communications.

NHTSA spent $1.5 million on specific projects related to older persons in 1987. This support went to projects examining the effects of glare, the benefits of the high-mounted brake light, and the dangers of driver inattention. The agency is working with FHWA and the National Safety Council to develop an educational program on pedestrian safety, including a pamphlet specifically for the older pedestrian, and with the American Association of Motor Vehicle Administrators to conduct workshops for older drivers. In addition, NHTSA will set aside funds in 1989 to implement applicable research recommendations from this TRB Special Report.

The Urban Mass Transportation Administration (UMTA) had no funds allocated for research in 1986 and spent $8.2 million on development. The agency's total budget was $4.16 billion in 1986. UMTA does not have any current development projects directly related to older persons. Past efforts of this type included the development of wheelchair lift technology and the "kneeling" bus to assist boarding passengers.

The National Institute on Aging (NIA) spent $19.8 million in 1986 on its Intramural Research Program (OMB 1987). The most immediately relevant of NIA's many programs to issues of mobility is the Behavioral Sciences Research Program, which specifically focuses on prolonging the productive, healthy middle years of life. The program seeks to prevent or reverse such decrements of old age as memory loss, chronic ill health, sensory deficits, low self-esteem, and withdrawal from activities. NIA's studies are concerned with social, psychological, cultural, and economic factors affecting the process of growing old. Their research and training focus on the behavioral and social mechanisms that influence cognitive and intellectual functioning.

NIA extended research grants of $3.2 million to studies that involved issues of personal mobility, such as Aged Living Alone—Medical and Psychiatric Consequences; Age, Physical Fitness, and Information Processing Speed; and Age-Related Changes in the Visual Control of Locomotion. NIA supports many projects for improving the cognitive skills of older persons through training or redesigning the environment. These projects include studies to improve the visual processing of older adults, research on the long-term effects of cognitive training on the elderly population, and assessment of the performance of older adults under time pressure. Topics related to human factors and driving are now under consideration for future funding.

The Administration on Aging (AoA) spent $21.3 million on research, training, and discretionary programs in 1986 (OMB 1987). The mission of AoA is to improve the lives of older people, particularly the most socially and economically needy persons. Programs funded in 1986 emphasized assisting state and local agencies on aging to promote family- and community-based systems of care for vulnerable older adults. Past areas of research include social attitudes toward old age, community roles for older persons, housing preferences of older persons, and social services used by the aged.

AoA supports state educational programs that train older pedestrians and drivers. For example, the California Traffic Safety Project received $150,000 to educate adults over 55 years of age regarding vehicle and pedestrian safety. In addition to providing educational materials, this

California project is increasing the number of trainers, establishing a technical center to provide information to other organizations, and working with other senior-serving organizations to ensure that these activities continue. AoA supports a similar project in Florida, which also received $150,000. The Driver Retraining and Certification Program designed and developed a commercially marketable driver-retraining program. The program received $82,000 over a 2-year period from AoA.

The Veterans Administration research budget for 1986 was $186.2 million, divided among three services (OMB 1987). The Medical Research Service, which investigates the nature of diseases and their treatment, received almost 90 percent of these research funds. The Rehabilitation Research and Development Service focuses on rehabilitation programs, including prostheses for amputees, mobility support for the disabled, and aids for those with visual, hearing, and speech disorders. This service spent $14.3 million in 1986. The Health Systems Research and Development Division supports programs that improve the effectiveness and economy of health services delivery. It also seeks to improve the accessibility of services to veterans. Though the Veterans Administration does not focus on older persons, an increasing proportion of veterans are over 65. Many of its programs assist veterans in maintaining their mobility despite various disabilities. These efforts provide beneficial information to older nonveterans with similar disabilities.

PRIVATE FOUNDATIONS

In addition to federal research funds, private foundations support research on the needs of older people. Reviewed below are six of these foundations that assist older people to participate in diverse activities. These foundations are nationwide in their scope and interests. Many other foundations focus on the health care needs of older people.

The American Automobile Association (AAA) Foundation for Traffic Safety spent $600,000 in 1986 on research aimed at improving the driver's capabilities and safety performance. The foundation is a charitable research organization funded by voluntary contributions from AAA members in Canada and the United States. Their funding priorities evolved from the results of practical research applied toward safety programs. Projects supported by the foundation include the development of an older-driver vision diagnostic test using a computer, a study on physical fitness routines to improve the performance of the older driver, a report on safe and unsafe driving practices as revealed in self-assessment tests, and a number of studies on the licensing practices of state motor vehicle departments.

The Andrus Foundation of the American Association of Retired Persons distributed $1.3 million in 1986 for applied gerontological research (Herring 1987). The foundation supports projects that produce practical and usable products or information that assists older persons. Areas of interest include developing innovative programs to improve service delivery and establishing an information base for policy considerations. Research on coping and support mechanisms for older people and their caregivers, on the effect of retirement on income, and on issues concerning part-time employment of the older worker received support.

The efforts of several other foundations assist older people to live independently. The Commonwealth Fund made grants of $350,000 in 1985 to support programs to improve the well-being of elderly people living alone by reducing their isolation and improving their health care and financial status (Foundation Center Staff 1987). The fund established a Commission on Elderly People Living Alone to develop and manage research and demonstration projects. The Retirement Research Foundation provided $1.2 million in 1985 for community programs aimed at maintaining independent living for older and other disabled persons (Foundation Center Staff 1987). The Hartford Insurance Group funded an exhibit of a demonstration apartment designed specifically for an older person. The Villers Foundation awarded $280,000 in 1985 to projects that are focused on older citizens' financial and health status in society (Foundation Center Staff 1987). An example of their applied policy research was an assessment of Medicaid accessibility to rural patients.

SUMMARY

Implications for the transportation system of an aging population are just beginning to be studied. The research effort has been small but is growing. Federal efforts so far have been on a small scale. The three most active federal agencies involved have spent about $700,000 annually over the last three years for projects specific to older persons. Other research under way will benefit older people but is not aimed at one age group. An example is research to reduce glare for drivers. A fourth federal agency spends about

$3 million annually in research on the personal mobility of older persons around their homes.

The current research effort to improve the mobility and safety needs of older persons is fragmented among federal agencies. The project with the broadest scope is FHWA's assessment of whether highway design elements accommodate drivers with diminished capabilities. NHTSA spends the most research funds on programs related to older drivers and pedestrians. With only $1.5 million expended in this area, however, NHTSA's program is limited to specific priority topics. AoA has committed $430,000 since 1985 to improving transportation for older persons. Ninety percent of these funds are for development programs to retrain older drivers or teach pedestrian and driver safety.

Private organizations fund numerous development and research projects related to maintaining independent living for older persons. In 1986 less than $2 million in foundation support went to research and development projects to improve the mobility of older persons.

Awareness and concern for the mobility needs of older persons are growing. Funds for research on the mobility of older persons cover very diverse topics and there is relatively little coordination among organizations. As research expenditures grow, the need for more communication across federal agencies increases. Federal and private funders have little opportunity to share their priorities with one another or to set a broad research agenda. One result to date has been an inadequate research base for public policy questions arising from growing concern about the mobility and safety of older persons.

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STUDY COMMITTEE

Biographical Information

James L. Malfetti, *Chairman*, is Professor of Education and Director of the Safety Research and Education Project at Teachers College, Columbia University. He received his B.S. from the College of the City of New York, and after service in the Navy, received his M.A. and Ed.D. from Columbia University. Dr. Malfetti has been Director of the Safety Research and Education Project since 1957; over the years he has served as consultant to national, state, and local organizations in the development of traffic safety programs. Recently, he was an Associate Fellow for Advanced Study in Gerontology and Geriatrics at the Andrus Center of the University of Southern California, chaired a panel addressing the needs and problems of older drivers, and edited the proceedings of the panel's discussion at the Older Driver Colloquium sponsored by the American Automobile Association (AAA) Foundation for Traffic Safety in 1985. Dr. Malfetti has authored numerous publications on education and traffic safety, and has served on several TRB committees involved with traffic safety, human factors, and driver education.

Merrill J. Allen is Professor of Optometry at Indiana University. He received his B.S. in optometry, an M.S., and a Ph.D. in physiological optics from Ohio State University. Dr. Allen began his career as a Research Assistant at Ohio State. During World War II he was a physicist at

Frankfort Arsenal in Pennsylvania and rose to the rank of Lieutenant Commander in the U.S. Naval Reserve. He returned to academia and became an Associate Professor and then full Professor at Indiana University; he was awarded Emeritus status in 1987. Dr. Allen has authored numerous papers and a book dealing with driver vision and with visibility problems of pedestrians and cyclists. He has conducted many research projects and also served as a panel member for the 1985 AAA Older Driver Colloquium. Dr. Allen also serves as a consultant to industries, attorneys, and governmental agencies.

William G. Bell is Professor of Urban and Regional Planning, Senior Research Associate, and former Director of the Institute on Aging at Florida State University in Tallahassee. He received his B.A. in sociology from Denver University, D.S.W. from the University of Toronto, and a Ph.D. in social welfare planning (gerontology) from Brandeis University, Waltham, Massachusetts. After three years with the State University of New York at Buffalo, he joined the faculty at Florida State, where he has been since 1969. Dr. Bell has concentrated on specialized transportation, both on a national and an international level, since 1971. He has coordinated 10 national conferences on specialized transportation under the auspices of Florida State University and chairs the planning committee for the 11th conference, to be held in 1988 under the auspices of TRB. Dr. Bell is Editor-in-Chief of the journal *Specialized Transportation Planning and Practice.* He serves as a member of several TRB committees and represented TRB on the Institute of Medicine Committee on an Aging Society, chairing the 1984 Symposium on the Social and Built Environment in an Aging Society. He is a Fellow of the Gerontological Society of America.

Daniel S. Brame is Vice President, Kimley-Horn and Associates. Mr. Brame's B.S. in civil engineering was earned at Vanderbilt University. He received his Master of Engineering degree from the University of South Carolina. He served as Planning and Roadway Aspects Manager for Atlanta, Georgia, and then became Acting Head of Traffic Engineering for Central Missouri State University. Mr. Brame served as Traffic Operations Engineer for Sioux City, Iowa, and as Deputy Director of Public Works for Transportation for the City of Orlando. He is president of the Florida chapter and an active member of the Institute of Transportation Engineers and of TRB.

Douglas M. Fergusson, who served for a year on the study committee before his death in August 1987, was Director of Safety Services for Nationwide Insurance Company. He received his B.A. from Ohio State and his J.D. from Cleveland State University. Mr. Fergusson had been with Nationwide since 1953. He began as an underwriter and became a safety specialist, rising to become Safety Officer in 1985. He was a member of the National Commission Against Drunk Driving; on the Board of Directors for the Highway Loss Data Institute; past Chairman of the Traffic Division, National Safety Council; and a member of the Safety Committee of the Society of Automotive Engineers.

Donald W. Kline is Professor and Head of the Department of Psychology at the University of Calgary. After receiving a Ph.D. in psychology with a specialty in gerontology from the University of Southern California, he was associated with the University of Notre Dame and Northwestern University. He is the author of numerous articles dealing with aging and vision and is one of the editors of *Aging and Human Visual Function* (with R. Sekuler and K. Dismukes). His work in human factors engineering has emphasized air traffic control, nuclear control room design review, and the impact of aging on driver and pilot performance. He was a member of the Institute of Medicine Study on Scientific Evidence Relevant to Mandatory Age Retirement for Airline Pilots and a member of Working Groups 55 (Aging and Visual Function in Pilots) and 59 (Aging Workers and Visual Impairment) of the Committee on Vision, National Research Council. Dr. Kline is a fellow of the Gerontological Society of America and a member of the Association for Research in Vision and Ophthalmology.

David A. Kuemmel is Commissioner of Public Works for the City of Milwaukee. He received his B.S. from Marquette University and his M.S. from the University of Wisconsin, both in civil engineering. He has worked for the City of Milwaukee since 1956, first as a civil engineer, then as a traffic engineer. He served as Assistant Superintendent of the Department of Public Works for 10 years before Commissioner. He is a fellow of the Institute of Transportation Engineers, the former Chairman of the

Signals Subcommittee for the National Advisory Committee on Uniform Traffic Control Devices, and is on the Executive Council of the American Public Works Association Transportation Institute. Mr. Kuemmel was named one of APWA's "Top Ten" public works directors for 1987.

Claire E. McKnight is Assistant Professor of the Department of Civil Engineering at the City College of New York. She received her B.A. in architecture from the University of Illinois at Urbana, her M.A. in urban planning and policy from the University of Illinois at Chicago Circle, and her Ph.D. in public policy from the University of Illinois. She worked as an architectural programmer for the City of Chicago and as a research assistant for the School of Urban Sciences and Research Associate at the University of Illinois. She has conducted several research projects and coauthored several articles on paratransit for the elderly and handicapped.

David E. Martin was Director of Automotive Safety Engineering for General Motors Corporation until his retirement in 1987. He received a B.S. in mechanical engineering and an M.S. in theoretical and applied mechanics from the University of Illinois. He joined the GM research staff as a Senior Research Engineer and was promoted to Assistant Head of Vehicle Research, directing studies in biomechanics, vehicle structural impact behavior, and accident-injury statistics. Mr. Martin is a member of Sigma Xi, Society of Automotive Engineers, and, formerly, of the American Association of Automotive Medicine.

Bernice L. Neugarten is Rothschild Distinguished Scholar and Professor Emeritus of the University of Chicago. She received a B.A., M.A., and Ph.D. from the University of Chicago, where she was Professor of Human Development with the Department of Behavioral Sciences and director of the graduate training program in aging until 1980. From 1980 to 1988 she was Professor of Human Development and Social Policy at the School of Education and Social Policy of Northwestern University. A former President of the Gerontological Society of America, she has served on the National Advisory Council of the National Institute on Aging, on the Federal Council on Aging, and as Deputy Chairman of the 1981 White House Conference on Aging. She received the Kleemeier Award (in 1971), the Brookdale Award (in 1983), and the Sandoz International Prize (in

1988) for research in gerontology. She is a member of the Committee on an Aging Society, a Senior Member of the Institute of Medicine, and a fellow of the American Academy of Arts and Sciences.

PAUL L. OLSON is Head of the Human Factors Group at the University of Michigan Transportation Research Institute (UMTRI). He received his B.S. in psychology from the University of Illinois and his M.S. in industrial and experimental psychology and his Ph.D. from Purdue University. He served as Research Fellow in the Department of Psychology at Purdue and as a Senior Research Psychologist in the GM Research Laboratories before becoming a Research Scientist at UMTRI. He has authored numerous articles dealing with lighting and visibility, traffic control, and perception and has conducted research comparing differences in abilities among age groups. Dr. Olson is a member of the Human Factors Society, TRB, and the Vehicle Lighting Committee of the Society of Automotive Engineers.

FRED C. SCHWENDIMAN is Director of Driver License Services of the Utah Department of Public Safety. He received his B.A. in sociology and business administration from Southern Utah State College and studied Criminal Justice Administration at the University of Virginia while attending the FBI National Academy, from which he was graduated in 1980. He served as Director of Administrative Services for the Utah Department of Public Safety before becoming Director of Driver License Services. Since 1975 he has also served as a part-time instructor in defensive driving for the National Safety Council. Mr. Schwendiman has served as the chairman of the Driver License and Control Committee of the American Association of Motor Vehicle Administrators.

MICHAEL SEATON is Director of the 55 Alive/Mature Driving Program of the American Association of Retired Persons. He received a B.A. in political science from Iowa Wesleyan College; an M.A. in association administration from Lindenwood College in St. Charles, Missouri; and has done graduate work at the University of Southern California. Mr. Seaton worked as a Research Associate for the Midwest Research Institute and has held several positions with AARP since joining their staff. In his current position he is responsible for designing, implementing, and administering AARP's driver education program.

Rachel Shrauner is Director of Cobb County Transit in Marietta, Georgia. She received her B.A. in economics from Oklahoma Baptist University and has done graduate work in transportation planning at Northwestern University Transportation Center and in traffic engineering at the Polytechnic Institute of New York. She has worked with the Metropolitan Transportation Authority of New York, with the San Diego Transit Corporation, and with the Southeastern Michigan Transportation Authority. She was Deputy Director for Metrobus Operation with the Metro-Dade Transportation Administration in Miami, Florida, before assuming her current position.

John D. States is Professor of Orthopaedics at University of Rochester School of Medicine and Dentistry and Chairman Emeritus of the Department of Orthopaedics at Rochester General Hospital. After receiving his M.D. from Harvard University, he interned and did a surgical residency at Rochester General Hospital. Dr. States was Orthopaedic Resident at Children's Hospital and at Massachusetts General Hospital in Boston. He is Past President of the American Association for Automotive Medicine and Past Chairman of the Crashworthiness Committee of the National Motor Vehicle Safety Advisory Council. He was Chairman of the New York Coalition for Safety Belt Use and a member of the AAA Older Driver Colloquium held in Orlando, Florida, in 1985. He is the author of numerous articles on automotive safety design for occupant protection and injury mechanisms and tolerances of the musculoskeletal system.

William F. Ventry, a professional engineer, is Deputy Assistant Secretary for Technical Policy and Engineering Services with the Florida Department of Transportation. He received his B.A. in management sciences from Florida A&M University in 1978. He began his career with the Florida Department of Transportation as a planner in 1971. Since then he has served as Chief of the Bureau of Value Engineering and as Chief of the Bureau of Right of Way. In 1984 he was appointed Director of the Division of Preconstruction and Design, a position he held until assuming his current one in 1985.

Martin Wachs is Professor of Urban Planning at the School of Architecture and Urban Planning, University of California at Los Angeles. After receiving his B.S. from City University of New York and his M.S. and Ph.D. from Northwestern University, he became Assistant Professor of Planning at the University of Illinois at Chicago Circle and then Assistant Professor of Urban Planning at Northwestern. Dr. Wachs is the author of many articles on urban transportation, public transportation, and statistical modeling. His book *Transportation for the Elderly: Changing Lifestyles, Changing Needs* was published in 1979. He is active in TRB, the American Planning Association, and other professional organizations.

Sam Yaksich, Jr., is Executive Director of the AAA Foundation for Traffic Safety. He received his B.A. from Miami University in Oxford, Ohio, and his M.A. from George Washington University. Mr. Yaksich has held various positions in the Traffic Safety Department of the AAA. During his career with AAA he has published several special studies on pedestrian accidents, one of which concerned older pedestrians. As Executive Director of the AAA Foundation for Traffic Safety, he has been responsible for the research and development of driver and traffic safety programs, including those directed at older drivers and pedestrians. Mr. Yaksich is also a member of the National Safety Council's Highway Traffic Safety Division.

The Transportation Research Board is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate the information produced by the research, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 300 committees, task forces, and panels composed of more than 3,500 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical mattters. Dr. Frank Press is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Robert M. White is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Samuel O. Thier is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Frank Press and Dr. Robert M. White are chairman and vice chairman, respectively, of the National Research Council.