

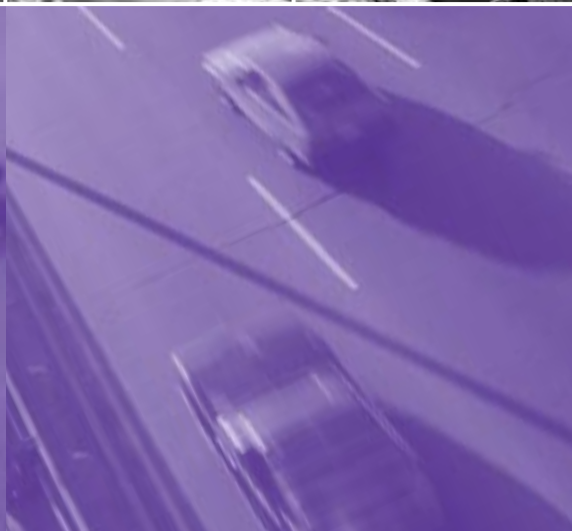
CONFERENCE PROCEEDINGS 27

# Transportation in an Aging Society

*A Decade of Experience*



Technical Papers and Reports  
from a Conference



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# Transportation in an Aging Society

## *A Decade of Experience*

Technical Papers and Reports from a Conference

November 7–9, 1999  
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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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# Preface

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The Transportation Research Board (TRB) Conference on Transportation in an Aging Society: A Decade of Experience, held in November 1999, grew out of a recommendation in TRB Special Report 218, *Transportation in an Aging Society* (1988), that an organization be formed to encourage, coordinate, and disseminate research, information, and programs on older-person driving and mobility. Although resources were not available to establish such an organization, John Eberhard of the National Highway Traffic Safety Administration (NHTSA) considered this an important activity and approached TRB about forming a group of volunteers to move forward in that direction. The results of that effort, which began 12 years ago, are the current TRB Committee on Older Person Safety and Mobility and the conference that is reported on in these proceedings.

The purpose of the conference was to review what had been accomplished in research and implementation since the publication of Special Report 218 and to identify future research and implementation needs for achieving safer mobility for older persons. Funding for the conference was provided by NHTSA; the Federal Highway Administration; the Federal Transit Administration; the Office of the Secretary, U.S. Department of Transportation; the National Institute on Aging of the National Institutes of Health; the National Center for Injury Prevention and Control of the Centers for Disease Control and Prevention; the Eno Transportation Foundation; the AAA Foundation for Traffic Safety; the Beverly Foundation; and TRB. The National Research

Council (NRC) appointed a committee, under the chairmanship of Richard Marottoli, to plan and conduct the conference, which was held on November 7–9, 1999, at the National Institutes of Health in Bethesda, Maryland (the full roster of conference participants appears on pp. 322–325).

The conference was organized around a series of background papers commissioned by the committee. Initial drafts of each paper were assigned to one of the following experts to peer review:

- Audrey K. Straight, AARP Public Policy Institute, Washington, D.C.;
- Katherine Freund, Katherine Freund Associates, Portland, Maine;
- Martin E. H. Lee-Gosselin, University of Laval, Quebec, Canada;
- Thomas A. Ranney, Liberty Mutual Research Center, Hopkinton, Massachusetts;
- Desmond O'Neill, Meath Hospital, Dublin, Ireland;
- Vivek D. Bhise, Ford Motor Company (retired), Dearborn, Michigan;
- Philip R. Oxley, Cranfield University (retired), Bedford, United Kingdom;
- Robert Dewar, Western Ergonomics, Inc., Calgary, Canada;
- Leo Tasca, Ontario Ministry of Transportation, Downsview, Canada; and
- Lauren Marchetti, University of North Carolina, Chapel Hill.

Final drafts based on the reviews by the assigned experts were prepared and presented at the conference. The conference included breakout sessions focusing on each of the background paper topics. Following the conference, paper authors revised their drafts based on comments heard at the conference and on comments from members of the conference committee. These revised papers, which were reviewed by the committee, form the chapters in this report.

Based on discussions in plenary and breakout sessions at the conference, the conference committee concluded that four topics had not been adequately covered in the original set of topics. As a result, additional authors were commissioned to prepare papers on pedestrians, land use, medical conditions, and alternative transportation concepts. The additional papers were reviewed and are included in this report.

Before the conference, two separate but related activities took place. First, Damian Kulash of the Eno Transportation Foundation prepared a draft “national agenda for older person mobility.” The agenda has been revised and modified several times since Kulash first presented it at the conference, and a summary and description of the most recent version, prepared by John Eberhard and Donald Trilling, is included in this proceedings. Second, a series of focus groups with older persons and older-person caregivers was held around the country. Based on these sessions, the user community perspective was brought to the conference. A summary of the focus group results—prepared and presented by the Beverly Foundation, which conducted the focus groups—is included in this report.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by NRC’s Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the charge. The review comments and draft manuscript remain confi-

dential to protect the integrity of the process. We wish to thank the following individuals for their review of portions of this report:

- Jon E. Burkhardt, WESTAT, Inc., Rockville, Maryland;
- Fred R. Hanscom, Transportation Research Corporation, Markham, Virginia;
- David L. Harkey, Highway Safety Research Center, University of North Carolina, Chapel Hill;
- Kenneth R. Stack, Stanwood, Michigan;
- Harold van Cott, Bethesda, Maryland; and
- Robert B. Wallace, University of Iowa, College of Medicine, Iowa City.

Although the reviewers have provided many constructive comments and suggestions, they did not see the final draft of the report before its release. The review of this report was overseen by Lester A. Hoel, University of Virginia. Appointed by NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. The views expressed in the papers and presentations contained in this report are those of the authors and do not necessarily reflect the views of the committee, TRB, NRC, or the sponsors of the conference.

Wholehearted thanks go to the sponsoring organizations and to the many individuals who contributed to the organization of the conference, participated in the conference, and assisted in the preparation of this report. Special thanks are due to Susan Herbel, who performed a technical edit of all of the chapters, and to the TRB Publications Office staff, who did the final edit of the manuscript and prepared it for publication.

**Richard A. Marottoli**  
Chair, Committee for the Conference on  
Transportation in an Aging Society:  
A Decade of Experience



# Data and Characteristics of Older Drivers

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# Mobility of the Elderly

## Good News and Bad News

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Sandra Rosenbloom, *The Drachman Institute, University of Arizona, Tucson*

Ten years ago there was clear evidence that for an aging population the future holds both great promise and extreme mobility challenges. Today the evidence for both possibilities is even more clear. By almost any measure, in the coming decades the elderly will have longer, happier, fuller lives than their counterparts today and certainly than the elderly of just a few decades ago. However, a 1996 Organisation for Economic Co-operation and Development (OECD) study surveyed the implications of global aging and commented:

The basic news is good. Increased longevity, good health and independence are key values in their own right. They are also a reflection of the underlying strength of social and economic issues . . . [but] there will be difficult transitional problems before that good news is fully realized. (1, pp. 5–6)

Some of these transitional problems in an otherwise promising situation arise from a growing gap among the elderly. Although many elderly will have substantial resources to confront their retirement years, a significant subset will not. Many will be active and healthy for decades after retirement, but an important group will not. Older women, in particular, may face far bleaker futures as they age. The news is not all good.

Almost every positive trend in aging over the last 10 years has contained at least a kernel of negative news. Older people today have more energetic, busy, and mobile lives. Mobility, defined principally as the trip rate

by all modes, includes walking and biking as well as driving and using the various other modes of transportation. Integral to their active lifestyle—and to many of the positive features of aging—is easy, convenient, and flexible access to a range of desired services and facilities. In the future when older people lose the ability or resources to engage in those activities, the drop in their well-being may be substantial and may have profound physical and psychological implications.

A direct cause of deterioration in the lifestyle of the elderly in coming decades will be declining mobility, that is, the inability to drive or to find satisfactory travel alternatives to access needed services and facilities. There is no evidence that older people's desire to travel will decline at the same rate as their ability to drive or to find other options. Many older people may ultimately find themselves cut off from the very aspects of life that made their early retirement years so much better than those of older people only a few decades ago.

This paper has seven sections that accomplish the following purposes:

1. Evaluate older people's population trends and analyze the demographic differences;
2. Identify basic travel patterns and trends among the elderly, including the dramatic increase in automobility and travel over the last 10 years;
3. Consider differences in the travel patterns of those with and without a driver's license;
4. Focus on women's travel and the still growing gender disparities as people age;



5. Evaluate differences in travel patterns by race and ethnicity (differences not generally explained by income or residential location);
6. Summarize the “bad news”; and
7. Outline positive steps to ensure that the good news about aging outweighs the bad.

For the entire 20th century, the growth rate in the number of Americans over age 65 has greatly exceeded the growth rate of the population as a whole. In 1996 the elderly population was 11 times larger than in 1900. The Bureau of the Census predicts that the number of senior Americans will more than double between 1996 and 2050—from 34 million to 78 million (2). But the sheer number of older people may not be as important as the substantial shift in the structure of the population. The American elderly now comprise a significant proportion of the total population. Where once the U.S. population looked like a pyramid, with many children and young people at the bottom and only a few older people at the top, today the population has “squared” itself because of the rapid growth in the proportion of the population over age 65.

There are two major reasons for the growth in both the number and percentage of older people. First, older people are living longer because of increased income, enhanced education, and improved medical care and public health interventions. In 1998 the average U.S. life expectancy was 76.1 years (3). Two hundred years before, at the country’s birth, it was less than half that. In fact, average U.S. life expectancy was below 50 years until the beginning of this century (4). Second, those of childbearing age are having fewer children. In spite of predictions to the contrary, fertility rates have continued to fall for the last 40 years (5).

Combined with demographic trends have been sweeping changes in the social, economic, and health status of the elderly. Older Americans are better educated and better housed than comparable older Americans just a few decades ago. They are more likely to be well-off economically and less likely to be poor. Until 1974, for example, the poverty rate of the elderly exceeded that of children. In the United States, the median income for elderly people more than doubled between 1957 and 1992 and the poverty rate was halved (6). Older Americans are also more likely to be healthy—a fact that is clearly linked to longer life expectancy. Chronic disability and institutionalization rates among the elderly have continued to drop, and death rates from heart disease, which is the major killer of the elderly, have fallen substantially since 1960 (6).

## DIFFERENCES AMONG THE ELDERLY

It is easy to see the good news in the basic demographic trends. But these trends (*a*) hide substantial differences between and among groups of older people in health, housing, medical, and economic status and (*b*) may contain a sort of time bomb that will go off as the baby boomers continue to age—an event with significant transportation implications.

First, as a 1995 Bureau of the Census report notes,

[t]he perception of “elderly” and “poor” as practically synonymous has changed in recent years to a view that the noninstitutionalized elderly are better off than other Americans. Both views are simplistic. There is actually great variation among elderly subgroups. (4)

There are significant groups of older people who live in poverty, ill health, and inadequate housing. Even older people who start from a position of privilege or well-being may face difficulties as they grow older or experience a major life change. The most profound impacts are often felt by women who are widowed, because they can move quickly into poverty or near poverty. Younger people frequently move in and out of poverty as they gain and lose jobs. Older people are less likely to fall into poverty, but once they do, they have few escape routes. As older people continue to age, their physical and medical condition may worsen. People once mobile may become dependent on others. People who once met their own needs independently may now need assistance. People who could once live alone may now need to move into special facilities.

Increasingly, many of those over age 65 will be very old—over age 80–85. In the United States, the number of those over age 85 grew 300% between 1960 and 1996—to 3.8 million people, comprising 1% of the U.S. population (2). By the middle of the next century, 1 in 20 Americans will be over age 85 (4). Not only are the elderly increasingly very old, but they are also increasingly women—that is, there is a “feminization of aging.” As a 1997 Bureau of the Census report comments:

Women are the majority of the older population in virtually all nations and face different circumstances and challenges than men as they age. Older women are more likely to be widowed, to live alone and to live in poverty. Older women tend to have lower educational attainment, less formal labor force experience and more family care giving responsibilities than do older men. (7)

In addition, America is increasingly diverse and the older population is starting to reflect that diversity. Just

as the elderly constitute the fastest-growing segment of the U.S. population, people of color represent one of the fastest-growing groups of adults over age 65 (2). In 1994 roughly 1 in 7 American elderly were from a racial or ethnic minority (8).

A growing body of research shows that there are sometimes major differences by race and ethnicity in the travel patterns of the elderly. The 1990 Nationwide Personal Transportation Survey (NPTS) indicated substantial variations in the trip-making behavior of the elderly from different racial and ethnic groups, even when controlling for income. The causes of these differences are still unknown. Some no doubt reflect historical income patterns, some voluntary or involuntary residential segregation, and still others may represent ethnic and racial differences in attitudes, preferences, culture, and family beliefs about travel (9–11). Certainly not all differences are problems to be redressed, but they are or should be a concern of planners because these differences may structure how society effectively provides a range of services to different groups of older people.

There is also the problem of the ticking time bomb with so many people living to be very old: more will eventually face chronic, limiting illnesses and disabling conditions, bringing increasing dependence on others for help in performing daily activities. For example, in 1990–1991 half of those 85 years old or older and not institutionalized needed personal assistance in performing activities such as bathing, getting around inside the home, and preparing meals (4). Unfortunately, those who will be 85 years old in two decades will have had fewer children, so they will have fewer people to provide that assistance. For example, in 1997 17% of baby boom women in the United States were childless. Many of these women may find themselves with no family support at all in their old age.

One aggregate measure of this factor is the parent support ratio or the number of people who are age 80 or older for every 100 who are age 50–64. When the ratio is lower, there is a larger number of younger people available to assist older people. In 1998 the parent support ratio was 22 in the United States, but it is expected to grow to 24, which indicates less family support for the growing number of older people who will need it (12). In addition, there will be less overall societal support since the number of younger employed people will be falling as the number of older retirees increases.

But even those older people who have younger families may experience difficulties because so many of their relatives are working and raising families. Current middle-aged adults have been termed the “sandwich generation” because they find themselves

working, raising their children, and caring for their older relatives all at the same time. As a Bureau of the Census study commented:

The increases in life expectancy experienced in most countries have enhanced the likelihood that middle-aged adults will find themselves caring for older parents. When the sandwich generation has to care for parents who are aged, the demands of care giving are likely to increase as parents in this age group often have more pressing needs than their younger counterparts. (12, p. 2)

## BASIC TRANSPORTATION TRENDS

Over the last 10 years, older people have become more dependent on the private car and this dependency has had an increasing impact on their lives. The car appears to have given older people more choices, a wider range of possible activities, flexibility, and independence. Certainly, some argue that by supporting suburbanization and the decentralization of U.S. communities, the car has made it necessary for everyone to drive and removed walking, biking, and transit as options. But whether cause or effect, reliance on the private car is the backbone of the lifestyle enjoyed by the majority of older people today.

The following sections describe trends in travel and current transportation patterns among older people. The overall patterns indicate greater mobility and access among the elderly if measured by trips taken and miles traveled. Subsequent sections focus on adults for whom the news is not so good—who do not seem to have experienced the same growth in mobility and access as the average older person.

### Licensing and Travel

Driver licensing among the elderly is very high and still growing, although there is not much more room to grow. Figure 1 shows that licensing rates increased for all cohorts over age 50 from 1992 to 1997 but was faster among women than men, especially among those over age 70. This trend, of course, does not include people suddenly deciding to become drivers but rather younger, active adults aging into their retirement years. As a result, in 1997 almost 92% of all men and 70% of all women over 60 years old had a driver license. Licensing is close to universal among those who will become 65 years old in the next 15 years. By 2012 almost every U.S. man and more than 9 out of 10 U.S. women will enter their retirement years as drivers.

Data from NPTS (1995) and FHWA (1997) are shown in Table 1. It is striking that in 1997 almost three out of four men over age 85 are licensed drivers. These data suggest that within 20 years, more than 90% of all men over age 65 will be or have been licensed drivers.

There is compelling evidence that licensing rates are strongly related to greater use of the private car. Figure 2 shows that the percentage of all trips taken by older people in a car through 1995 has continued to increase, perhaps paralleling the growing licensing rates. It is striking how high the base rate is. Even in 1983 adults over age 70 took more than 3 out of 4 trips by car, as a passenger or as a driver. But by 1995 those over age 70 took approximately 9 of 10 trips by car. Again, this is not because they were suddenly becoming more mobile, but because younger, more active elderly were aging without giving up mobility.

Increasing access to a car is related to substantial growth in travel among older people. Table 2 shows that between 1983 and 1995, older Americans increased their travel activity on every index. They made 77% more vehicle trips, spent almost 40% more time driving, and drove 99.6% more miles than they had in 1983. Older Americans also increased the average trip length by 13% and increased all trip lengths by 11%. Older people had the largest increase of any age group on almost all these indicators.

At the same time, older people travel less than younger people. An NPTS report found that older people make 3.43 trips per day or 22.4% fewer than those under age 65 and noted that “[s]ome of this reduction in mobility may be by choice but some of it is commonly perceived to be the result of mobility and access issues” (13, p. 26). The common assumption that the

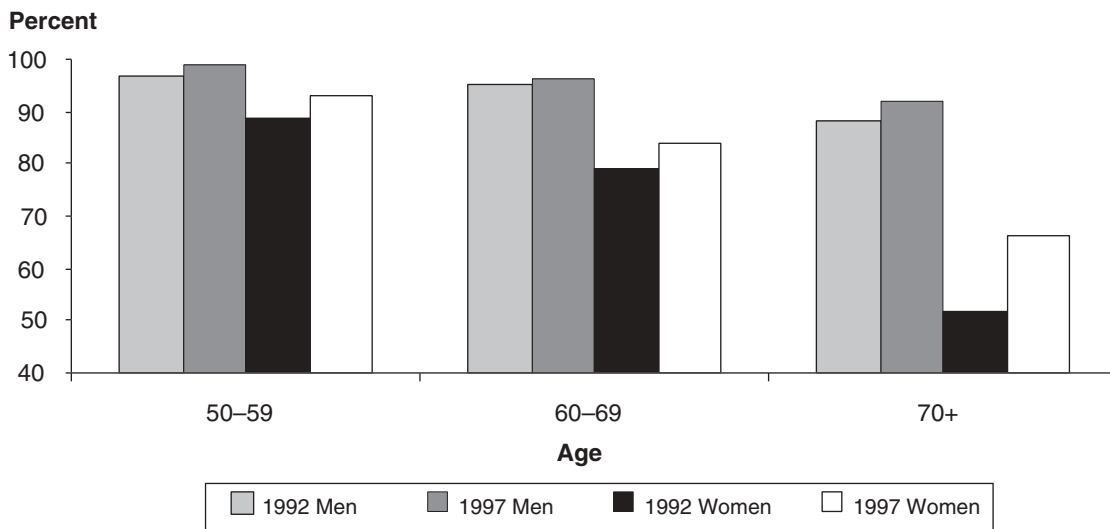


FIGURE 1 U.S. driver license rates by age and sex, 1992 and 1997. (SOURCE: Office of Highway Information Management, FHWA Table DL-20.)

TABLE 1 Percentage of Older American Licensed Drivers, 1995 and 1997 (percent)

Age Cohort	Male		Female	
	FHWA 1997	NPTS 1995	FHWA 1997	NPTS 1995
65-69	94.5	93.0	79.9	80.8
70-74	96.0	92.4	77.7	75.3
75-79	90.0	88.8	68.4	69.7
80-84	86.7	81.5	54.9	52.0
85+	71.4	69.1	31.5	28.3
Total	91.7	89.7	66.4	68.8

SOURCE: Unpublished data from the 1995 NPTS and the Office of Highway Information Management, FHWA, Table DL-20.

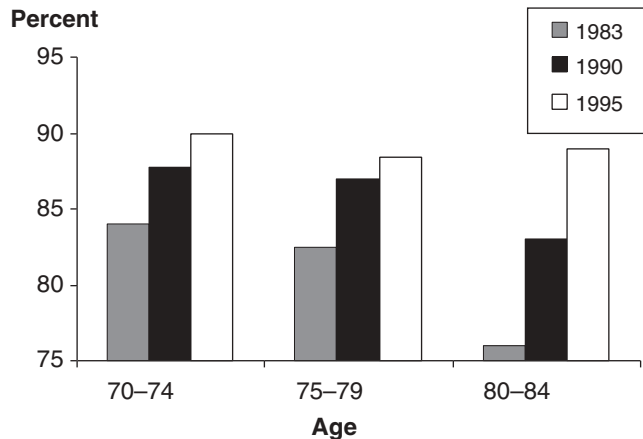


FIGURE 2 Percentage of all trips taken by car by older people in the United States, 1983.

**TABLE 2 Daily Travel Statistics for Older Americans Age 65 or Older, 1983–1995**

Statistic	1990		1995	Percent Change 1983–1995
	1983	(Adjusted)		
Vehicle trips per driver	1.66	2.27	2.94	77.1
Vehicle miles traveled per driver	9.80	14.83	19.56	99.6
Average vehicle trip length (mi)	5.92	6.61	6.69	13.0
Average time spent driving (min)	NA	30.83	42.89	39.1 <sup>a</sup>
Person-trips per person	1.82	2.49	3.43	88.5
Person-miles per person	12.21	19.85	25.24	106.7
Average person-trip length (mi)	6.70	8.12	7.46	11.3

<sup>a</sup> Percent change 1990–1995.

SOURCE: Computed from Table 29 draft 1995 NPTS Summary of Travel Trends.

drop in trip making at retirement is a drop in mobility is more than a definitional issue.

Table 3 shows daily trip rates and miles traveled (via all modes) in the United States for cohorts under and over age 65. Even if differences were examined in the total trip rate, which includes a large number of work trips made by younger travelers, the trip rates of older people would not be substantially lower than younger travelers until age 75. But older men under age 85 take substantially more nonwork trips than do younger men

**TABLE 3 U.S. Total Trip and Nonwork Trip Rates by Age and Gender, 1995**

Age Cohort	Sex	Total Daily		Daily Non-work	
		Trips	Miles	Trips	Miles
18–64	Male	4.6	51.3	3.1	29.3
	Female	4.7	37.5	3.7	28.0
65–69	Male	4.4	37.4	3.8	32.0
	Female	3.7	24.9	3.5	23.1
70–74	Male	4.2	34.5	3.8	31.1
	Female	3.4	20.6	3.2	20.0
75–79	Male	3.5	23.8	3.3	21.8
	Female	2.9	16.4	2.8	15.8
80–84	Male	3.4	19.0	3.4	18.5
	Female	2.4	13.0	2.3	12.7
85+	Male	2.1	13.1	2.0	13.3
	Female	1.3	7.3	1.3	7.2

NOTE: “Nonwork” excludes trips to and from work and those work related.

SOURCE: Unpublished data from the 1995 NPTS.

(age 18–64). Older women take fewer than younger women, but the drop is not very large until age 75. For example, men age 70–74 take 23% more and men age 80–84 take 8% more nonwork trips than men under age 65. Conversely, women age 70–74 take 12% fewer and women age 75–79 take 24% fewer nonwork trips than do younger women.

Older people travel substantially fewer total miles each day than younger travelers. This is not surprising since the lengthy work trip is largely gone from the travel patterns of older people. But as with trip rates, for nonwork travel, older men make longer trips than younger men do until they reach age 75. For example, men age 70–74 travel 31.1 mi each day for nonwork purposes compared with 29.3 mi for men under age 65, a 6% difference. Older women drive less than younger women, but again the biggest drop comes at age 75. If nothing else, this exercise indicates the danger of talking about all adults over age 65 as if they had the same patterns or of using an average number (of trips, miles, etc.) for all adults age 65 or older, which actually describes no one’s travel behavior.

These data suggest that older people are very active and mobile after they reach 65 years old and even 75 years old. These travel boundaries may well extend as even more active (and automobile-dependent) people age in the coming decades. It is entirely possible that the drop in trip making now seen among women as they age is the result of cohort and income effects instead of a reduced desire for travel, at least until age 75 or 80.

As women come to more closely resemble men on their retirement in terms of years of driving experience, education, professional accomplishments, and so forth, they may display the same demand for additional travel as now seen among older men. As more women enter their retirement years with better incomes, they may have the means to travel as often and as long as men. Substantially more travel among older women and even less of a gap in trip making between all adults over and under age 65 may be seen than Table 3 suggests.

### Travel Patterns

Given the findings above, it is no surprise that older people are remarkably dependent on the private car for their mobility and access, as shown in Table 4. No cohort of older travelers takes less than 8 out of 10 trips in a private vehicle, and until they reach age 85, older travelers take 9 out of 10 trips by car. Of course, as they age, older people become the passenger in the car and not the driver. But until age 80, the increase is not very large. Before they reach age 85, more than two-thirds of those riding in a car are driving that car. Even among

TABLE 4 Mode Choice for All Trips by Age, 1995 (percent)

Age Cohort	Private Automobile			Public Transit	Taxi	Walk	Bike	Other Modes
	Total	Driver	Passenger					
65-69	90.1	71.5	18.6	1.7	0.2	4.5	0.2	3.4
70-74	89.4	67.6	21.8	1.5	0.2	5.5	0.2	3.2
75-79	88.4	63.3	25.1	2.1	0.3	5.9	<sup>a</sup>	3.4
80-84	89.0	57.6	31.4	1.6	0.2	5.3	0.3	3.6
85+	81.5	49.3	32.2	2.3	0.9	11.0	0.0	4.4

<sup>a</sup> Less than 0.01.

SOURCE: Unpublished data from the 1995 NPTS.

adults over age 85, almost 50% of those traveling in a private vehicle are the driver.<sup>1</sup>

Conversely, no cohort of the elderly takes more than 2.3% of their trips by transit. Walking is a more frequent mode choice for older people than public transit by a factor of at least two. Taxis are included because although they account for only a small percentage of all travel by older people, their use has been increasing substantially since 1983.

The mode choice made by older people depends in part on the type of trip they make. The car remains the dominant mode for all types of trips for both groups of drivers. In fact, there is no statistical difference between those over and under age 65. Roughly 90% of all trips, except recreation, are made in a private vehicle by travelers of all ages. At the same time, older people are slightly more likely to be the passenger and less likely to

be the driver for all trips. The biggest difference is for family and personal business trips when older people are almost 50% more likely to be the passenger in the car, but the actual percentage-point differences are small.

Older people are generally less likely to use public transit for any of their trips than those under age 65 (with the exception of work and family business). They are more likely to walk than younger travelers for all trips except medical ones. Older people are more likely to use a taxi for their medical and recreational trips than younger travelers. But most striking is how small the differences are between the mode choices of younger and older people.

The majority of older people do not take many work trips; conversely, they take more of most other types of trips. But as Table 5 shows, there are interesting differences by age and gender. Older men are more likely to make work or work-related trips than older women; in fact, men as old as 75 years are making one 1 of 12

<sup>1</sup> Source is unpublished data from the 1996 NPTS.

TABLE 5 U.S. Trip Purpose by Age and Gender, 1995 (percent)

Age Cohort	Sex	Work Related	Medical	Shopping	Family/ Personal	Recreation/		Others <sup>a</sup>
						Religious	Social	
16-64	Male	31.6	1.0	18.0	22.4	4.7	22.0	0.4
	Female	20.8	1.6	22.8	28.3	5.5	20.7	0.3
65-69	Male	13.1	2.5	6.2	27.4	4.3	26.1	0.4
	Female	6.6	4.0	30.4	29.0	4.6	25.1	0.2
70-74	Male	8.7	2.7	27.2	29.7	4.6	26.8	0.3
	Female	4.4	3.9	33.8	25.1	7.4	25.0	0.4
75-79	Male	5.2	3.7	28.6	25.6	5.1	31.4	0.5
	Female	3.2	4.6	33.1	25.6	5.4	27.9	0.1
80-84	Male	2.4	4.9	32.9	25.4	7.4	26.9	0.2
	Female	2.0	4.0	25.9	26.4	11.7	30.0	<sup>b</sup>
85+	Male	2.9	5.8	28.8	30.0	5.9	26.6	0.0
	Female	1.1	5.4	23.8	31.2	8.7	29.8	0.0

NOTE: From 1990 trip categories. <sup>a</sup> Rounding errors. <sup>b</sup> Less than 0.01.

SOURCE: Unpublished data from the 1995 NPTS.



trips for work. NPTS data not presented in Table 5 show that the largest trip purpose for those over age 65 is shopping. Interestingly, older women make a larger percentage of their trips for shopping than do men but only until they reach age 80.

The next most important trip type is family and personal business. This trip type also increases in importance as people get older. Older people make more medical trips than adults aged 16–64, and this trend increases with age. The elderly over age 85 make roughly twice as high a proportion of their trips for medical purposes as those aged 65–69. At the same time, no cohort of older people makes more than 6% of all trips to visit the doctor or dentist.

However, the residential patterns of the elderly diverge, creating important differences among otherwise comparable people. Since 1960 more elderly people have lived in low-density places than in the core of U.S. central cities. In 1990 almost three-fourths of all adults over age 65 lived outside the city. Unpublished 1995 NPTS data show that older people living in suburban or rural areas made more trips and traveled longer than those living in urban areas. Travel implications can be seen in Table 6, which displays only three of the five residential categories in the 1995 NPTS. Older people living outside urban cores make more of their trips in a car than those who live in central cities, sometimes by striking margins. In general, this trend represents both the lack of alternatives to the private car and the fact that origins and destinations are more widely spread in low-density areas.

The growing concentration of older people in both rural areas and in the suburbs is largely a continuation of the aging-in-place phenomenon that has driven metropolitan residential patterns for at least five decades. Older people actually moved to the suburbs when they were younger and stayed on in the houses in which they had raised children, long after their children had gone. There have been efforts to encourage older people to move back to the core of the city in part to reduce their dependency on the car and to make it more efficient to provide needed services. Daphne Spain argued, in a paper

prepared for FHWA, that the United States should develop a national policy of incentive programs designed to reconcentrate older people in the center cities (14). Edward Evans of the American Association of Retired People commented favorably on this suggestion (15).

The success of such a policy would certainly depend on the kind and magnitude of the incentives, because the elderly are the least likely to move of all citizens. Moreover, their tendency to move has dropped consistently over the last 20 years. In fact, older people are about one-fourth as likely to move in any given year as adults age 30–44 and one-half as likely as adults age 45–64. When they do move, they do not move far. Roughly 60% of all moves by those over age 65 are within the same county as their previous home (16).

### Implications

These trends individually and collectively have important mobility consequences. Linked to growing health and income among older people is a growing reliance on the private car, and linked to greater access to a car is a far more active lifestyle. Older people today take more trips, a greater variety of trips, and longer trips than those who were age 65 or older just a few years ago. By almost all accounts, they enjoy greater access and mobility than their counterparts of just a few years ago.

The car has permitted or caused increased suburbanization. This phenomenon has hastened the decline of public transit and made walking an impractical option, creating even greater problems for subgroups of the elderly with limited access to a car. Given the declining number of children, how much support will the elderly of the future be able to count on from families, friends, or societal resources? Without intelligent policy responses now, what will happen to the majority of older people who are currently able to enjoy the advantages offered by the car when, as almost inevitably happens, they lose the ability to drive or maintain the vehicle?

### MOBILITY WITHOUT A LICENSE?

Although the majority of older people are licensed to drive, a substantial subset of certain groups is not. Those living in the center of the city, older women (particularly over age 75), those who are poor, those living alone, and ethnic and racial minorities are all less likely to be licensed to drive. These groups overlap substantially, but there are several million older people who do not drive but are still active and need mobility.

The overall implications are shown in Table 7 and Figure 3. Table 7 shows that there is a substantial trip

TABLE 6 Car Use by Older People and Residential Location, 1995 (percent)

Mode	Urban	Suburban	Rural
Automobile	74.0	91.2	91.0
Driver	53.0	70.1	65.7
Passenger	21.0	21.1	25.3
Public transit	8.2	0.8	0.3
Walking or bike	13.0	4.4	4.4
All others	4.7	3.1	4.4

SOURCE: Unpublished data from the 1995 NPTS.

TABLE 7 U.S. Trip Rates by Age and Licensure, 1995

Age Cohort	With a License	Without a License	Percent Difference
65-69	4.3	2.3	87.0
70-74	4.1	1.9	115.8
75-79	3.5	1.9	84.2
80-84	3.5	1.6	118.8
85+	2.3	1.0	133.0

SOURCE: Unpublished data from the 1995 NPTS.

gap between those who do and those who do not have a driver's license in every age cohort. For example, licensed drivers age 65-69 make 4.3 trips per day or 87% more trips than those without a license (2.3 trips). Presenting these data by age cohort is important because it is easy to assume that those without a license are all very old. The average does not represent real differences among younger old people (age 65-75). Even at age 85, it is clear that adults with a license make more than twice as many trips as do those without a license. Figure 3 focuses on the daily miles traveled by older people in various cohorts and shows the same pattern as seen in trip rates. There is a large and consistent gap in miles traveled between older people with and without a license among all cohorts of older travelers.

Table 8 and Figure 4 further disaggregate these trip and mileage gaps by also controlling for gender. Table 8 displays the percentage difference in trips and mileage between adults with and without a driver's license. In all cohorts, men and women who do not have a license experience a substantial gap in trip making and distance

TABLE 8 U.S. Daily Trips by Age, Gender, and Licensure, 1995

Age Cohort	Sex	License		Trips	Percent of Difference Between	Daily Miles
		With	Without			
65-69	Male	4.6	2.1	119.0		80.5
	Female	4.0	2.4	66.7		166.4
70-74	Male	4.3	2.1	104.8		232.1
	Female	3.9	1.8	116.7		181.7
75-79	Male	3.7	2.0	85.0		102.3
	Female	3.3	1.9	73.7		163.9
80-84	Male	3.9	1.4	178.6		343.6
	Female	3.1	1.6	93.8		148.6
85+	Male	2.6	1.1	136.4		24.6
	Female	2.1	1.0	110.0		429.4

SOURCE: Unpublished data from the 1995 NPTS.

traveled. For example, in the age 70-74 cohort, women with a driver's license made almost 117% more trips and traveled more than 180% more miles daily than women without a driver's license. Men age 70-74 with a driver's license traveled 232% more miles and made more than 100% more trips than men without a driver's license. It is important to understand that not all of these differences represent poor mobility or access. Older people without a driver's license may live in areas where they do not need to travel as long or as often. They may live with relatives or friends who bring them goods and services, so they do not need to travel outside the home.

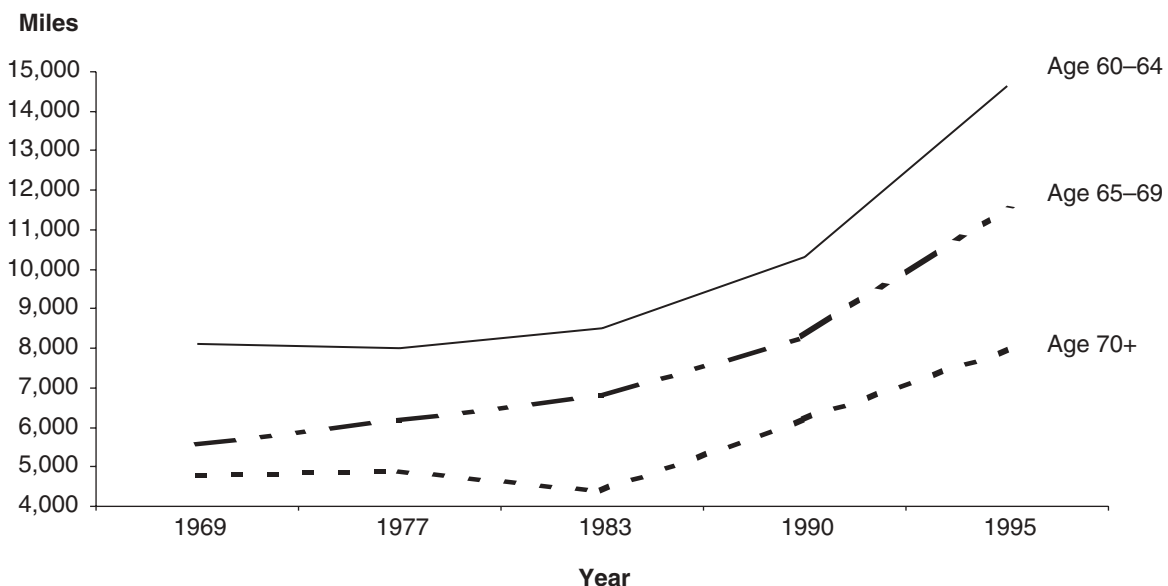


FIGURE 3 Average miles driven by older people in the United States. (SOURCE: Unpublished data from 1995 NPTS.)

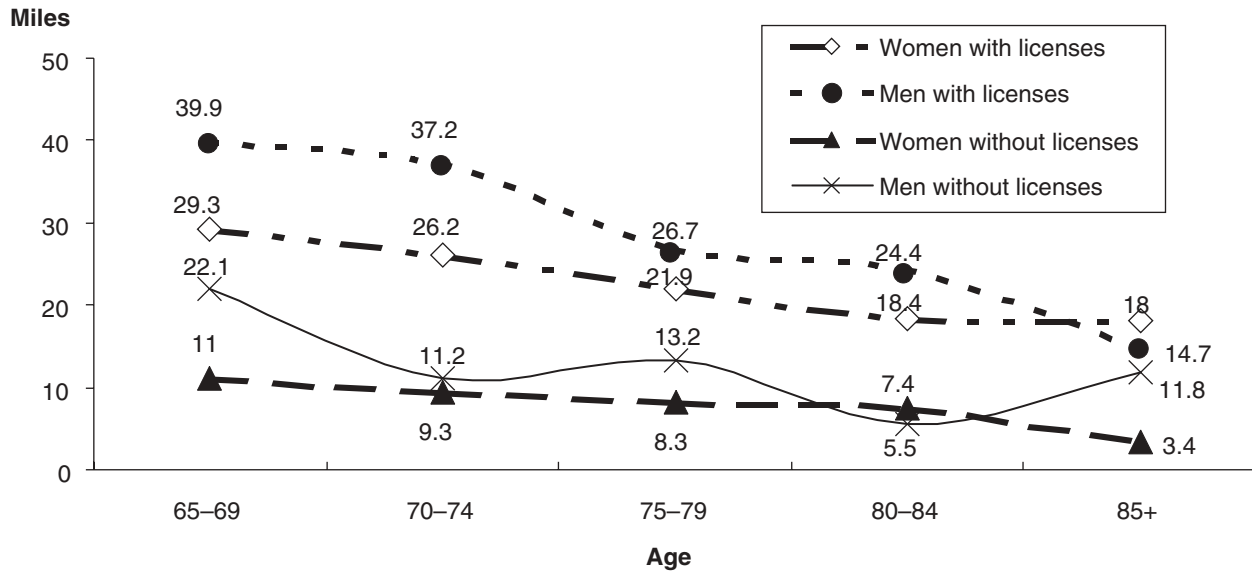


FIGURE 4 U.S. daily miles traveled by age, sex, and licensure, 1995. (SOURCE: Unpublished data from 1995 NPTS.)

Or they may be too ill or otherwise disadvantaged to leave their homes.

If one claims that some or all of the increased travel experiences by the average older person over the last few decades is an indication of increased access and mobility, it is hard to escape the conclusion that some of the trips not made by those without a license must represent the opposite. Clearly there is some bad news here, even if one cannot say with certainty what its dimensions are.

These data obscure another complexity. In 1995 some adults without a driver's license had never had one, while others had given it up. The travel patterns of these two groups may be very different. Those who have never driven are far more likely to choose homes where they can walk or use public transit and where they can limit their need to travel at all or by car. Those who formerly drove may actually be more disadvantaged because they made a range of lifestyle choices based on ability to drive. By 2030 the overwhelming majority of older people without a driver's license will be in the second group—people who had a license but lost it or gave it up.

## MOBILITY OF WOMEN: WHAT IS THE NEWS?

### Current Trends

Women currently live longer than men, a result of the so-called female advantage in aging, which begins around age 35. In the United States, in 1998 there were

roughly 0.7 men over age 65 for every 1 woman over age 65. This means that a majority of the population over age 65 were women; the same will be true roughly three decades from now. Men will enjoy a slightly longer life expectancy in the future; some analysts believe that the female advantage may narrow, but so far there is no clear evidence that it has. In France, Germany, and Japan, gains in female longevity continue to outpace gains in male longevity (17).

The growth of the oldest old has many important implications for social planning, since these individuals are more likely to be in poorer health and require more services than the younger old. Given the preponderance of women among the oldest old, many of the needs of the oldest old are actually the needs of women. (12, p. 2)

Because they live longer, many older women live alone. In 1993 elderly American women (not living in institutions) were almost half as likely as comparable men to be married and living with spouses—75% versus 41%. For many older people, the main caregiver is the spouse. Thus, “while most elderly men have a spouse for assistance, especially when health fails, most elderly women do not” (12, p. 2).

Older women living alone are substantially more likely to be living in poverty or in inadequate housing (18). In 1997 almost 14% of women but only 7% of men over 65 years old lived below the poverty level in the United States (19). In 1990 58% of women over 75 years old living alone—but only 42% of comparable



men—had incomes under \$10,000, while 40% of women over 85 years old living alone were poor compared with 27% of men in the same cohort. As a result, although women comprised 58% of those over 65 years old, they accounted for almost 75% of the poor elderly in the United States in 1992.

Whether these issues cause differences in travel is not clear, but older women do have different transportation patterns from those of older men, as Tables 3 indicates. The data show that older women make fewer trips and travel fewer miles than men in all age cohorts. The biggest gaps are at the oldest ages. For example, men age 75–79 made 3.5 trips per day or almost 21% more than comparable women; they traveled 25.2 mi per day or 42% more than comparable women. But men age 85 or older made almost 52% more trips and traveled 84% more miles than women of that age did.

Younger women also travel fewer miles than comparable men, but they do make more trips. So it is interesting to consider why older women make fewer trips than older men. License holding may explain some of the remaining difference. In Table 8 and Figure 4, licensure was controlled, and show the same pattern was found. Table 5 focuses on trip type differences between older men and women. For all trip purposes, except religious ones, men were more reliant on the car than women.

### What Does the Future Hold?

The travel patterns of elderly men and women today reflect in part the experiences they had when younger—experiences not shared by those who will become 65 years old in the next three decades. Women born in 1930 are far less likely to have a driver's license or a job outside the home than women born in 1950. They are likely to have more children than a woman born in 1960. Different societal forces and trends have structured the way these women and those in the future will approach their senior years, the activities in which they will engage, the places they will want to go, and the frequency and mode of their travel.

There will be a substantial increase in the number of female retirees—women with their own retirement income. In mid-1970, slightly more than half of all American women older than age 65 considered themselves retired. But because so many of these women were poorly paid, their incomes were generally less than men's. Moreover, many of those women were alone and living entirely on their own personal pensions. A number of older women continued to work after the age at which they would have liked to retire because they had insufficient retirement benefits. In fact, in 1994 only 38% of American women retirees received pension ben-

efits and only 21% received health coverage that could be continued for life (20).

Substantial increases in female employment will have perhaps contradictory influences on the activity and travel choices these women will make when older. Because of their presence in the labor force, they may develop more active and involved lifestyles than women who spent most of their lives as housewives. They may wish to continue these active lifestyles after they retire. On the other hand, they may have less personal income with which to do so, no spouse to share expenses, and no children to provide needed assistance.

If anything, a larger gap may be created between the activities they wish to engage in and their ability to do so in comparison with the gap faced by otherwise comparable older women today. When these women are elderly, they may do without, suffering relative deprivation, or they may act more like men do today and drive to meet their needs, even when they find driving difficult or dangerous.

### IS A DIVERSE SOCIETY A MOBILE SOCIETY?

Recently released Bureau of the Census statistics for 2000 make it clear that the United States is far more diverse than it was even a decade ago. This trend is also seen among the elderly and will grow in the coming decades. In fact, people of color are one of the fastest-growing groups over age 65 (2). A Bureau of the Census report predicts that the percentage of people of color in the elderly population will more than double in the next 50 years. By 2050 15% of all elderly will be African American, 16% will be Asian and Pacific Islander, 15% will be Hispanic (of any race), and more than 12% will be American Indian.

### Ethnicity and Race

Previous work on the travel patterns of older people by race and ethnicity is fairly sparse. A seminal study on this issue was conducted by Wachs in Los Angeles, California, in 1976. He found important travel differences by ethnicity. For example, elderly Mexican-American women were significantly less likely to have a driver's license but more likely to make trips in cars than comparably situated Anglos or other minority women, generally traveling with relatives (21). A 1976 study conducted in Los Angeles for the National Science Foundation (NSF) found significant differences in ride sharing and ride giving as well as variations in responses to transit cost and fear for personal safety among African American, Anglo, and Hispanic elderly with comparable socioeconomic status (22). The NSF study

concluded that “differences in cultural orientations and needs of minority groups [were] not adequately taken into account” in transportation planning (22).

In analyses of the 1990 NPTS data, Rosenbloom found great differences among older people by race and ethnicity. Hispanics made fewer person-trips than all other categories of travelers, even though they traveled for longer distances than African American or other travelers. These patterns held true in rural as well as urban places and were not explained by income or license status (23). The 1990 NPTS analyses also showed that whites and Hispanics (of any race) were much more dependent on the private car and much less dependent on walking or public transit than African American or other older people. Moreover, the gap between the sexes was greater in some ethnic groupings. For example, Hispanic older men were much more likely to use a private vehicle and much less likely to walk than Hispanic women. This gender difference was greater than among other older travelers.

Rosenbloom (23) also found that men and women from varying ethnic and racial backgrounds had different daily trip rates and covered different distances. For example, white older men made 32% more person-trips than African American older men and 22% more than Hispanic older men. White older women traveled more than three times the daily miles covered by African American or Hispanic older women. Differences in income level did not explain these disparities in travel patterns. At all income levels, white older women made substantially more trips per day than did older women from other backgrounds. There were also important differences between those women. For example, Hispanic older women in households with incomes under \$20,000 made 50% fewer daily trips than did African American older women in comparable house-

holds. Similar patterns were seen among older men from different backgrounds, although the differences were not as great.

Are travel differences linked to race and ethnicity, or do they result from other factors such as differences in living patterns? Hispanic and African American elderly are more likely to live in large, densely populated metropolitan regions. Even in the West and Southwest, they may live in the higher-density areas of these regions, which are places more likely to have public transit services. In 1990, for instance, roughly 80% of all African Americans and almost 90% of all Hispanics lived within metropolitan regions as compared with 73% of whites (24).

Figure 5 shows some fairly large differences in the licensing rates of older people from different ethnic and racial backgrounds. First, white men are more likely to be licensed than men from any other background, and some differences are fairly large. For example, almost 92% of white men but only 70% of African American older men are licensed drivers. There is far more similarity between white and Hispanic (of any race) men. White older women are also more likely to have a driver’s license than women from other backgrounds and sometimes by gaps even larger than among men. Roughly 74% of all white women over age 65 have a driver’s license compared with only 37% of African American and 42% of Asian older women.

In addition, Figure 5 shows that the gender gap is very different for elderly from different backgrounds. There is a gap of 18 percentage points in the rates of white men and women but a gap of more than 40 percentage points between the rates of Hispanic and Asian men and women. These data suggest that people in such cultures have or had different views about the appropriateness of women driving.

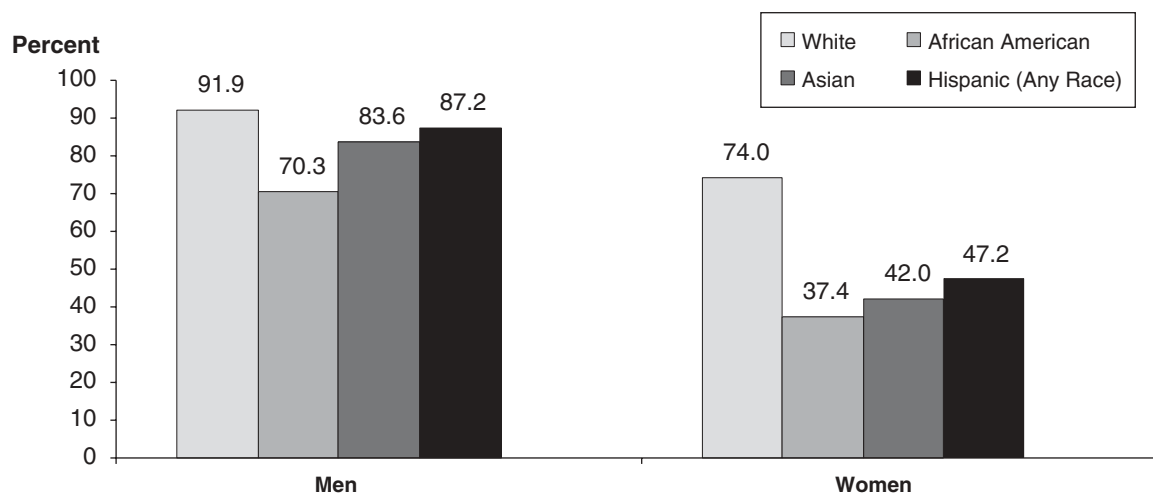


FIGURE 5 U.S. licensure of older people by gender, ethnicity, and race, 1995 (percent). (SOURCE: Unpublished data from 1995 NPTS.)

Figure 6 shows the differences in the daily trip rates of older people by gender and background. White men and women make more trips each day than do older people of either gender from other racial or ethnic backgrounds. White men make 4.1 trips daily or 36% more than African American men. White women make 3.2 trips per day or 33% more than African American women. In fact, white women make more daily trips than African American men. The gender gap also differs here, as it did in Figure 5.

Table 9 explores mode choice by race and ethnicity and by residential location to account for the fact that people of color are more likely to live in urban areas. The table shows that residential patterns make a significant difference, far more for African Americans and Asians than for Hispanics or whites. African American elderly living in urban cores were substantially less likely to travel by car and substantially more likely to use public transit than the other three types of travelers or African Americans living in less-dense residential areas. In fact, African American elderly were more likely than whites to travel by private car in two of the five residential categories. Asians too showed a surpris-

ing difference in travel behavior if they did not live in the central core.

### Another Look at the Issues

In 1999 Rosenbloom and Waldorf tried to identify the factors related to differences in travel patterns by race and ethnicity (25). Using 1995 NPTS residential location variables based on the size, density, and function of residential areas, they questioned whether the mode choice of white, non-Hispanic elderly differed from otherwise comparable ethnic and racial elderly when controlling for residential location and other important variables. They used two estimation (logit) models, with mode choice as the dependent variable, and controlled for residential location and a variety of other factors, including age, licensure, income, gender, and transit availability. They found important differences in mode choice by race and ethnicity even when other key variables were held constant (25).

In particular, Rosenbloom and Waldorf found that race and ethnicity were significant covariates of choice for

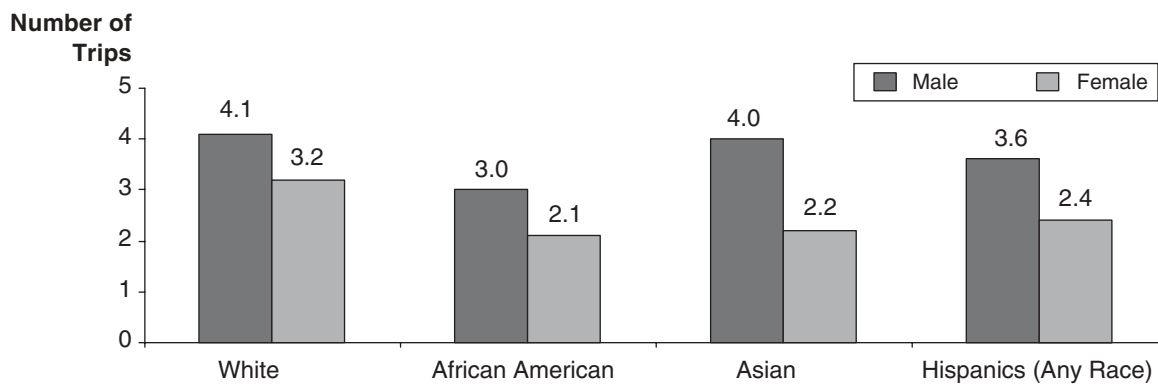


FIGURE 6 Daily trip rates by gender, race, and ethnicity for adults age 65 or older, 1995. (SOURCE: Unpublished data from 1995 NPTS.)

TABLE 9 Mode Choice for All Trips by Race and Ethnicity of People Age 65 or Older, 1995 (percent)

Locale	White		African American		Asian		Hispanic (of Any Race)	
	Private Vehicle	Public Transit	Private Vehicle	Public Transit	Private Vehicle	Public Transit	Private Vehicle	Public Transit
Urban	78.8	6.4	52.3	24.1	61.5	22.8	76.1	1.0
Town	92.4	0.5	95.9	0.2	66.0	34.0	93.1	0.0
Suburb	92.6	0.9	84.5	4.5	95.1	0.0	95.5	0.0
Second city	93.0	0.8	80.7	8.6	85.5	0.0	76.0	4.2
Rural	91.5	0.5	97.1	0.0	100.0	0.0	98.7	0.0

SOURCE: Unpublished data from the 1995 NPTS.

older trip makers. That is, controlling for the effects of residential location did not eliminate racial disparities and vice versa. Race disparities were most pronounced in suburban locations and in low-income groups. Moreover, residential location disparities in mode choice were much more pronounced for African American elderly than for white elderly trip makers. That is, white elderly were more likely to drive and less likely to use public transit than African American elderly in certain residential areas, holding all other variables, including income, constant. However, this race gap was substantially weaker among women than men.

Rosenbloom and Waldorf also found that ethnicity, as well as race, played a significant role in mode choice. Surprisingly, Hispanic elderly were significantly less likely to choose public transportation and significantly more likely to choose privately owned vehicles than non-Hispanic trip makers. Even more interesting, Hispanic women were more likely to use a privately owned vehicle and less likely to choose public transportation than men, if all other variables were held constant. Finally, they found that income effects were significant in choosing a privately owned vehicle—that is, the higher the income, the greater the likelihood of using a car.

Will these differences continue? There is evidence among younger travelers that with acculturation—that is, length of stay in the United States—immigrants become less dependent on public transit and more

dependent on the car (26). At the same time, a recent study by the Transit Cooperative Research Program found that immigrants were more likely than comparable workers to commute to work using public transit—with income and other variables held constant—for at least the first 10 years in the United States (27). Moreover, that same study found that African Americans were always more likely to use public transit than comparable workers, regardless of income, size, or density of the metropolitan areas in which they lived. Although some differences may disappear over time, for others it is not so certain.

Figures 7 and 8 address one aspect of the following question: “Will older people of color still be less likely to have a driver’s license in the future?” Figure 7 shows that among men, whites and Asians are roughly equally likely to have a driver’s license in the cohorts age 30–60. However, both Hispanic (of any race) and African American men are far less likely to have a driver’s license than whites or Asians—a trend that is likely to continue.

The racial and ethnic differences are even more clear among women, as shown in Figure 8. White women age 30–60 are substantially more likely to have a driver’s license than women from other racial or ethnic backgrounds. For example, only 81% of African American women but more than 95% of white women age 30–39 have a driver’s license. Thus, over the next 30 years, the large gap in licensing rates among women from different

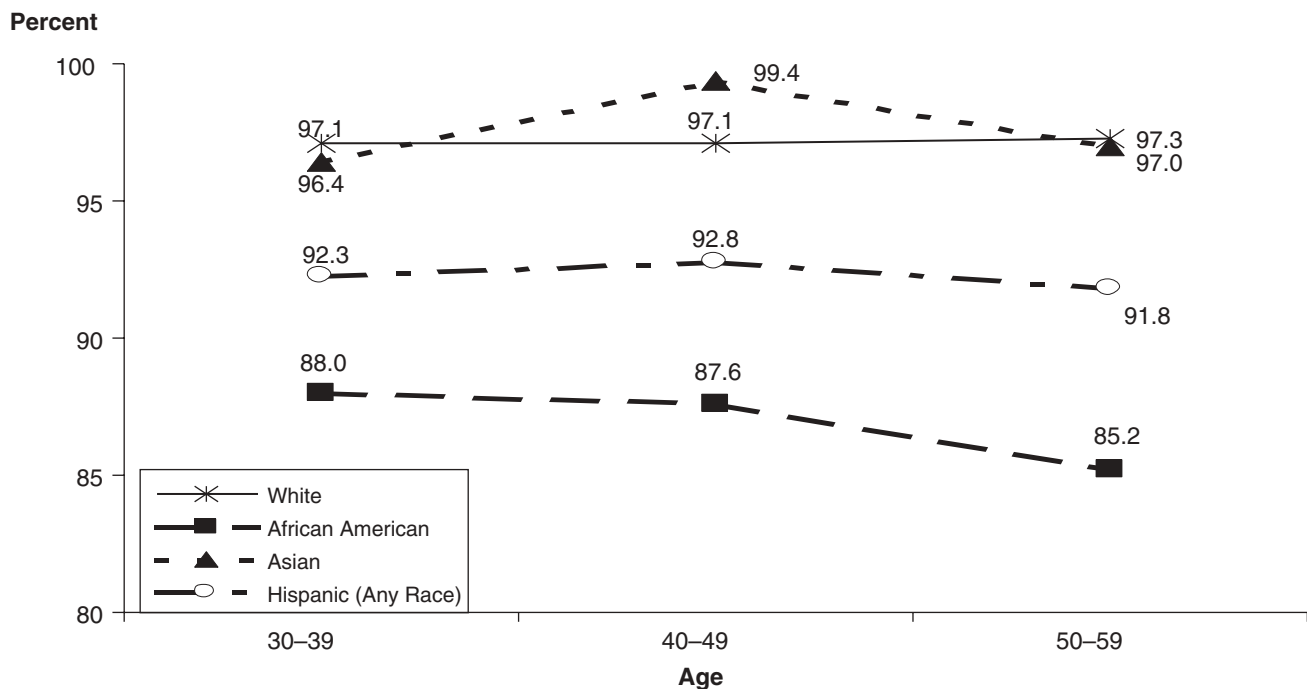


FIGURE 7 Licensing rates for men under age 60 by age, race, and ethnicity, 1995. (SOURCE: Unpublished data from 1995 NPTS.)

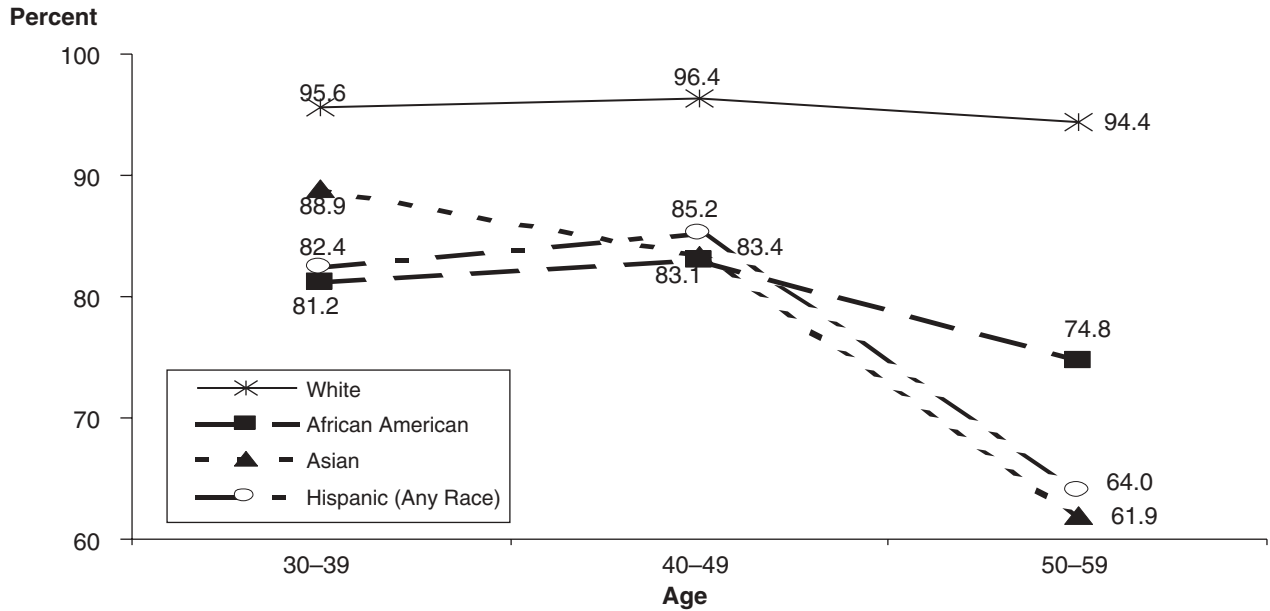


FIGURE 8 Licensing rates for women under age 60 by age, race, and ethnicity, 1995. (SOURCE: Unpublished data from 1995 NPTS.)

backgrounds will continue to be seen among the elderly. Overall, given how trip patterns are linked to car use, it is likely that some of the travel differences currently observed among the elderly from different racial and ethnic backgrounds will persist over the next three decades.

### Implications

What do these differences mean? First, it still appears that there are gaps in travel that represent lost trips or trips not made by people of color but made by whites. Unfortunately, the full magnitude of this loss is not known. Second—and just as important—strong evidence is emerging that some of the differences between and among older people from different backgrounds represent different values, attitudes, norms, and beliefs about lifestyle and activity patterns.

In response to the growing number of older people who will face a declining ability to drive or maintain a car, it will be important to understand how older people from different communities interact with their families and friends in ways that affect their activity choices and their transportation needs. These data suggest that strategies to induce older people to stop driving when they have difficulties, as well as what alternatives must be offered to ensure their mobility, will need to vary with racial and ethnic backgrounds.

### THE REALLY BAD NEWS

Older Americans are now more dependent on the private car than at any time in U.S. history. For the last two decades, every automobile-related travel indicator for the elderly has increased, in terms of vehicle miles, licensing, daily trips, daily miles, time spent driving, and more. The use of alternative modes has decreased. The elderly are now less likely to take public transit and more likely to walk than younger people.

Unfortunately, as people age, they often lose the skills necessary to drive safely (28). For example, a 1997 study notes that crashes among the elderly

can be linked to the aging process. . . . [A]ging phenomena put older drivers at risk while driving, especially if they are not aware of them or do not modify their travel behavior accordingly. . . . Given this model, the view to the future with respect to highway safety may seem bleak. (29)

It is important to note that older people, who represent 13% of the U.S. population, constitute 18% of U.S. motor vehicle deaths. Moreover, people over age 75 have more motor vehicle deaths per 1,000 than any other cohort of the population except those under age 25. Per mile driven, they have more crashes than all other drivers except teenagers.

Policy analysts have long debated if and when the current generation of older people should cease driving (30–32). But a more important question is whether a new generation of elderly, far more used to and dependent on the private car, will stop driving when faced with similar situations. Further, if older people now or in the future cease driving, how will they meet their mobility needs?

### Will Older People Reduce or Stop Driving?

It is generally assumed that older drivers reduce or change their driving as skill levels (or financial resources) decline. They may drive less and avoid certain traffic conditions. At the same time, it appears that older drivers strongly resist a total cessation of driving. The evidence about the extent of self-regulation tends to be anecdotal and self-reported. However, it is believed that older drivers self-regulate because they have fewer accidents per capita than almost any other group of drivers although they have more accidents per exposure or trips made (33).

But self-regulation is a term used casually even in scientific work. In fact, it is not known how much and how often current elderly drivers reduce the total number of trips they make versus modifying their driving—for example, buying bigger mirrors, having their eyes or ears checked, or making three right turns to avoid a left turn. Traffic safety experts in the past rarely made a distinction between the two sets of activities because the bottom line for them was safety, not mobility.

Increasingly, the evidence is that the self-regulation linked to lower per capita crash rates is largely a result of reducing the number of trips made with different implications for mobility and lifestyle. It makes a big difference to older people if they are forced to make fewer total trips as opposed to traveling at different times or making right turns to avoid left turns. Their quality of life may be diminished as the gap increases between their desired activities and those they find accessible. This diminished quality of life helps explain the growing resistance to driving cessation. People with active lifestyles and dependent on a car will face real mobility losses when forced to stop driving. In fact, there is a large and growing body of research literature that shows drivers, particularly men, strongly resist the total cessation of driving, sometimes long after they objectively should stop. As a 1998 focus group study of older drivers at the University of Michigan noted:

Nearly all participants had strong emotional feelings about the importance of driving. . . . Healthy older drivers, in particular, described busy, active lives that

required the use of a car on an almost daily basis. . . . Only a few older drivers had made adjustments to their housing situation to accommodate the eventual inability to drive. Many, including nearly all the male participants, had not even thought about the eventual need to reduce or stop driving. (34)

An often-cited 1995 study at the Yale University School of Medicine found that the cessation of driving among elderly people was significantly related to substantial declines in activity levels and substantial increases in depression, holding all demographic, psychosocial, and medical factors constant (32). Even though women today are more likely to give up driving when they detect problems, it is entirely possible that women in the future will be as resistant as comparable men for the same reasons.

In a 1997 study for NHTSA, people in a focus group explained why their older family members resisted driving cessation: “[y]ou know how that feels when you don’t have the car. . . . The next step’s the old folk’s home and the next step after that is the cemetery. . . . It’s so hard to give up your independence” (35, p. 27).

### Have the Elderly Thought About Alternatives?

Intertwined with unwillingness to even think about driving cessation is an unwillingness or inability to say how trips will be made if and when driving must be curtailed. In 1998–2000 the Drachman Institute at the University of Arizona asked 1,300 older drivers how they would make a range of trips if they were forced to stop driving. Table 10 shows the overall results for two kinds of trips: grocery and social. If forced to stop driving, most respondents assumed that they would somehow make the trips. Men were substantially more likely than women to assume that they would go by car. They reported twice as much that someone else in their own home, usually their spouse, would drive them. Women said more than men that they would take a taxi, less often take a bus for social trips, and slightly more often take a bus for grocery trips. Still, overall, no less than 57% of all respondents thought that they would still rely on a car.

Table 11 breaks the responses down by age cohort. The data show that as people age, they report the car less frequently as a possible alternative. For example, although at least 70% of adults age 65–69 think that someone else will give them a ride for their grocery shopping or social trips, only 44% of those over age 85 think so. As people aged, they were also far less likely to report that someone in their own home would drive but not much more likely to report that someone out-



TABLE 10 Tucson's Nondriving Older People: Alternative Modes by Trip Type (percent)

Trip Type	Sex	Someone Else Drives		Taxi	Bus	Walk	Others <sup>a</sup>	Do Not	
		In Home	Not in Home					Know	No Answer
Social	Male	46.6	25.8	1.8	3.7	2.1	1.3	15.3	3.5
	Female	21.5	37.0	2.5	2.4	1.3	4.9	25.3	5.1
Grocery	Male	48.9	24.2	1.8	4.4	4.8	3.0	10.9	2.1
	Female	23.7	33.1	2.4	4.6	7.0	6.0	19.9	3.3

<sup>a</sup> Rounding errors.

SOURCE: Unpublished data from the Tucson Older Driver Project, Stage 99A.

TABLE 11 Tucson's Nondriving Older People: Alternative Modes by Age (percent)

Trip Type	Age Cohort	Someone Else Drives		Taxi	Bus	Walk	Others <sup>a</sup>	Do Not	
		In Home	Not in Home					Know	No Answer
Grocery	65-69	43.3	29.4	2.5	3.1	5.9	2.2	12.4	1.2
	70-74	41.2	27.8	1.3	4.0	5.1	4.3	14.4	1.9
	75-79	29.1	28.7	2.8	6.4	8.2	4.3	16.0	4.6
	80-84	24.4	31.4	2.6	2.6	5.8	7.7	22.4	3.2
	85+	19.7	26.2	0.0	11.5	1.6	13.1	21.3	6.6
Social	65-69	42.7	27.9	2.8	3.1	0.9	1.6	18.0	3.1
	70-74	36.6	29.4	1.6	2.7	2.4	4.3	19.0	4.0
	75-79	27.7	36.5	2.5	3.9	1.4	2.8	20.2	5.2
	80-84	23.7	37.2	2.6	1.9	1.3	3.8	26.3	3.2
	85+	14.8	29.5	0.0	3.3	3.3	4.9	31.2	13.1

<sup>a</sup> Rounding errors.

SOURCE: Unpublished data from the Tucson Older Driver Project, Stage 99A.

side their home would. Reports of potential taxi use rose with age for grocery trips but not for social trips. Most respondents did not actively consider using the bus or even walking.

Perhaps as striking as the gender differences are the high number of respondents who reported that they did not know how they would make these trips if forced to stop driving. Women were substantially more likely not to have an answer or to say that they did not know. This uncertainty went up with age. Among elderly age 80-84, almost 26% gave no response when questioned about how they would go grocery shopping if they had to stop driving. These nonresponse percentages were even higher for social trips, perhaps reflecting a willingness to ask someone for assistance with a "necessary" trip but an unwillingness to ask for social trips. Among elderly age 80-84, for example, almost 30% had no idea what they would do to make social trips, while more than 44% of those over age 85 did not have an answer.

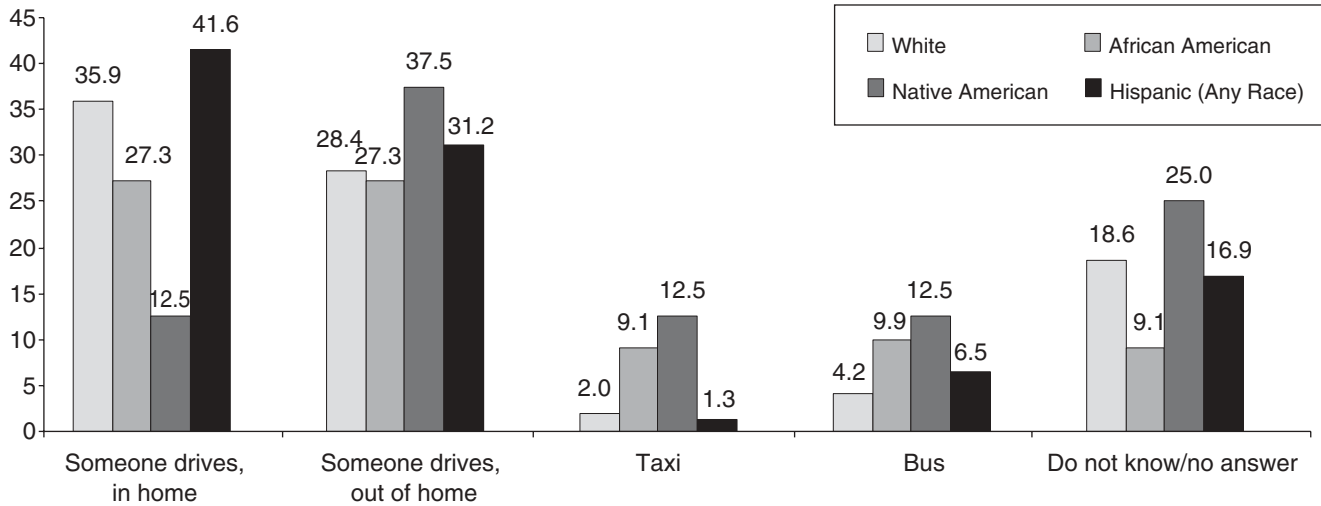
Following the earlier analyses, Figure 9 shows the impact of ethnicity and race on the answers given by older Tucson drivers to the question of what they would do if they were forced to stop driving. Hispanics (of any race) were the most likely to think that someone would drive them. At the same time, the driver would differ;

Hispanics were substantially more likely than any other groups to think that someone within their own home would drive them.

Native Americans were the least likely to report that someone in their own home would drive them and most likely to say that they would take a taxi. More than 12% of Native American respondents would use a taxi for grocery shopping if forced to stop driving. Ethnicity and race also affected bus use. Native Americans were as likely to report that they would take the bus as take a taxi (12.5%), while African Americans were only slightly more likely to favor the bus over a taxi (9.9% versus 9.1%).

There were also important differences in the "did not know" and "no answer" responses by race and ethnicity. Native Americans were the most likely to report uncertainty. One in four could not think of a response or an alternative. African Americans were the least likely to report that they did not know or to leave the answer blank. One in six Hispanics and whites did not know or could not provide an answer.

Tucson may not be representative of the universe of older people, but these findings are alarming. First, they suggest that people are very dependent on other elderly people in their own homes for transportation, and they

**Number of Trips**

**FIGURE 9** Tucson's nondriving older people: alternative modes for grocery trips by race and ethnicity, 1999. (SOURCE: Unpublished data from the Tucson Older Driver Project, Stage 99A.)

may have limited resources beyond their own homes. Second, the fact that older people have not been willing to give thought to some basic questions about maintaining their lifestyle may be more than "bad planning." Their avoidance may reflect a realistic assessment of the lack of viable alternatives. In the words of an 83-year-old woman in Tucson, "the only option is to cross that bridge when I come to it."

## CONCLUSIONS

Older people today are substantially more mobile than their counterparts of just 10 years ago, and much of their mobility is linked to the car. Ironically, these same people are far more at risk of suffering significant declines in their quality of life when they can no longer drive than those in the 1970s or 1980s, because so many of the places they want to go and things they want to do are only possible with a car. It is not at all surprising that older people resist driving cessation. In many ways, it is also not surprising that they refuse to think carefully about the alternatives that could meet their needs when they must stop driving, including moving or changing the places they want to go, because they lack realistic options. They seem compelled to avoid facing the issue at all.

The disadvantages of losing the ability to drive will not fall evenly on the elderly population. Elderly living alone, particularly women, may face a disproportionate burden because they have no family or household members to assist them. There is substantial evidence that

women, because they live longer, are more likely to spend more of their years alone. Moreover, aging baby boomer women will have fewer children than the current elderly. In addition, far fewer older people live with their children than in the past (36). Thus, many older women will lack the household resources, such as a family member providing trips or bringing them groceries, which may be available to men with spouses or who live with family.

The burden of losing the car may also fall disproportionately on some older people of color. In the Tucson study of 1,300 older drivers, Hispanics were far more likely to think that family and friends would provide them with rides, while Native Americans and African Americans were less likely than whites to think that their families would help. Again, this raises the issue of the role of family in care giving and suggests that older people in different kinds of families may have different travel and mobility needs.

## SUMMARY

In the coming decades, there will be a huge increase in both the absolute number of older people and in their percentage of the U.S. population. The elderly in the future will look different compared with the elderly in the past. Most will be healthier and more independent for two and three decades after they retire. Almost all older men and a majority of older women will be car drivers and accustomed to the convenience and flexibility that the car provides. As a result of both trends,



older people in the future will enjoy active and mobile lifestyles.

Unfortunately, some older people who lack access to a car will not share those advantages. But even older people who do drive will increasingly experience physical, financial, emotional, and even mental barriers when using various transport modes for moving around their communities and accessing the services and facilities they desire. There is no indication that older people's need for activities outside the home will drop as fast as their skill levels or mobility resources. Sadly, for many older people, there will be a large gap between what they want to do and what they have the transportation resources to do. Certain older people will be especially disadvantaged, particularly those who live alone, have no close family, or have limited financial resources. Many of those hit hardest will be the very oldest and women living alone.

It is clear that traditional responses will not meet the large and growing needs of the new generations of older people. But it also should be clear that no single policy strategy can address the growing mobility gap. No single policy program will overcome the growing access barriers older people will encounter. People's travel needs and their problems result as much from land use and housing patterns, social and human service delivery systems, neighborhood and community design, and the physical specifications of various transport modes as they do from actual transportation programs and resources.

To meet the needs of older people, a comprehensive strategy will need to be developed—one that encompasses all the substantive issues and links all the policy arenas that affect the travel patterns of older people:

- Effective driver evaluation and retraining programs,
  - Better-designed cars and improved signage and information systems on roads and highways,
  - User-friendly public transport networks,
  - Choice of transportation alternatives,
  - Well-designed land use and housing choices,
  - Cost-effective delivery of private and public services,
- and
- Coordinated delivery of human and social services.

As a 1995 Population Reference Bureau report cautions:

Today's generation of elders has taught us that the older years can be both the best and worst of times in an individual's life. With some exceptions, most people now enter their older years with the health and resources to pursue full and independent lives. But the aging process does take a toll. . . . The transition from active, independent living to a period

when greater assistance is required can be a painful time. . . . Addressing this need will be one of the greatest challenges that individuals and society will face in the 21st Century. (36, p. 39)

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# Safety of Older Persons in Traffic

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Recent developments and the current situation in the safety of older road users—vehicle drivers, occupants, pedestrians, and cyclists—lead to the conclusion that although older drivers clearly have a higher risk of serious injury and fatality in traffic, the question of whether they also are at higher risk of crashes remains unresolved. Older persons' greater physical vulnerability leads to an overrepresentation—called the “frailty bias”—of their crashes in databases based on injury outcome. Similarly, their risk estimates based on mileage driven are overestimated—called “short mileage bias”—when compared with those of younger drivers with a higher yearly mileage (1, 2). Older drivers' crash-type distribution reflects both their strengths and their weaknesses. Most of their crashes occur at intersections, and older drivers' crashes seldom involve speeding or risky overtaking.

Attempts to relate crash risk to driver characteristics have successfully shown an increased risk related to certain illnesses such as dementia of the Alzheimer's type (DAT). In contrast, correlations between crash rates and measures of specific functional abilities in healthy older drivers typically have been low. As a consequence of their increasing participation in traffic, older drivers' share of traffic crashes undoubtedly will grow during the next few decades. However, future trends in crash rates may present a discontinuous development because of changes in the older driver population itself and in the physical and social operating environment.

## RECENT DEVELOPMENTS IN OLDER ROAD USERS' SAFETY

According to the 1988 Transportation Research Board *Special Report 218*, of the 45,802 persons killed in traffic crashes in the United States in 1986, 5,895 were 65 years of age or older (3). Traffic deaths of those age 65 or older accounted for about 13% of all traffic fatalities, roughly this cohort's proportion of the population (12%). The report stated that the amount of exposure to risk faced by older persons during the next few decades will increase as a consequence of both an increase in the share of older persons in the driving population and a probable increase in the average yearly miles driven by future older drivers. On the basis of this trend, a prediction was offered that older persons might account for 17% of all traffic deaths by 2020. By 1996 older persons' share of fatalities already had reached this level (from the same data sources used in *Special Report 218*; 4, 5). Of the 42,065 persons killed in traffic crashes in 1996, at least 7,112 were aged 65 years or older (Table 1). In contrast to their share of the population, which did not increase markedly from 1986,<sup>1</sup> their share of traffic fatalities was 16.9% in 1996. For those age 75 or older, in 1986 their share of the population was 5.9% and their share of traffic fatalities was 6.5%. In 1996 the corresponding amounts were 5.8% and 9.3%, respectively.

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<sup>1</sup> Older people made up 12.8% of the population in 1996 as compared with 12.1% in 1986.

TABLE 1 Traffic Fatalities and Population by Age and Gender, 1996

Age	No.			Percent			Population (percent)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
0-4	493	399	892	1.76	2.86	2.12	7.62	6.94	7.27
5-9	469	348	817	1.68	2.49	1.94	7.68	6.99	7.33
10-14	652	417	1,069	2.33	2.99	2.54	7.52	6.83	7.17
15-19	3,486	1,740	5,226	12.46	12.46	12.42	7.43	6.70	7.05
20-24	3,955	1,283	5,238	14.14	9.19	12.45	6.88	6.34	6.60
25-29	2,933	1,101	4,034	10.48	7.89	9.59	7.29	6.99	7.14
30-34	2,556	1,035	3,591	9.14	7.41	8.54	8.18	7.90	8.04
35-39	2,436	1,102	3,538	8.71	7.89	8.41	8.66	8.35	8.50
40-44	2,108	896	3,004	7.54	6.42	7.14	7.95	7.75	7.85
45-49	1,717	782	2,499	6.14	5.60	5.94	6.99	6.91	6.95
50-54	1,255	629	1,884	4.49	4.51	4.48	5.22	5.28	5.25
55-59	1,044	525	1,569	3.73	3.76	3.73	4.21	4.35	4.28
60-64	886	579	1,465	3.17	4.15	3.48	3.64	3.90	3.77
65-69	922	613	1,535	3.30	4.39	3.65	3.48	3.97	3.73
70-74	920	748	1,668	3.29	5.36	3.97	2.95	3.66	3.31
75-79	861	718	1,579	3.08	5.14	3.75	2.18	2.99	2.60
80-84	726	614	1,340	2.60	4.40	3.19	1.29	2.14	1.73
85+	557	433	990	1.99	3.10	2.35	0.83	2.00	1.43
Unknown	85	29	117 <sup>a</sup>	0.30	0.21	0.28			
<b>Total</b>	<b>27,976</b>	<b>13,962</b>	<b>42,065<sup>a</sup></b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>

<sup>a</sup> Counts include 13 fatalities of unknown gender.

In the United States, total traffic fatalities and fatality rates per person and per distance driven have essentially gone unchanged since 1991. However, the elderly are dying in traffic at a much higher rate than before. The fatality rates of nonmotorists (pedestrians and cyclists) have declined by 52% and 66% for those age 65-74 and age 75 or older, respectively, from 1975 to 1996. In contrast, from 1982 to 1996, the driver fatality rates for the same age groups increased by 41% and 97%, respectively (6). As shown in Table 2, in 1997 U.S. car crashes were the most serious source of concern regarding older persons' traffic safety. For 1997, in the age group 65 or older, the fatality rate per 100,000 persons was 12.70 for drivers, 5.21 for car passengers, 3.38 for pedestrians, and 0.18 for bicyclists (3).

In Europe the situation is somewhat different. The elderly are more likely to be killed as pedestrians than in a car (7). As an example, in 1997 in Finland, for the age group 75 or older, the fatality rate per 100,000 persons was 5.4 for drivers and 8.3 for pedestrians. From 1995 to 1997, 45% of those killed in traffic as pedestrians were 65 years or older (8). The crash picture of the U.S. elderly reflects the dominance of the private car as the main means of transport. Therefore, the rest of this chapter focuses on drivers.

## DATA SOURCES

The U.S. data come from the following sources:

- Crash data retrieved from the Fatal Accident Reporting System database and provided electronically by the National Highway Traffic Safety Administration (4),
- Population estimates based on the Bureau of the Census midrange estimates (5, 9),
- Estimates of licensed drivers from the Federal Highway Administration's Highway Statistics Series (10), and
- Estimates of yearly mileage by driver age based on the 1995 Nationwide Personal Transportation Survey—the survey's database describes the 1995 situation but can be used in combination with crash data from years around 1995 on the assumption that abrupt changes in the mileage by age distribution are unlikely (11).

## OLDER DRIVERS' SAFETY PROBLEMS

### Historical Background of the "Older Driver Problem"

The safety of older persons in traffic has been a source of concern and an object of scientific inquiry for several

TABLE 2 Number of U.S. Fatalities and Fatality Rate per 100,000 Persons by Age and Transportation Mode, 1997

Age	Pedestrians						Bicyclists						Drivers						Car Passengers					
	Male		Female		Total		Male		Female		Total		Male		Female		Total		Male		Female		Total	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
0-4	99	1.01	66	0.71	165	0.86	5	0.05	0	0.00	5	0.03	0	0.00	0	0.00	0	0.00	300	3.07	302	3.24	604	3.16
5-9	144	1.43	96	1.00	240	1.22	72	0.71	16	0.17	88	0.45	1	0.01	0	0.00	1	0.01	237	2.35	237	2.46	475	2.41
10-14	110	1.12	77	0.83	187	0.98	113	1.16	24	0.26	137	0.72	60	0.61	17	0.18	77	0.40	320	3.27	311	3.34	632	3.31
15-19	183	1.86	102	1.10	285	1.49	81	0.82	8	0.09	89	0.46	1850	18.80	793	8.53	2643	13.81	1217	12.37	864	9.29	2082	10.88
20-24	246	2.77	74	0.86	320	1.83	44	0.49	6	0.07	50	0.29	2469	27.76	685	7.98	3154	18.04	896	10.07	448	5.22	1346	7.70
25-29	253	2.70	83	0.88	336	1.79	49	0.52	6	0.06	55	0.29	1996	21.30	630	6.67	2626	13.96	531	5.67	314	3.33	845	4.49
30-34	318	3.09	103	0.99	421	2.03	48	0.47	4	0.04	52	0.25	1726	16.78	604	5.78	2331	11.24	372	3.62	283	2.71	656	3.16
35-39	331	2.94	137	1.20	468	2.07	65	0.58	15	0.13	80	0.35	1707	15.16	591	5.20	2299	10.16	278	2.47	284	2.50	563	2.49
40-44	336	3.18	118	1.09	454	2.12	53	0.50	6	0.06	59	0.28	1449	13.70	540	5.00	1989	9.30	230	2.17	253	2.34	483	2.26
45-49	288	3.18	116	1.23	404	2.19	45	0.50	5	0.05	50	0.27	1230	13.58	451	4.79	1681	9.10	177	1.95	240	2.55	417	2.26
50-54	221	3.00	76	0.98	297	1.96	35	0.47	0	0.00	35	0.23	1044	14.16	365	4.69	1409	9.30	140	1.90	208	2.67	349	2.30
55-59	174	3.09	64	1.05	238	2.02	21	0.37	3	0.05	24	0.20	746	13.23	342	5.59	1088	9.26	95	1.68	194	3.17	290	2.47
60-64	170	3.58	80	1.50	250	2.48	16	0.34	2	0.04	18	0.18	655	13.80	260	4.89	915	9.09	88	1.85	210	3.95	299	2.97
65-69	159	3.56	83	1.56	242	2.48	11	0.25	0	0.00	11	0.11	608	13.61	318	5.99	926	9.47	106	2.37	230	4.33	336	3.44
70-74	160	3.58	101	2.05	261	2.98	19	0.43	3	0.06	22	0.25	687	15.38	343	6.95	1030	11.77	90	2.02	269	5.45	359	4.10
75-79	147	5.02	97	2.33	244	3.44	16	0.55	0	0.00	16	0.23	621	21.22	333	8.00	954	13.46	111	3.79	313	7.52	424	5.98
80-84	126	7.32	87	2.96	213	4.57	6	0.35	0	0.00	6	0.13	493	28.65	303	10.30	796	17.07	96	5.58	240	8.15	336	7.20
85+	113	9.96	83	2.98	196	5.00	7	0.62	0	0.00	7	0.18	410	36.16	174	6.25	584	14.90	75	6.61	253	9.08	328	8.37

decades (Table 3). The “older driver problem” was recognized and established as a scientific and social problem after a first wave of intensive research in the late 1960s and early 1970s, mainly in the United States. In its first formulation, the problem was conceptualized as a general age-related safety problem. The focus was on the aging drivers’ functional deficiencies. The characteristics of the traffic system were taken largely for granted and not associated with crash causation. In line with this thinking, the first proposed safety measures were dominantly oriented toward screening drivers and eliminating from the driver population those at higher risk.

Research efforts in the 1980s were largely oriented toward describing in more detail the accident epidemiology of older drivers and developing a more thorough understanding of its general causes. As a consequence of this work, the first straightforward conclusions about age-related risk increase were contested to some extent. In particular, it was understood that the overrepresentation of older drivers in serious crashes did not reflect their crash rates per se, that is, their crash proneness as drivers. Rather, the overrepresentation was a combined product of the frequency with which they were involved in crashes and the chance of injury or death as a result of the crash (2). The societal importance of the older driver problem also was reconsidered. Although early research had focused on safety, the later focus shifted toward mobility (12, 13). The proposed safety measures also became more system oriented in character. This coincides with the changing road environment, as traffic volumes increase steadily and vehicles and roadway operations evolve.

Research efforts in the late 1980s attempted to describe in more detail the general nature of the older driver problem. At the same time, it was increasingly recognized that the problem might not be a general one. Gerontological research repeatedly demonstrated that interindividual variance on most performance variables increases with age. Clinical experience pointed out certain subgroups of older patients as a major source of safety concern instead of persons suffering from nothing more than normal aging. Older patients suffering from dementia, especially DAT, were identified as the highest-risk subgroup. During the 1990s, the focus of

research increasingly switched from a general approach to a differential one on high-risk subgroups.

## Crash Rates and Consequences

### *Are Older Drivers Overrepresented in Crashes?*

In traffic safety forecasts, reference has often been made to older driver overrepresentation or higher risk. As argued by Hauer (2), such an argument is neither empirically nor logically convincing. It also does not have crucial importance for the planning of safety measures. From a cost–benefit point of view it is reasonable to design safety measures for existing road user populations. As the number of older drivers increases in proportion to all drivers, gains in safety benefits from measures targeted toward older drivers also will increase. For this conclusion to be valid, assumptions about their overrepresentation are not needed.

Figure 1 shows injury and fatality rates for drivers in different age groups in 1997 in the United States using different exposure measures. All of these measures are commonly used in accident studies, and all have certain validity problems. The figure appears to show that although age-related risk increase is modest when related to population or number of licensed drivers, there is a sharp age-related risk increase in crashes by mileage. Hence, one might conclude—as often has been done—that older drivers become more dangerous with age but compensate by driving less. Such an explanation, although perhaps not entirely erroneous, does not take into account certain methodological difficulties to interpret the findings presented in the figure.

Both terms of the equation

$$\text{Risk} = \text{accidents} / \text{exposure}$$

have certain validity problems when used in comparisons among age groups, however measured. In most accident databases, cases are included on the basis of the consequences of the crash, such as “leading to personal injury” or “leading to fatality within vehicle.” For older drivers, this situation leads to frailty bias. A larger

TABLE 3 Synopsis of Research on Older Drivers

1970s	1980s	1990s
<ul style="list-style-type: none"> <li>• Safety problem—more crashes</li> <li>• General age-related cause—deficient drivers</li> <li>• Lacked system perspective</li> </ul>	<ul style="list-style-type: none"> <li>• Risk of crash vs. risk of injury</li> <li>• Mobility limitations as the problem</li> <li>• System perspective—pedestrians included</li> </ul>	<ul style="list-style-type: none"> <li>• Whose risk increases with aging?</li> <li>• Different problems related to different aging patterns</li> </ul>



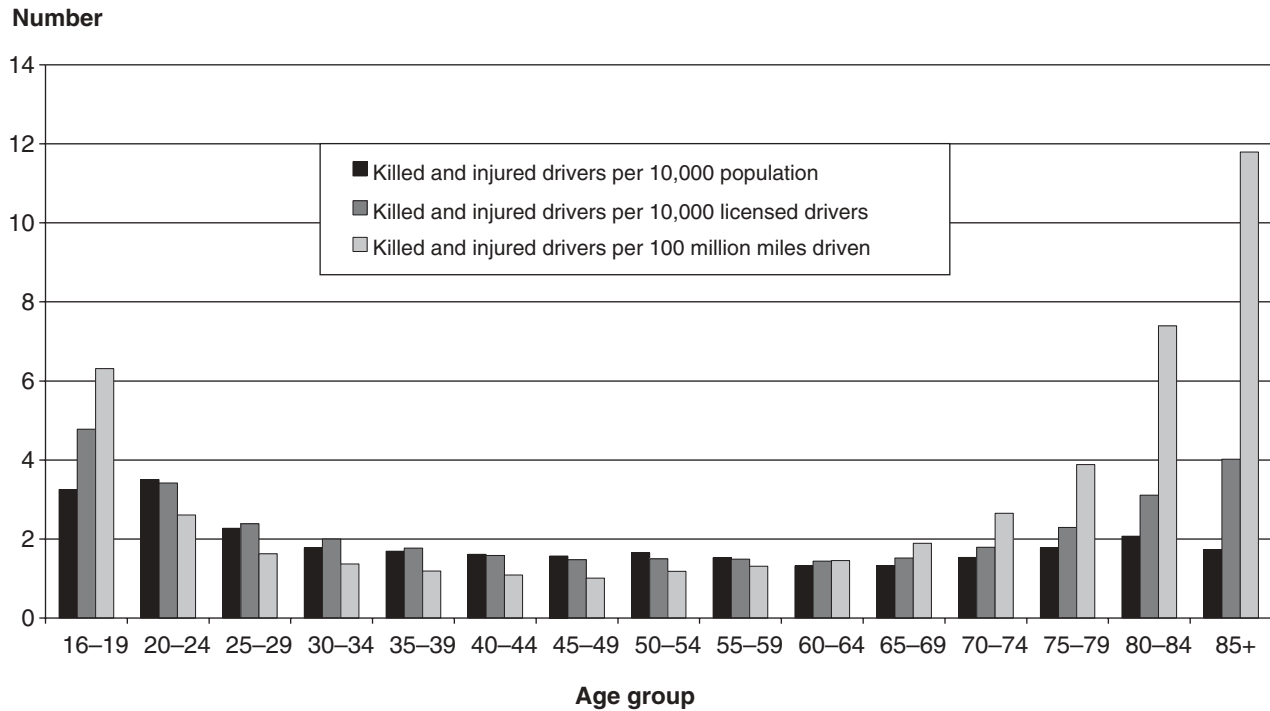


FIGURE 1 Driver fatalities and injuries by age, related to population, number of driver licenses, and mileage driven, 1997 (4).

share of older driver crashes is included in the official statistics because an old organism is more easily injured by a given physical impact. As demonstrated by Hauer (2), a graph showing a marked increase in older drivers' fatality rates flattens considerably when fatalities are replaced by crashes of sufficient severity to kill, for example, an 80-year-old male driver.

According to Maycock (14), half of the increased fatality risk of drivers 75 years old or older compared with 30-year-old drivers might be due to the enhanced susceptibility of the older drivers to be killed in the crashes in which they are involved—that is, because of the frailty bias instead of their higher probability of crash involvement. This sampling bias affects all three measures presented in Figure 1 and makes the age-related risk increase appear larger than it is.

Exposure measure choice results in different findings in age comparisons. In the late 1960s and early 1970s, it was accepted that older drivers in the United States had fewer crashes per capita and per licensed driver but more crashes per mileage than others (14). This finding was replicated repeatedly (12, 15). Crashes per population are a reasonable indicator of the general public safety impact of the crashes of a given age group. Because of different licensing rates in different age groups, however, the number of driver licenses provides a more accurate estimate of the number of drivers sharing the collective risk of any given age group.

Unfortunately, not even this measure provides a valid basis for age comparisons since the ratio of licensed drivers to active drivers may differ greatly among age groups, especially if different legal measures, such as health controls or driving tests, or differing access to automobile insurance, are applied at a certain age. Screening measures usually make it less plausible for nondrivers with increasing age to take the trouble of continuing to be licensed, which gives these age groups a worse crash-to-license ratio. In addition, active driver groups of comparable sizes have dissimilar exposure to crashes if their yearly mileage differs. To overcome this source of error in estimating driver safety, it is generally believed that a hard estimate of the actual amount of driving (e.g., miles driven) is needed. Unfortunately again for the validity of the findings, the relationship between yearly mileage and crash rates per mile is not linear but curvilinear, so that high-mileage drivers have, independent of age, lower crash rates per mile than low-mileage drivers. Hence, older drivers' risk estimates based on miles driven are overestimated when compared with those of younger drivers having a higher yearly mileage (16). Moreover, there is no available adjustment for the degree of difficulty of the roads older drivers choose to use. In conclusion, none of the measures presented in Figure 1 permits straightforward conclusions about how drivers' individual risk of crashes increases with age.

### Are Older Drivers a Threat to Other Road Users?

Contrary to common belief, older drivers do not present an excessive risk to other road users. They are more likely to be injured themselves in a crash because of their greater physical frailty and typical crash patterns. For example, when analyzing risk posed to other road users by the driver group age 65–74 compared with that posed by younger (<age 65) drivers, Dulisse (17) found in the Wisconsin crash outcomes data for 1991 that the risk to other road users per mileage was lower than for the group of older drivers. Only for drivers age 75 or older was it slightly higher. However, all statistical differences disappeared after controlling for certain confounding background variables. Maycock (14) presented a similar conclusion based on data from the United Kingdom. As shown in Figure 2, in the United States in 1997, older drivers produced only a small share of all crashes leading to injury or death of pedestrians.

### Typical Crashes and Explanations

#### Crash Types

Older drivers as a group have not only different crash rates but also qualitatively different crashes than younger drivers. Compared with the crashes of younger drivers, a larger share of older drivers' crashes involves a collision between vehicles as opposed to a single-vehicle crash (18, 19). Older drivers also tend to

be the legally responsible party in their collisions (18, 20, 21). In a typical intersection crash situation, older drivers apparently do not see the other vehicle in time and fail to yield the right-of-way. Conversely, their small share of crashes as nonresponsible parties also reflects the fact that older drivers have a slow, conservative, and cautious driving style, which makes them harder to hit as innocent parties than are younger, less defensive drivers (16, 22).

Many older drivers' collisions occur at intersections (2, 19, 23–25). In a typical situation, the older driver turns left against the oncoming traffic of the main road and is hit by a vehicle with the right-of-way. Figure 3 shows the percentage by driver age of angle collisions for fatal crashes of U.S. drivers in 1997. In these data, the share of angle collisions, typically involving intersection situations, more than doubles from the youngest driver group to those age 80 or older. The high share of angle collisions when the older driver is hit from the side by an oncoming vehicle offers a partial explanation, in addition to the frailty effect, of why older drivers' crashes tend to have the most serious consequences for themselves and why their counterparts are less likely to be injured.

In the literature, age-related changes in crash patterns are often discussed in terms of overrepresentation. This approach easily leads to proportional comparisons fallacy—that is, a decrease in one crash type automatically leads to an increase in the share of the others and vice versa. Yet all driver groups have their crashes somewhere. For older drivers, the increase of intersection crashes has been such a salient finding that less attention is generally paid to the fact that older drivers

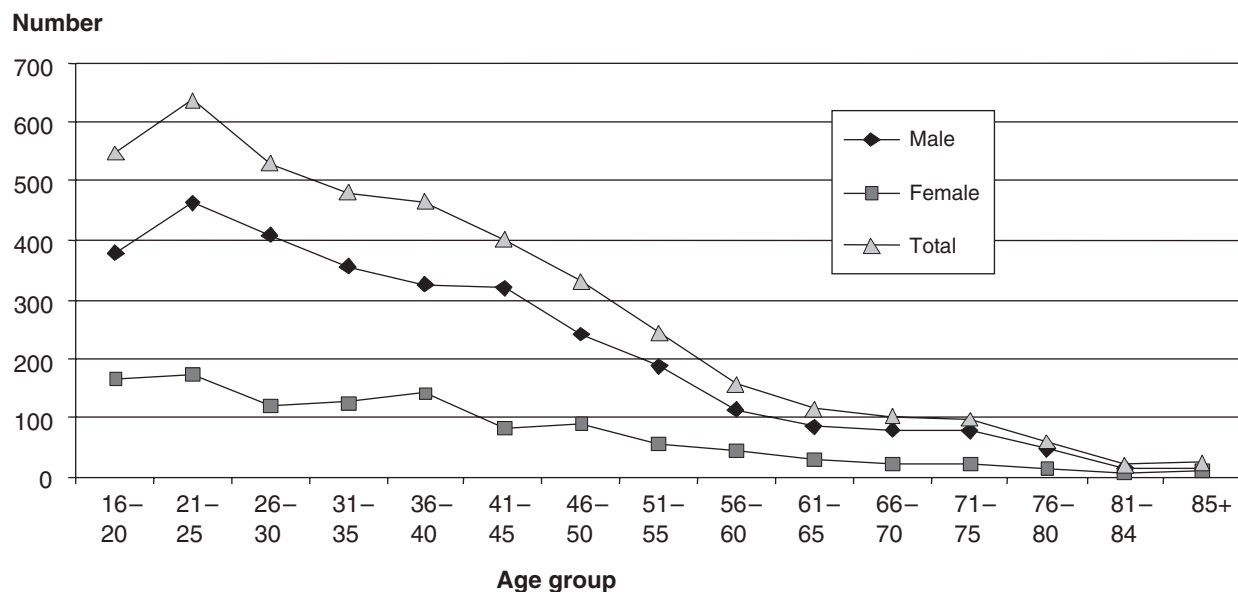


FIGURE 2 Single-vehicle fatal crashes leading to pedestrian fatality by driver age and gender, 1997 (4).



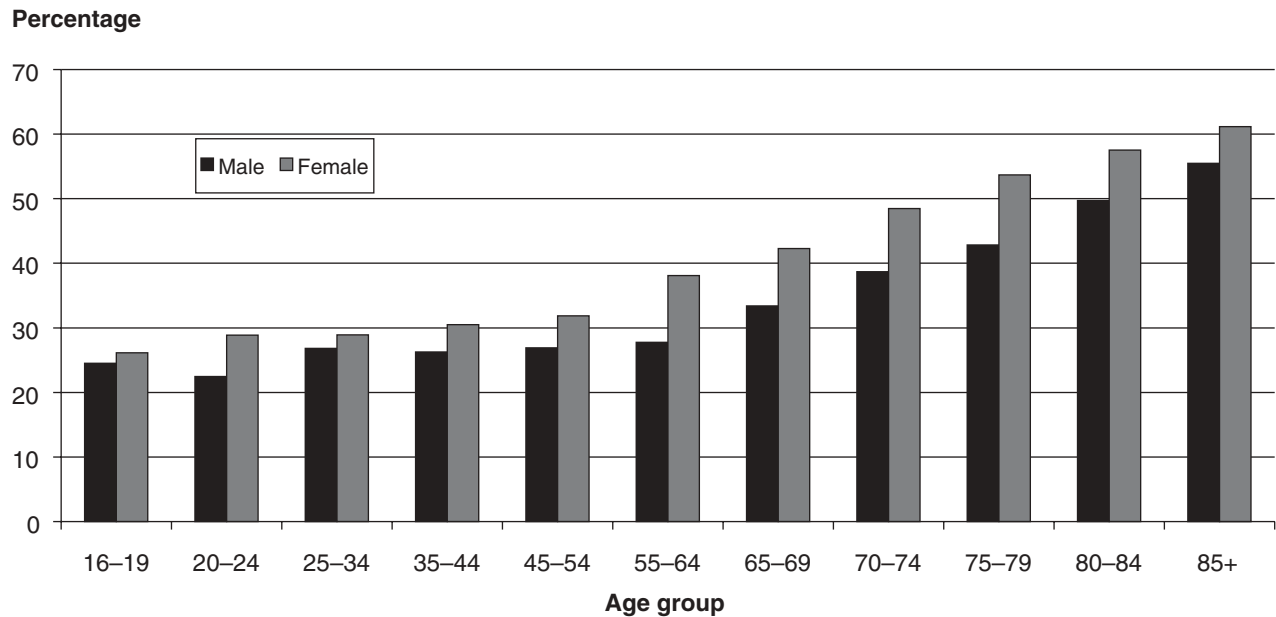


FIGURE 3 Percentage of angle collisions among all fatal collisions by driver age, 1997 (4).

are underrepresented in the other types of crashes, such as single-vehicle crashes involving loss of control or collisions because of speeding or risky overtaking. However, the decrease in crashes because of high speeds is also a significant finding since it corresponds to what is known about changes in older drivers' habits.

### *Behavioral Adaptations and Crash Risk*

Older drivers are known to modify their driving in several ways. First, they drive less. According to all available studies, yearly mileage driven decreases with age. This statistic is probably related to both the older drivers' changing mobility needs, especially following retirement, and a personal choice based on subjective judgment. Second, older drivers tend to avoid driving in difficult conditions, such as darkness, slippery roads, peak hours, and other stress-inducing situations (26-28). Third, their driving style becomes calmer, and their decision making in traffic more conservative. Older drivers choose lower speeds, prefer longer time gaps for merging at intersections (29, 30), and avoid simultaneous activities such as smoking or adjusting the radio while driving (31). These compensatory changes reflect both the older person's mature judgment—sometimes called wisdom—and a behavioral adaptation to age-related changes in the performance levels of certain important functions. It may not be entirely accurate to label such behavioral adaptations compensation, however, since that term implies responding to a loss. Not

all behavioral changes need be compensatory in the sense of counteracting experienced difficulties; they may simply reflect personal preferences. Most drivers would probably avoid driving in darkness and during peak hours if not forced to by circumstances beyond their control. Note that this group-level description of older driver behavior hides considerable interindividual variance. For example, older female drivers report self-imposed limitations on their driving more often than their male counterparts (27). It also is likely that older drivers with illnesses affecting their higher mental functions do not display the same cautious driving behavior as older drivers with intact judgment.

The crash conditions of older drivers reflect their typical driving habits and behavior. Older driver crashes most often occur during the daytime and in good weather (18). In addition to avoiding difficult external conditions, older drivers appear able to cope with variations in their own internal condition, such as being in a hurry. A Finnish study showed that neither being in a hurry nor alcohol intoxication affected the probability of an older driver being the legally responsible party in a crash. Conversely, among middle-aged drivers, the probability of being found guilty was strongly increased by these same conditions (32).

### *Functional Changes and Crash Risk*

The large share of intersection crashes is often interpreted as a sign of older drivers' failing capacity for

dealing with complex environments. Less often is their small share of single-vehicle crashes seen as a sign of a mature, safety-oriented driving style. Without adopting such an ageistic perspective, one might, however, pose the following question: since older drivers seem successful in avoiding crashes involving loss of control, why are they not equally successful in avoiding crashes in complex environments such as intersections?

Two aspects of the task of negotiating intersections merit consideration. First, although an older driver's main strategy for facilitating a driving task is to decrease momentary load by driving slower, negotiating intersections is in many cases not a self-paced task but a forced-paced one, defined by the number of roads, lanes, and cars to scan and their respective free-sight distances. Therefore, older drivers may be forced to perform under a time pressure that exceeds their capacity. Second, driving in intersections is a complex task, accumulating a number of subtasks involving perceptual, attentional, and motor domains, which all are known to deteriorate with age. For example, regarding attention, drivers have to divide their attention between different road directions to scan and vehicle handling. They have to select, focus attention on, and switch among the task-relevant aspects of the traffic situation, and they have to ignore any irrelevant information. All these attentional functions have been shown to deteriorate to some extent with age (33).

In summary, intersection driving may become a testing-the-limits type of task since it combines a host of age-sensitive functions, while limiting the usefulness of normal safe-driving strategy—that is, driving slowly. It would therefore appear plausible that an individual risk increase is related to a combined deterioration pattern for many relevant perceptual and cognitive functions instead of the deterioration levels of single functions. This idea is supported by the research literature. Despite repeated efforts, correlations between single functions and crash rates are at best low and often only are found in extreme subpopulations of older drivers (34). It may be relatively easy for an older driver with intact judgment to compensate for one single specific loss of function, such as moderate shrinkage of the visual field. In contrast, a simultaneous deterioration of several relevant functions probably poses greater demands on higher-level monitoring and compensating activities. If higher-level functions, such as judgment, were impaired, a considerable risk increase would be expected.

### *Differentiation of Older Driver Crashes*

In figures depicting crash risk by age, the impression is easily created that chronological age per se affects a person's safety as a driver. However, crashes are not

equally distributed among all older drivers. Moderate functional changes related to normal aging do not necessarily lead to a discernible increase in crash risk. In addition, an important part of the risk of the oldest driver groups probably is attributable to patterns of functional deficits. These deficits are related to certain illnesses whose prevalence increases with age, especially illnesses leading to cognitive deterioration such as different dementias. As a consequence of the first studies in the late 1980s showing that DAT dramatically increases a driver's crash risk (35, 36), there has been a change of direction in older driver crash research from a general approach asking "why do older drivers have higher crash risk?" to a differential one asking "which older drivers have higher crash risk?"

Most studies show a substantial risk increase because of dementia (37–47). However, it also has been shown that the risk does not necessarily increase in the early stages of the illness and that many patients with a DAT diagnosis have intact driving ability (47). Therefore, it has been suggested that beginning or mild dementia should not lead to an automatic loss of one's driver's license and that assessing functional abilities related to driver competence in the mild stages of dementia is a better approach.

It also has been suggested that several other medical conditions, such as epilepsy or insulin-treated diabetes, increase a driver's crash risk (48). Medical considerations are discussed in more detail in these proceedings by O'Neill and Dobbs (pp. 56–66). The prevalence of most of these is not, however, as clearly related to age as that of the different dementias. For many well-studied medical conditions, conclusive evidence about risk increase in traffic is still limited. Thus, again, functional assessment may be warranted instead of reliance on a diagnosis.

### FUTURE DEVELOPMENTS

Unless there are dramatic changes in auto safety, travel patterns, and fatality trends, older drivers' share of serious traffic crashes will undoubtedly grow during the next few decades, but it is difficult to produce accurate predictions about future developments of the older road users' safety situation. As seen earlier, the prediction from *Special Report 218* clearly underestimated the increase of older road-user crash rates, especially those of older drivers. Since future trends in licensing rates, driving habits, and crash rates may present a discontinuous development for several reasons, extrapolations based on the current situation are subject to considerable uncertainty.

Figure 4 shows a projection of older (age 65 or older) driver fatalities in the United States (6) on the basis of conservative estimates of licensing rates and yearly

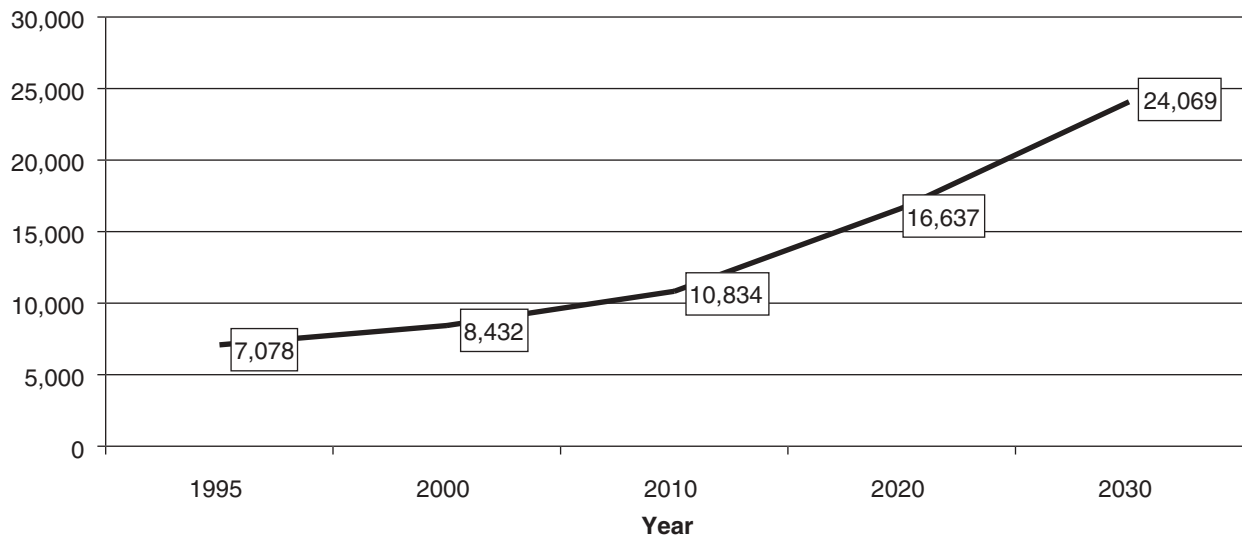
**Fatality involvements**

FIGURE 4 Projection of fatalities involving older drivers in the United States, 1995–2030 [adapted from Burkhardt et al. (6)].

mileage; it is likely that future involvement rates also will be underestimated. The figure shows that the development between 1995 and 2000 is projected to be less dramatic than during the following decades. This projection exemplifies a classic source of error in gerontological studies, namely, time-related variation. During the 1920s, birth rates were temporarily down in several industrialized countries. As a consequence, increases in the elderly population slowed temporarily during the 1990s, making the decade less representative of the overall aging trend. Probably more important in the present context, however, are cohort- and gender-related variations and their interactions.

### Cohort Effects

Private-car use is a relatively recent phenomenon. Older drivers in many countries are a select group of their cohorts and often have learned to drive as adults. In future cohorts of older drivers, the majority will have a driver's license and will have started driving in their youth. In addition, during the active driving career of the present older drivers, the task environment—including the design of cars, roads, and rule systems—and the rhythm of road traffic have undergone profound changes. Hence, the specific experience pattern of current older drivers may produce behavioral and safety outcomes that will not be repeated among future cohorts, who will probably have a more homogeneous learning history. It is therefore difficult to say which findings concerning older drivers' accident epidemiology

are truly age related and valid as a basis for predictions and which ones are merely cohort-specific phenomena.

According to the accumulated research literature, older people born later are more likely to have a driver's license, and they tend to drive farther than their cohorts born earlier. Hence, the older driver groups' exposure to crashes will certainly grow. However, several studies indicate that older driver crash rates do not increase in direct proportion to their representation in the licensed-driver population—that is, elderly drivers born later are safer than their cohorts born earlier (49–51). As to the types of crashes, a study based on Finnish data (52) shows that for both male and female drivers age 60–79, the tendency to incur a crash at intersections increased with age in all cohorts. However, younger cohorts show the age-typical crash picture at a somewhat later age than older cohorts. Even the dominance of intersection crashes thus appears both an age-related and a cohort-related phenomenon—age related in the sense that it will emerge eventually, but with cohort-related variance in timing.

### Gender Effects

Older women's participation in traffic and their driving behavior are major sources of uncertainty in predicting the future. In 1995 in the United States, 55% of women and 84% of men age 75 or older had a driver's license. In successive cohorts, this gap shrinks. Among baby boom women, 94% have a driver's license (53). In the future, an increasing proportion of older drivers will be

female. However, although gender differences in licensing rates and access to a private vehicle are vanishing, gender differences in travel patterns still persist. Women make shorter work trips, use public transit more, make more trips for the purpose of serving another person's travel needs, and drive lower yearly mileage than men (54, 55).

The safety impact of the increasing share of older women drivers is hard to estimate, since even the risk estimates for this category are somewhat ambiguous. Older women are less likely to be involved in a crash than older men per licensed driver, but per mileage the involvement rate is almost twice that of older men's (27). However, given older women drivers' considerably lower yearly mileage (56), the latter estimate is subject to error, as discussed earlier. Older women drivers also have been found to have more self-reported problems in intersections (57) and with navigation (58), and they are more likely than older men to limit their driving exposure to avoid difficult driving conditions (27). Older women also appear to acquire a more elderly-like crash profile, with a high share of intersection crashes, at an earlier age than do older men (19, 25). It has been suggested that these gender differences might be due to a lack of—or different quality of—driving experience in comparison with older men (19). However, cohort effects within gender effects are likely to complicate the picture in the future, since gender differences in driving habits and experience histories are likely to become smaller in younger cohorts than in current elderly drivers.

### System Changes

The sources of uncertainty in safety projections described earlier are related to older drivers only: licensing rates, travel patterns, and driving behavior. However, it reasonably can be expected that the transition of older drivers from a minority group with special needs and habits to one of the important subgroups of drivers will affect the dynamics of the whole system, including the behavior of other road users. An occasional older woman driving slower than the speed limit may be a source of irritation for others, but there is little point in protesting the driving style of 30% of one's fellow drivers. The increasing probability of having to interact with an older driver may elicit profound changes in the behavior of all drivers, as well as in the patterns of interaction among the participants of the traffic system.

This issue may be addressed by drawing a parallel with Smeed's law, which states that the first few private cars in a country have high fatality rates per car, but with increasing car density, the fatality rates per car go down (59). A similar development has been observed

for other phenomena whose frequency increases over time (e.g., bicycle use in general, bicycle densities at specific intersections; 60). As these observations appear to suggest, if there is a more general "unit density law," then one also may predict that with increasing participation of older drivers in traffic, the crash rates per older driver will go down.

Figure 5 is a speculative attempt to test this hypothesis. It shows each state and the District of Columbia ordered according to the percentage of licensed drivers who are age 65 or older and the percentage of drivers age 65 or older involved in fatal crashes. In general, the increase of the share of older drivers does not entail a corresponding increase in their share of fatal crashes. However, the difference in the slopes of the regression lines is modest, and the figure does not provide strong support for the idea that an increase of the share of older drivers will automatically decrease their crash rates per driver.

### CONCLUSION

With the increasing participation of older drivers in traffic, their share of crashes will inevitably grow. In addition, since physical vulnerability increases with age, crashes involving older drivers will more often lead to serious injuries and fatalities. Despite difficulties in predicting future developments, clearly there is reason for serious concern. Add to that what research shows about a possible increase in driver risk with age. So far, the evidence concerning age-related increases in crash rates is inconclusive for two reasons. First, a large part of what appears an increase in driver risk with age is due to biases inherent in the measurement of risk. Second, the issue is not age per se but which older drivers are at increased risk because of illness or age-related functional decline.

Since the ultimate objective of traffic safety work must be to increase well-being in the present context, it is important to point out that crashes are not the only traffic-related health hazard for older people. Lack of adequate mobility options may hamper an older person's opportunities for an active life and negatively affect his or her health and wellness. This situation should be kept in mind especially when discussing such age-related control measures as driver screening, unless such screening measures are used to improve driver competence through further training or remediation programs, as discussed in these proceedings by Staplin and Hunt (pp. 69–94). Since crashes are rare events, the exclusion of an older driver from the driver population produces at best an uncertain gain—that is, the prevention of a crash with an uncertain likelihood. In contrast, it often leads to predictable disadvantages, such as the

Percentage

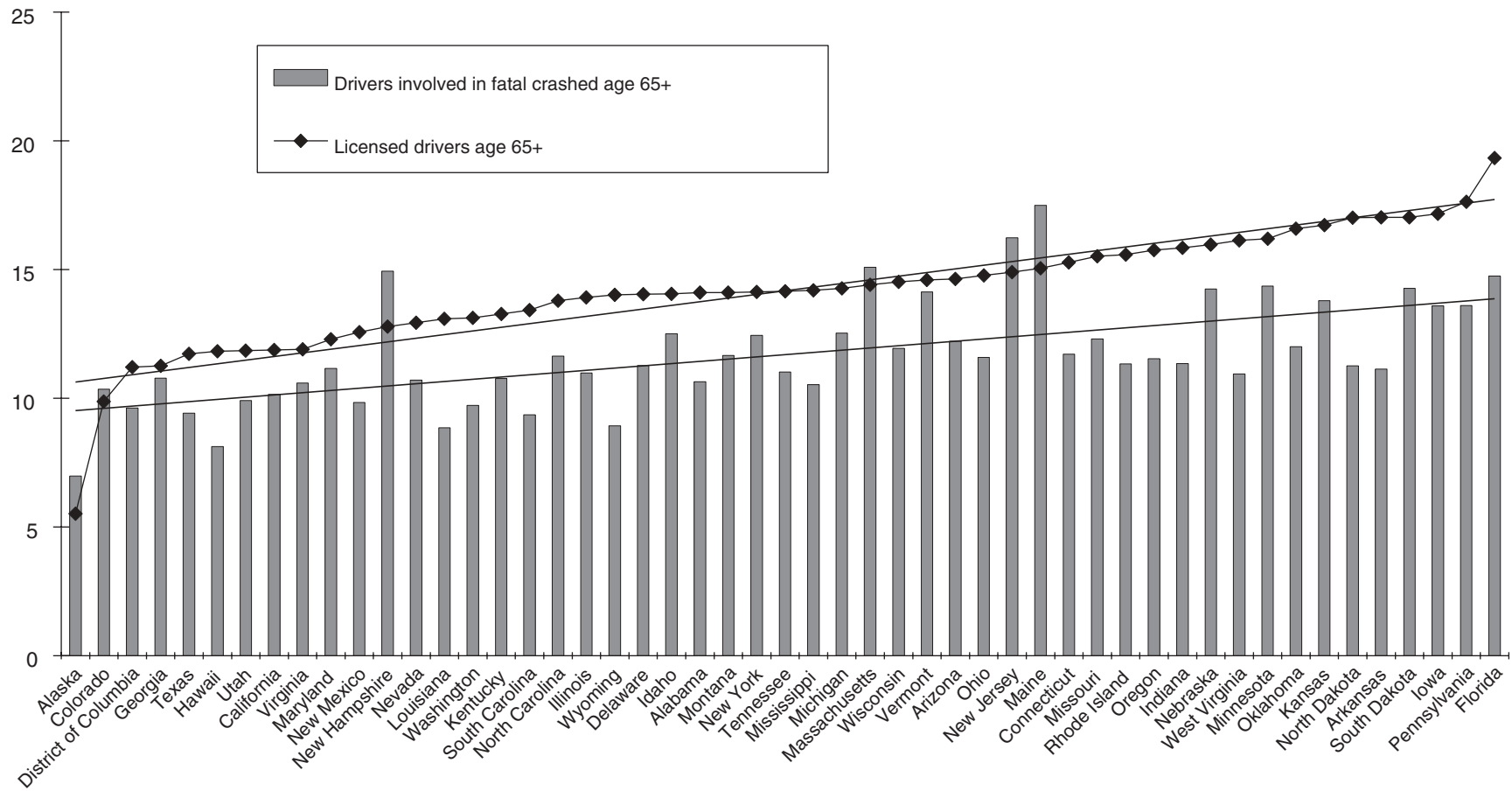


FIGURE 5 Projection of driver fatalities in the age 65 or older group by percent of licensed drivers.

choice of more dangerous transport modes, reduced mobility, and increased dependency on others. It is easier to get reliable cost-benefit ratios with measures aimed at the amelioration of the traffic environment or the vehicles. For such measures, older drivers are an excellent target group, since measures planned for older drivers tend to be beneficial for all drivers.

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# Adaptive Strategies of Older Drivers

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The aging process affects the visual, auditory, and information-processing abilities, all of which in turn affect driving. The bulk of the literature on older drivers focuses on the negative changes in driver performance or, as Evans (1) defined it, “what the driver can do.” Is there any hope for older drivers? Somewhat less attention has been given to what the driver does do. Here, there is more room for optimism about older drivers. Humans are by nature adaptive. The *Oxford English Dictionary* defines adaptation as the “process of modifying to suit new conditions.” Changes in physical, perceptual, and cognitive abilities are new conditions that everyone faces with time. Adaptive changes concern conscious and unconscious decisions made by older drivers in relation to driving and in response to conscious and unconscious awareness of declining functions and changing mobility needs.

## MODELING DRIVING BEHAVIOR

It is useful to consider driving in terms of three levels of behavior (2):

- Strategic behavior concerns such high-level decisions as whether to continue to drive, where to live in relation to destinations of choice (e.g., friends, family), which mode of transit to use, what time of day to make a trip, what weather conditions to drive in, and whether to wear a seat belt. Strategic decisions take place before the drive even begins.

- Tactical behavior concerns decisions such as at what speed to drive, what gaps in traffic to accept, and what headway to adopt.
- Operational behavior concerns the details of driving, such as the method used to scan the roadway, the amplitude and frequency of steering movements, and the variation in speed.

This hierarchy parallels Rasmussen’s (3) knowledge-, rule-, and skill-based descriptions of behavior (4). Strategic behavior is the most amenable to individual conscious choice and thus can be considered knowledge-based behavior. Strategic decisions, such as continuing to drive or whether to drive in the rain, depend on reflection of personal limitations. Such decisions are made over time, not on a second-to-second basis.

Tactical behaviors occur at the rule-based level. Tactical behavior concerns speed choice, headway choice, and gap selection—choices determined by the rules of the road and experience in traffic. The rules allow a certain range of operation within which older drivers have some choice. However, there is a limit. To reduce information-processing demands, older drivers may wish, for example, to drive at 40 mph on a freeway or wait for a 10-s gap before turning left; but they dare not because they realize that they may be increasing the risk of an accident and the irritation of other drivers. Although tactical decisions can be modified to a degree, there are definite limits.

Operational behavior can be defined as skill based (i.e., highly automated after much practice) and second-to-second behavior. Drivers are unconscious of the

details of this behavior. For example, few drivers know when they are using heading-angle versus heading-rate cues, nor would they be able to describe how their visual search patterns change in different traffic situations. Such behavior is the least amenable to adaptive choices.

First, older drivers' perception of their capabilities and of their changing social needs is examined. Then, evidence for adaptations made at the strategic, tactical, and operational level is considered. Finally, on a global level, the degree to which adaptation to the aging process allows older drivers to maintain the same level of accident risk as middle-aged drivers is explored.

### Awareness of the Need to Adapt

Compensatory changes in behavior are more likely if drivers are aware that they need to adapt. Numerous studies have considered the issue of driver self-perception of capabilities and risk of an accident. The general finding is that the majority of drivers rate themselves as more skilled than the average driver. Holland (5) examined risk perception in a group of drivers over age 50, asking them to compare their risk of an accident with drivers age 30, 50, and 70. She found that older drivers had less self-bias than younger drivers did.

In Holland's study, two driving situations were considered. In the first situation, drivers were in control—for example, while changing lanes. In the second, drivers were not in control—for example, when a tire blew. In the latter situation, with increasing age, positive self-bias reduces and becomes negative. The 70-year-old group of drivers felt that younger drivers would be less likely to have an accident when not in control than their senior counterparts. With the in-control situation, the oldest drivers believed that they would do better than other drivers, but the degree of self-bias was reduced compared with younger drivers.

Thus, there is an awareness of increased likelihood of an accident with age and an awareness that in an uncontrollable situation, younger drivers may be capable of reacting and thinking more quickly. However, this awareness appears more general. Holland referred to earlier work by herself and Rabbitt, showing that older drivers did not believe themselves to be particularly at risk in situations that driver instructors identified as problematic for older drivers (6). Nor did they believe themselves at risk in situations that statistics show as having a higher probability of an accident. Holland mentioned intersection accidents in particular.

Lerner et al. (7), however, painted a slightly different picture of older-driver risk perception. They examined drivers' varied perceptions of risk on a second-by-second basis along a 21-mi primarily rural Maryland road section. Two groups of drivers were involved, with

mean ages 20 and 65, respectively. Subjects rotated between driving and being a passenger. As passengers, they continuously rated the risk of an accident by rotating a dial mounted on the dashboard. Older and younger drivers were similar in risk-perception patterns. For both groups, the main determinant of perceived risk was the geometric demand of the road. Subjects felt most at risk on sharp curves and as they crested hills with limited sight distance. Furthermore, perceived risk ratings collected during daytime driving were generally higher than nighttime ratings for both groups of drivers—an unexpected result, given the greater risk of nighttime driving.

Although the overall pattern of risk perception was generally the same, there were notable exceptions. Older drivers rated the risk higher overall. This difference was most pronounced in the daytime and less at night. Lerner et al. speculated that this might result from the reduction in visual complexity at night, so that the information-processing demands were more similar for younger and older drivers. They also attributed this effect to the lack of other traffic and, therefore, fewer problems for older drivers because of headlight glare.

On approaches to intersections, younger drivers' ratings tended to drop or stay relatively flat. In contrast, the older drivers' ratings often showed a sharp increase. Similarly, older drivers showed rating peaks when merging from a freeway on-ramp, exiting a freeway, and merging onto an arterial. Older drivers' perception of greater risk at intersections was appropriate, given the higher objective risk in these situations both overall and for older drivers in particular. In contrast, younger drivers did not perceive a high risk in these situations, despite the fact that the risk of an accident was higher objectively.

### Changes in Social Needs with Age

Older people modify where, when, and how much they drive as a result of changes in their social needs. In a study of the driving exposure of Ontario drivers (8), demographics were collected from about 4,500 drivers age 16–89. The sample was stratified into six age groups, of which three were groups of older drivers (ages 60–69, 70–79, and 80–89). In the age 60–69 group, depending on geographical location, only 8% to 25% were employed. The majority (71% to 83%) reported that they were retired or, for women, homemakers. These percentages increased with age. With retirement from paid employment comes flexibility in driving time and a cessation of the need to drive during peak hours.

Aging reduces the need to drive for some but increases the need for others—specifically widows who

previously relied on their husbands to drive them. In the sample of older drivers, 23% of the age 60–69 group of female drivers were widowed, divorced, or separated, compared with 8% of the male drivers. In the age 70–79 group, this rose to 43% of the women and 16% of the men. By age 80–89, 65% of the women were in this category but only 21% of the men.

The likelihood that many older women started driving in response to the loss of a mate is suggested by the higher median age at which female drivers obtained their driver's license. In the age 25–59 group, the median age was 18 years old for women. In the age 60 or older groups, the median age was 29–31 years old—as opposed to 20–24 years old for the men—suggesting that many older women started driving later in life.

Along with aging, there is a strong tendency toward increased morningness—the tendency to wake earlier—and early bedtimes. In combination with worse night vision and more free time during the day, this tendency means less desire to drive at night.

In summary, changing social roles result in reduced exposure for older drivers, with the exception of older widows who obtained a driver's license later in life. Changing social roles also reduce the need to drive at high-risk times, particularly at night and during peak hours.

## Adaptations

### Strategic

At the highest level, the most effective strategic adaptation with age is to live where there is a choice of travel mode. If declining abilities force a person to abandon driving, there are other ways of maintaining independent mobility. The most numerous mode choices are in the center of major cities. Thus, the best adaptation for older people would be to move to the city. However, the strategic choices that older people make—and are likely to make in the future with regard to residence—do not optimize mobility. *Special Report 218* on aging (9) indicates that most people grow old and remain in the same areas where they lived most of their lives. As the population moves more to suburban areas, older people also are expected to locate there in greater numbers. In Michigan, for example, the population over age 65 that lives in the inner city declined slightly from 3.1% in 1960 to 2.8% in 1990. In contrast, the figures for the fringe areas showed an increase from 1.5% to 4.6% (10).

In low-density suburban areas, public transit is minimal because it is not cost-effective. Mobility in the suburbs means reliance on a car. Consequently, the choice of living in the suburbs is not the best strategic adaptation in terms of mobility. Younger drivers do not make the

optimum strategic choice for transportation in regard to place of residence either. Lee-Gosselin (personal communication, 1999) noted that residential mobility is classically linked to the cost of the journey to work, not to the rest of travel, despite the fact that the rest of travel makes up 70% of all trip costs and is rising.

Instead, it appears that the main strategic adaptation to age is to reduce driving exposure. Studies commonly find reduced driving exposure with increasing age. For example, the Ontario study found that kilometers traveled declined from 37 km per day on average for age 25–59 drivers to 26 km, 19 km, and 12 km for age 60–69, 70–79, and 80–89 drivers, respectively (8).

Not only is exposure reduced overall, but high-risk exposure is reduced even more. The Ontario study examined seasonal differences in exposure and found that the likelihood of older people driving in the winter was about half that of older people driving during the rest of the year. In contrast, the youngest drivers, age 16–19, were as likely to drive in winter as in any other season. The reduction of driving in the winter is an appropriate adaptation for older people. The Ontario study showed that older drivers' accident risk is considerably higher in the winter compared with other times of the year—almost three times higher for the age 60–69 group in particular.

The higher risk of an accident during nighttime driving is well recognized. The Ontario study recorded the percentage of drivers taking one or more night trips, defined as trips starting between 9 p.m. and 3 a.m. (Figure 1). Note again that the youngest and most inexperienced drivers do the greatest amount of driving in this high-risk period.

In an issue of *Accident Analysis & Prevention* devoted to older road users, Ball et al. (11) reported reductions in high-risk driving situations among 257 older drivers who participated in a medical screening and completed an exposure questionnaire. Many older drivers were found to limit their exposure in challenging situations (e.g., rain, night, heavy traffic, peak hours). In an extensive survey of 2,414 seventy-year-old Finnish drivers, Hakamies-Blomqvist and Wahlström (12) found large percentages of drivers avoiding various situations. Slippery roads were most avoided (by about 55% of women and 35% of men), followed by peak hours, night driving, and driving in winter. Smaller percentages (12% or less) of drivers reported avoiding particular types of roads, such as urban areas and highways.

The circumstances in which accidents occur can reveal strategic choices made by older drivers. Hakamies-Blomqvist (13) used the database of all fatal accidents in Finland during 1984–1990 to determine the degree to which older drivers exhibit compensatory behavior. The accidents of drivers age 65 and older were compared with those of a younger group age 26–40. The

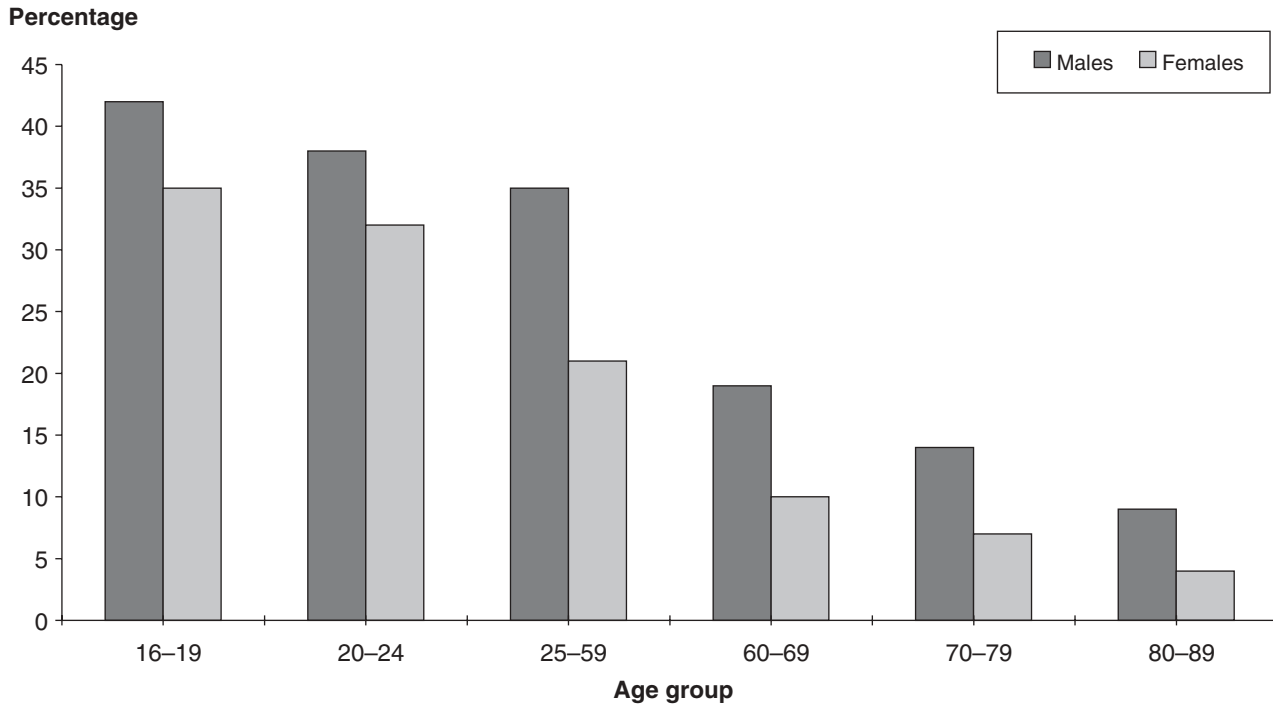


FIGURE 1 Percentage of drivers taking one or more night trips (8).

results supported the hypothesis of compensatory behavior by older drivers. Older drivers were less likely to be involved in nighttime accidents than were the younger group (6% versus 26% for accidents between 9 p.m. and 7 a.m.). It also was found that older drivers had more of their accidents in sunny weather (76% versus 35% for the younger group) and that older drivers in accidents were less likely to have consumed alcohol (7% versus 30%).

With respect to the effect of health on driving avoidance, Ball et al. (11) found that drivers who had visual or attentional impairments, or both, were more likely to report avoidance than drivers without the impairments. Although drivers with visual or attentional problems made appropriate adaptations, those with poor mental status did not report avoiding challenging driving situations, presumably because they lacked insight into their own behavior. Ball et al. noted that these results supported previous research. They also found that drivers with at-fault crashes within the last 5 years reported more avoidance than those with clean records, suggesting that such crashes trigger adaptive responses.

Giving up a driver's license represents the extreme case of avoidance. A study of Finnish drivers included 1,397 drivers who did not renew their license. Results showed that male drivers tended to drive until their health prevented them, while female drivers tended to be more affected by the stress of driving and placed less importance on driving. Only 6.9% of the ex-drivers

received professional advice to stop driving, suggesting that most stopped on their own accord.

The decision to wear a seat belt is a strategic choice that affects injury risk in an accident. A 1999 Transport Canada survey of more than 60,000 drivers found that approximately 93% of females wore seat belts (14). For females, age appeared to have no effect on the wearing rate. In contrast, there were large differences between males under age 25 (84%) and males age 50 or older (91%). Thus, with age, males appear to adopt more appropriate behavior with respect to safety.

In summary, although older drivers do not make the optimum strategic choice of living in areas well served by public transit, they do adapt to aging by limiting their exposure overall and their high-risk exposure in particular. Both the exposure and epidemiological studies discussed above show reduced driving at night and in poor weather conditions. The latter study also shows reduced driving after consumption of alcohol. Drivers with visual or attentional problems make appropriate adaptations, while those with poor mental status do not. Finally, older male drivers are more likely than their younger counterparts to wear seat belts.

### *Tactical*

With age, the ability to rapidly process information declines. Appropriate tactical adaptations are to drive

more slowly and to allow larger gaps when following another vehicle. These variables were measured in two observational studies (15, 16). Drivers were photographed from freeway overpasses. The license number was used to extract driver record data on age and sex of the vehicle owner and to determine if the driver photographed was likely the vehicle owner.

Figure 2 shows the steady decline in mean speed with increasing age, with 75-year-old drivers traveling on average 6.5 km/h slower than 20-year-old drivers.

Figure 3 illustrates the reciprocal of intervehicular headway, with lower values indicating longer headways. Drivers age 50 and older adopted mean headways approximately 15% longer than drivers age 20 years old or older [approximately 1.4 s ( $1 \div \text{headway of } 0.7$ ) versus 1.2 s; 16]. Lower speeds and longer headways allow more time for a response. As long as the speed adapted is not substantially below that of the traffic stream, this strategy should decrease crash risk.

Several studies indicate that intersections pose higher risks for older drivers (17, 18). This statistic may be related to the declining ability to assess closing speed with increasing age. Staplin (19) reported a study of both simulations and on-road testing to evaluate the effect of varying approach speeds on judgments of the last safe moment to initiate a left turn at an intersection with oncoming traffic. Three groups of subjects were used, with mean ages of 33, 65, and 79. Findings indicated a decreasing sensitivity to closing speed with age, forcing older drivers to rely on distance judgments and putting them at risk for vehicles moving faster than the traffic stream.

An appropriate adaptation in this case was that older drivers lengthened the gap that they were willing to accept. This lengthening was likely because they required a longer time to complete the left-turn maneuver and to clear the path of oncoming traffic. It is less likely that they lengthened the gap because they were aware of their decreased sensitivity to oncoming traffic.

Keskinen et al. (20) provided further insight into the higher intersection crash risks of older drivers. They observed the behavior of 1,125 Japanese drivers of all ages when turning at T intersections. Observers assessed driver's age as <30 years, 30–60 years, and >60 years. The authors found no difference in attentional behavior by age as indicated by the number and direction of head movements, nor did they find a difference because of age in the length of the time gap accepted at the start of the turning movement. However, they did find that once the driver had completed his or her turn, gaps with following traffic were shortest when older drivers turned to the right (equivalent to the left in the United States) and the approaching driver who caught up to them was young (age >30) or a motorcyclist. As noted earlier, young drivers accepted shorter headways and drove faster. Thus, the cautious behavior of older drivers in this circumstance was an adaptation that could be inappropriate, given the higher-risk behavior of younger drivers.

Another example of inappropriate cautious behavior was identified in an on-road study of older driver behavior at intersections. Staplin (19) found that older female drivers were more reluctant than others to pull into the intersection to improve their view around traffic in the opposing left turn bay in preparation for a left

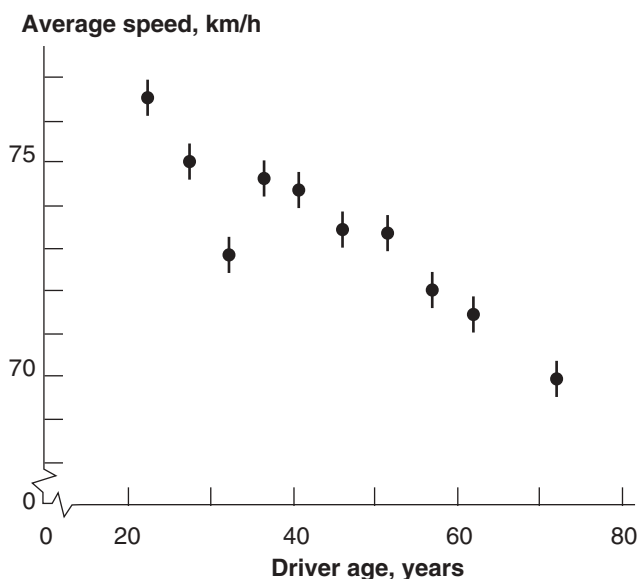


FIGURE 2 Observed travel speed versus driver age (15).

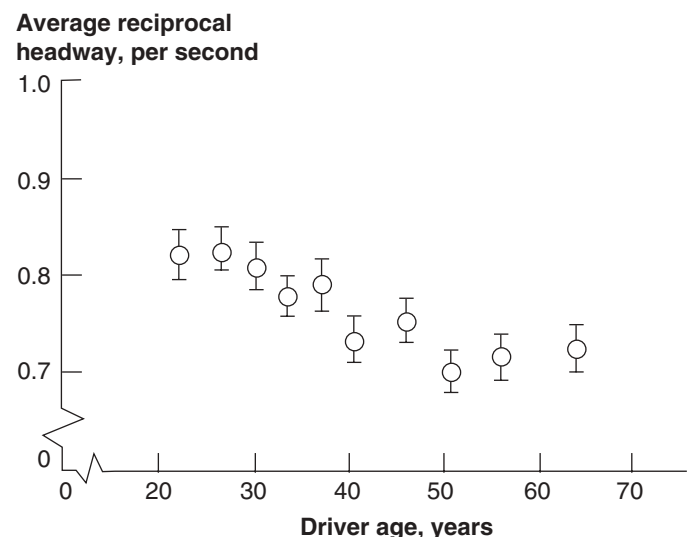


FIGURE 3 Observed tendency to follow closely (16).



turn. Not only would this have improved the view, it also would have shortened the time required for the turning movement.

In summary, tactical adaptations are seen in the speed, headway, gap acceptance, and positioning choices of older drivers. Although decreasing the stress of driving for older drivers, these adaptations in some circumstances can increase the risk of an accident as older and younger drivers interact.

### *Operational*

For the most part, older drivers do not—probably because they cannot—make operational adaptations to compensate for declining faculties. When older drivers are required to perform a specific driving task—whether in a laboratory simulator or on the road—they generally perform more poorly than younger or middle-aged drivers. For example, Maltz and Shinar (21) measured visual search of traffic scenes by older and younger drivers. Subjects were told to search the scene from the point of view of a driver. Areas related to driving safety were identified, and the search was examined in relation to these areas. Results showed that older drivers' searches were characterized by greater variability and occasional lapses, which resulted in searching difficulty. Shorter saccades and increased numbers of fixations, suggesting visual inattention, characterized the lapses. Visual-search patterns are largely unconscious and are likely to be difficult to change, requiring intensive one-on-one training. When slowed information processing and attentional lapses are the issues, remediation simply may not be possible.

Studies of in-vehicle devices, such as navigation systems and cell phones, showed generally poorer behavior by older drivers. In a driving simulator study, Alm and Nilsson (22) assessed the impact of cell phone use on tracking, headway, and choice reaction time for younger (mean age 29) and older (mean age 68) drivers. When the driver was on the cell phone, choice reaction time was significantly longer for both groups but particularly for the older drivers. The authors noted that one way to compensate for increased reaction time was to make the tactical choice of lengthening the headway. However, the design of the experiment precluded drivers having any control over headway until the moment at which the lead vehicle began to brake at a fairly substantial rate of 0.4 g. Older drivers with longer reaction times were at a disadvantage and unable to decrease their average headway to compensate for the increased attentional demands of a cell phone.

Only Hakamies-Blomqvist et al. (23) found an identified operation adaptation. They observed the car control movements (e.g., steering, clutch, accelerator, and

brake) of older and middle-aged drivers using an instrumented car in normal traffic. More serial behavior was observed in the older drivers—that is, they were more likely to use three controls simultaneously, instead of four or more as the middle-aged drivers did.

When no tactical or strategic choices are possible, such as selecting a long headway when a call is initiated or only using the cell phone when stopped, older drivers are limited in their ability to decrease risk. Although many adaptations can reduce risks, it is still the case that drivers sometimes are presented with hazardous situations that allow no time for adaptation and require immediate response.

### OLDER DRIVERS: CRASHES AND VIOLATIONS

The pattern of crashes and violations of older drivers is discussed at length by Hakamies-Blomqvist (13). These patterns substantiate the thesis of this paper that older drivers make significant adaptations in their behavior with age, and these adaptations allow them to maintain a lower level of risk of an accident than would be possible otherwise. As Hakamies-Blomqvist's data show, older drivers have fewer crashes than younger drivers in poor weather, at night, and after consuming alcohol—evidence of appropriate strategic choices.

The frailty of older drivers contributes substantially to their greater risk of injury or death in a given crash. Figure 4, from Hauer (24), shows estimated driver involvement per 1 million licensed drivers in crashes of sufficient severity to kill an 80-year-old male driver. The involvement rate declines and flattens with age, even up to age 85. This figure is in contrast to the usual U-shaped curve showing increased crash involvement with age. Together with the findings of Hakamies-Blomqvist (13), these data reveal that older drivers, through reductions in exposure overall and exposure to risky situations in particular, are successful in maintaining a low risk of crash involvement per driver, equivalent to that of middle-aged drivers.

### CONCLUSIONS

Older drivers have a general awareness of their diminishing capabilities and make numerous appropriate strategic and tactical adaptations to compensate. In contrast, when equivalent data from young drivers are available, there is no evidence of adaptation to compensate for inexperience (e.g., less driving at night or in the winter, for young males more use of seat belts). The success of older driver adaptation is shown by the fact that when their greater frailty is taken into account, absolute accident involvement rates, calculated per 1 million drivers, remain at the levels of middle-aged drivers.



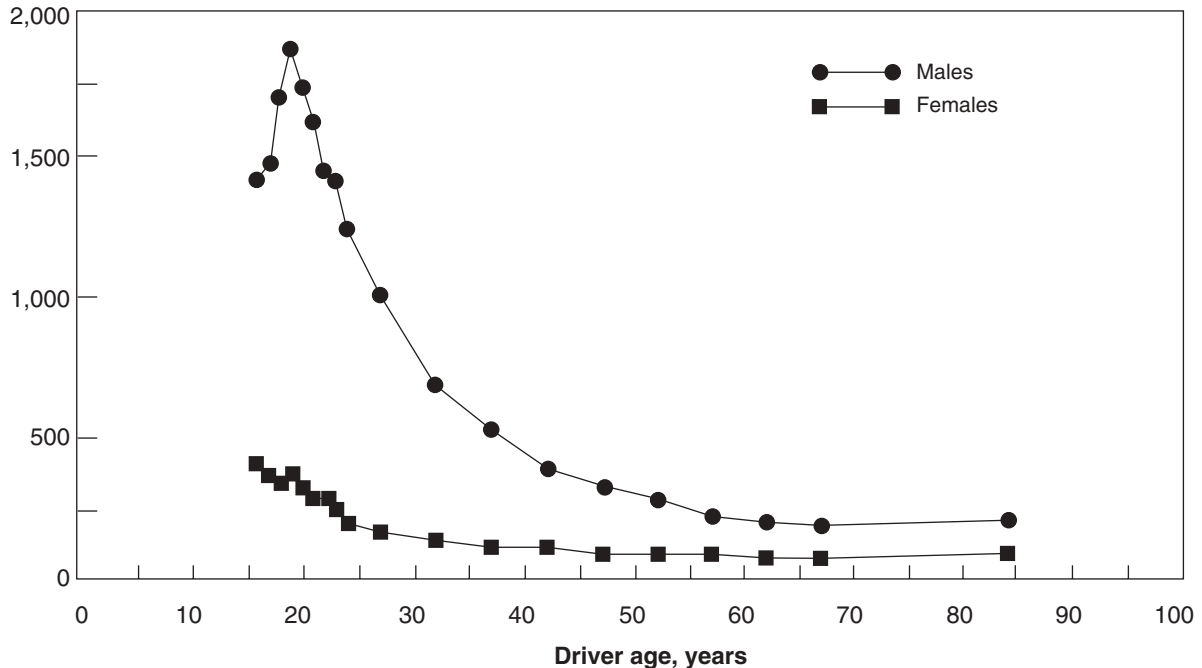


FIGURE 4 Estimated driver involvement (all motorized vehicles) in crashes of sufficient severity to kill an 80-year-old male driver per 1 million licensed drivers (24).

Not all adaptations support mobility and reductions in accident risk. In particular, strategic choices about where to live may mean reliance on a car. Although older drivers reduce their exposure to challenging situations, drivers with poor mental status do not. Tactical choices by older drivers, such as slow left turns and their placement before a left turn, are not appropriate, especially given young drivers' faster speeds and tolerance for shorter headways.

Older drivers can be assisted in making appropriate adaptations through driver education. Research is needed to develop specific advice on how best to reduce risk. Changes in operational choices are difficult to effect because the behavior is at the most automatic skill-based level. Any changes at this level are likely to require expensive one-on-one retraining. Thus, research should focus on strategic and tactical choices, instead of operational ones.

Strategic advice includes use of seat belts and a reduction in driving at night, in poor weather, and after drinking alcohol. Advice also should be offered with respect to identifying when drivers should restrict their driving in various ways (e.g., to daylight conditions, on familiar and low-speed roads) and when drivers should give up their licenses entirely.

Advice on tactical choices could include, for example, appropriate positioning at intersections for a better view of oncoming traffic when turning left, entering into traffic more quickly after the turn is ini-

tiated, and directing attention more consciously to the driving task as opposed to conversing with a passenger. Older drivers also should be made aware of specific limitations that develop with age, such as poorer ability to estimate speed of approaching traffic. Conscious awareness may elicit appropriate adaptation, improving safety. Educational material on older drivers also could be developed to alert family members to appropriate adaptations and to the fact that most older drivers adapt—with the notable exception of those with poor mental status—when intervention is required.

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# Driver Capabilities

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Safe driving relies on key skills involving visual, cognitive, and physical capabilities. Impairments in these functional capabilities can occur at any age but are more prevalent in the older population. A large body of research over the past decade has demonstrated that certain functional impairments in older drivers elevate crash risk and have a negative impact on driving performance. A clear understanding about how diminished capabilities contribute to crash risk in older drivers would greatly facilitate society's efforts to develop strategies for reducing crash rates in this population and to enhance driving mobility.

Certain medical conditions also affect driving in older adults (*a*) by engendering functional problems and (*b*) through the side-effects of the medications used in treatment. The role of medical factors is addressed in these proceedings in a paper by O'Neill and Dobbs (see pp. 56–66). The major advances over the past decade in understanding how diminished capabilities in the older population affect driver safety and performance are summarized and point toward research priorities for the future.

## FUNCTIONAL IMPAIRMENTS

### Visual

The literature addressing the relationship between visual impairment and driving is substantial, with one recent review listing about 200 articles on the topic, many from the last decade (1). The most common study

involves an examination of the associations between visual acuity and driving performance: acuity is the most ubiquitous visual-screening test used by licensing agencies to determine driving fitness. Some of the most-quoted work in this area was conducted by Burg in the 1960s on data collected from 17,500 California drivers (2, 3) and reanalyzed by Hills and Burg in the 1970s (4). Among older drivers, visual acuity was significantly associated with crash rate. However, the authors noted that despite statistical significance, the magnitude of the correlation was low. They cautioned that the relationships found should not be interpreted as meaning that poor acuity is a strong causal factor in automobile crashes among older drivers or that an acuity test is a good screen for high-risk older drivers. More recent studies reported positive yet weak associations between visual acuity and crash involvement (5–10) or no associations at all (11–18). Combining the older work with the more recent studies, there is little support from the literature for a strong association between visual acuity and unsafe driving in older drivers.

Visual acuity is related to the performance of certain driving tasks. For example, simulated acuity impairment (from induced optical blur) is related to decrements in road-sign recognition and road-hazard avoidance (19). In general, though, studies relying on the simulation of vision impairment in normal-sighted people—instead of studies of actual drivers with visual impairment—must be interpreted with caution. Simulations are abrupt onsets of reduced vision; although in actual visually impaired drivers, reductions in vision typically emerge gradually, affording the per-

son the opportunity to develop compensatory strategies and coping mechanisms for driving.

Given that visual acuity is the most common vision-screening test for licensure, it seems paradoxical that research does not support the conclusion that acuity tests can identify high-risk drivers effectively. Several possible reasons explain why studies failed to find strong associations between visual acuity and crash risk, as summarized here and discussed in detail elsewhere (1, 20, 21).

Letter-acuity tests were originally designed for the clinical diagnosis and monitoring of eye disease but not for the evaluation of visual performance skills in complex tasks such as driving. Guiding a vehicle along a roadway and through intersections involves the simultaneous use of central and peripheral vision and requires the monitoring of primary and secondary visual tasks—all in the midst of a visually cluttered array with elements in motion. Severe visual-acuity impairment (e.g., worse than 20/70-20/100) likely engenders driving performance problems and even decreased safety. However, other types of visual-processing impairments—even in the presence of good acuity—also jeopardize safe driving, as discussed below. An acuity screen would fail to identify these individuals as high risk.

Another potential reason studies do not find strong links between acuity impairment and driver safety is that drivers with severe visual-acuity impairments may not be on the road because of state-licensing requirements. In this sense, driving-license restrictions based on acuity deficits may increase public safety. Therefore, it would be impossible in many states to conduct the proper study to evaluate whether and to what extent visual acuity was associated with automobile collisions. Some states do not require vision rescreening and therefore are likely to have drivers with visual-acuity impairment on the road. Such situations in certain states represent unique opportunities to evaluate the impact of severe-acuity impairment on crash risk. Research also suggests that individuals with visual-acuity and other vision impairments, especially older drivers, may elect to give up driving or to limit their driving to familiar and low-risk situations (22–26), thus removing or minimizing exposure to the possibility of a crash. All of these factors would mitigate against finding an association between acuity and crash involvement.

Several studies have examined the role of deficits in peripheral vision in driver safety and performance. One of the most-quoted studies was conducted in California (27); crash and violation rates were twice as high among people with severe-binocular field loss compared with those without any loss, adjusting for annual mileage. More recently, a study reported a similar finding, showing that older drivers with impaired-peripheral vision in

the better-functioning eye were two times more likely to be involved in a crash compared with older drivers having good peripheral vision in the better eye (5). However, numerous other studies (2, 4, 11, 18, 28) did not report elevated crash rates for drivers with visual-field impairments. An important consideration in comparing these results is that the definition of impairment differs across the studies. The California study (27) defined impairment as severe binocular-field loss, although most other studies defined impairment as less severe.

Visual-field impairment also affects certain aspects of driving performance. In a series of studies from Australia (29–31), the impact of simulated visual-field restriction on driving performance was evaluated on a closed course. Visual-field impairment compromised some aspects of driving performance (identification of road signs, avoidance of obstacles, reaction time) but not all (speed estimation, stopping distance). A driving simulator study also demonstrated that field restriction impaired the detection of important targets in the affected area (32). The relevance of the findings from these studies to real-world driving is not clear-cut. As discussed earlier, it is likely that the impact of sudden, simulated visual-field restriction is different from that of naturally occurring restriction from eye disease, such that people with the latter may develop compensatory mechanisms over time. Closed course or simulator driving is likely to be less complex and demanding than actual driving and may not allow for the observation of critical driving problems, such as crashes. In several studies when real-world driving performance was assessed, drivers with visual-field impairment did not reveal an increased tendency to driving performance problems (10, 33–35).

When interpreting the literature on visual fields and driving, it is important to consider the visual-field measurement procedures. For example, some studies only determined the extreme limits of the visual field. Such screening techniques provide little information about the type or severity of visual-field impairment (e.g., scotomas and central field defects). Another possible explanation for the differences among study results is behavioral adaptation and compensatory strategies. Drivers with visual-field defects may overcome them partly by eye and head movement or reduced driving exposure, or both. In the future, studies should attempt to quantify the extent not only of visual-field defect but also of how drivers adjust and compensate. Drivers with visual-field defects who successfully modify their driving behavior so that their ability to drive safely is not compromised may provide a rationale for screening drivers for visual-field defects, because the negative ramifications of their field impairment on driving may be remediable. Such an approach could identify impaired drivers, assist

them in adopting accommodative strategies, and enhance their driving mobility and safety.

There are fewer studies on the role of contrast sensitivity in driving compared with the literature on acuity and visual fields. A few studies reported associations between contrast sensitivity and crash involvement. Greater impairment in contrast sensitivity has been linked to a higher number of at-fault crashes in the previous 5 years (5) and in the subsequent 3 years (36), although these associations were not adjusted for confounding factors. Marottoli et al. (10) also reported a positive univariate association between adverse driving events among older drivers and impaired contrast sensitivity. Wood et al. (29, 30) examined the impact of simulated contrast sensitivity on driving performance on a closed-road course. Better contrast sensitivity was associated with better driving skills. Rubin et al. (37) found that older drivers reporting difficulties with day and evening driving had worse contrast sensitivity. Both contrast sensitivity and acuity are linked to road-sign recognition (38–40).

A common cause of contrast-sensitivity loss in old adults is cataract—a prevalent eye condition in the elderly that involves an opacification of the crystalline lens. Almost half of adults exhibit early cataract by age 75, and approximately one-quarter have more advanced cataract (41, 42). A recent study (43) evaluated the role of contrast-sensitivity impairment in elevating crash risk in a large sample of older adults with clinically significant cataract (20/40 or worse in at least one eye). Older drivers with a history of recent crash involvement were eight times more likely to have severe contrast-sensitivity impairment in comparison with older drivers who were crash free. When adjusted for contrast-sensitivity deficits, impaired acuity was unrelated to crash involvement in drivers with cataract. Given the importance of image contrast in pattern vision and the evidence that contrast-sensitivity deficits underlie driving problems in older drivers with cataract, this area deserves further study.

Many other aspects of visual function have been considered with respect to driving. Because it is well established that older adults typically experience impairments in color discrimination (44), primarily along the tritan or blue–yellow axis, the question of how color discrimination affects their driving is relevant. The underlying rationale for color-vision testing in both personal and commercial driver licensing is not the belief that color deficiency is a major risk factor for crash involvement; instead, color-vision screening is simply a way to ensure that drivers can obey color traffic-control devices. The critical cues on the road usually can be obtained through multiple sources of information (e.g., luminance, position, pattern), so that drivers with color-vision anomalies do not experience serious difficulty in traffic-signal

recognition. In a comprehensive review of this literature, Vingrys and Cole (45) indicated that the vast majority of studies on color vision and road safety support this conclusion. They found no association between color deficiencies and vehicle crash involvement or impaired driving performance. On the basis of this overwhelming evidence, it is reasonable to conclude that color deficiency does not elevate crash risk in personal or commercial drivers or older drivers with modest color-discrimination problems.

The visual world of the driver is in constant motion; stationary test targets in driving-assessment tests do not represent the visual scene. Studies from the 1960s and 1970s that include both static and dynamic acuity measurements generally found that dynamic targets had stronger univariate associations with crash involvement than did static targets (2–4, 46). However, the associations between dynamic visual acuity and driver safety were still weak. Note that dynamic acuity deteriorates more rapidly with age. Individuals with the same static acuity can have widely divergent dynamic acuity. Tests of sensitivity for dynamic visual events require a closer look in terms of their association to driver safety and performance.

Disability glare problems have been discussed as a serious threat to the safety of older road users (47), but studies that scientifically confirm this statement are hard to find. This failure to find an association between glare and road safety may be due to methodological difficulties in defining glare and in measuring a multifaceted phenomenon as well as to a poor understanding of what people mean when they say they have glare problems.

The role of eye-movement disorders in driving is largely an untouched research area. Research on normal-sighted drivers indicates that experienced drivers continuously scan the road scene for useful information (48). Older drivers with restrictions on the ability to turn their heads experience a difficulty with the distances at which approaching traffic could be brought into the central visual field for inspection (49). Motion perception and optical-flow phenomena such as heading provide face value to the driving task, but little work has been conducted on how impairments in motion processing may affect driving performance and safety. Three decades ago, a study showed that performance in a motion–perception task was one of the best correlates of self-reported crash involvement among a large battery of vision tests, but the relationship was still weak (46). This study also found that acuity under low illumination was related to nighttime crash involvement, but again the link was weak. It has been suggested that drivers' errors and nighttime crashes may stem from a lack of awareness of perceptual limitations that occur in low light (50, 51).

Most vision-threatening eye conditions that occur in the elderly are bilateral in nature—that is, they affect



both eyes. Examples include cataract, age-related macular degeneration, glaucoma, and diabetic retinopathy. However, the severity and rate of progression of the condition can vary greatly between the two eyes, allowing for situations when one eye retains good function, while the other eye is seriously impaired. This issue may be relevant to understanding crash risk in older drivers, given the results of a recent study on older drivers with cataract (43). The study showed that impaired vision in only one eye substantially elevates crash risk. A handful of studies specifically examined the safety and driving-performance capabilities of monocular drivers. In these studies monocularity was defined in a variety of ways. Although in these studies one eye had good acuity or peripheral vision (often not precisely defined), the other eye varied across studies from no vision at all to acuity worse than 20/200, significant scotomas in the visual field, or even no definition of monocularity.

Therefore, interpreting study results and summarizing across studies can be difficult. With respect to actual driving performance, simulated monocular vision by occluding one eye did not affect driving maneuvers on a closed-road course (29, 30). Drivers with monocular-field loss did not have an elevated crash rate compared with a control group of drivers with the normal visual field in both eyes (27). Not all studies were consistent with these findings, however (52, 53), reporting higher rates of violations and mishaps among monocular drivers compared with drivers who had normal vision in both eyes. A growing body of evidence has suggested that monocularity—particularly visual-acuity impairment worse than 20/200 in one eye—elevates crash risk among commercial drivers who are exposed to high levels of driving often in intense traffic situations (54–56). The California Department of Motor Vehicles (56) performed a study on the safety of heavy-vehicle truck drivers and found that drivers who were monocular (acuity worse than 20/200 in one eye) had more total convictions and crashes than drivers who were not visually impaired. Yet this topic remains controversial. For example, a study (57) that assessed driving performance in both monocular and binocular commercial drivers reported no group differences in the safety with which most day-to-day driving maneuvers were performed.

### Visual–Cognitive

Because driving is a complex visual–cognitive task, it is unlikely that an assessment of visual–sensory impairment and the diagnosis of eye disease would alone be sufficient to identify people at elevated risk for crash involvement. Visual information-processing skills, not

only visual–sensory thresholds, have face value for the execution of safe driving practices. One such skill that appears relevant is visual attention. It is interesting that several studies from the early 1970s implied that impaired visual–attentional abilities were linked to crash involvement (58–60), but this finding was not explored further until recently.

During the late 1980s, a task called the Useful Field of View Test was developed to assess the visual-field area over which rapidly presented information is used (61–64). Unlike conventional measures of visual field—which assess visual–sensory sensitivity—the Useful Field of View Test relies on higher-order processing skills, such as selective and divided attention, and rapid visual-processing speed. Over the past decade, more than 50 articles have evaluated this measure in the context of driving competence (65). For example, reduction in the useful field of view in older drivers is associated with a history of at-fault crash involvement (5, 16) and injurious crash involvement (66). Drivers with the most-severe restrictions tended to have the highest number of crashes during the previous 5 years (5). In a prospective study (18), older drivers with a 40% impairment or more in the useful field of view were two times more likely to incur a crash during the 3 years of follow-up, after adjusting for age, sex, race, chronic medical conditions, mental status, and driving exposure. This association was primarily mediated by a difficulty to divide attention for brief target durations. Note that in this study, useful field of view impairment was the only type of visual deficit related to future crash involvement. Deficits in acuity, contrast sensitivity, and visual-field sensitivity were unrelated to future crashes.

The Useful Field of View Test also is used to study crash proneness in the population with Alzheimer's disease (AD). Studies indicated that in drivers with AD, the useful field of view reduction is one of the best predictors of crash involvement in a simulator and poor on-road performance in a driving test when compared with other cognitive tests (67–69). These studies implied that visual attention and visual-processing speed are critical considerations when evaluating safe-driving skills and may be better screening tests for detecting high-risk older drivers than visual–sensory tests—a practical issue worthy of focused investigation.

Impaired performance on other tests of higher-order visual-processing abilities also has been related to crash involvement and impaired driving performance, underscoring the importance of assessing visual skills beyond basic sensory capabilities. Studies reported associations between unsafe driving and deficits in visual-search and -sequencing abilities (67, 70), selective attention tasks (10, 67), spatial memory (69, 71), perception of three-dimensional structure from motion (68), and trails (5, 26, 68, 72–74). The strength of the association between

visual–cognitive measures and driving competence is consistently much stronger than with visual–sensory function alone.

### Cognitive

Because higher-order visual-processing abilities that rely on intact cognitive function were discussed above, further discussion of cognitive impairment focuses on studies relating mental status and AD to driving competence. Several studies identified cognitive impairment as a risk factor for unsafe driving among older adults. Older drivers with cognitive impairments, regardless of etiology, are at least twice as likely to be involved in a crash, depending on the study (5, 13, 14, 16, 75). At face value, this is not surprising. Control of a vehicle during a typical drive involves many cognitive skills, such as visual attention, memory, and reasoning. Previous work has documented this link. Older drivers with general cognitive impairment (e.g., as assessed by short mental status screening tests, such as the Mini-Mental State Examination), exhibit on-road driving problems (70, 76–78) and an elevated crash risk (13, 14). Furthermore, studies focusing on specific cognitive domains found that crash involvement and poor on-road or simulated driving performance are linked to attention problems (5, 10, 16, 18, 36) and impairments in visual search (66) and spatial memory (68).

Although most experts agree that driving is unsafe and unwarranted in the moderate to severe stages of dementia (79), with AD—the most common diagnosis—there is a great deal of controversy about whether people with mild dementia should be behind the wheel. A hotly debated issue is what to do about the driving privileges of an individual once he or she is diagnosed with dementia (80–87). This issue stems from a concern for the safety of both elderly drivers with dementia and other road users. Several studies focused on the diagnosis of AD as a risk factor for crash involvement. Studies have reported that older drivers diagnosed with AD are more likely to be involved in a crash than are drivers without this diagnosis in the same age range (79–83). For example, several studies implied that between 30% and 40% of drivers with AD are likely to be involved in a motor vehicle crash after the onset of symptoms (83, 84, 87).

One study found that although older drivers with AD had a slightly higher annual rate of crash occurrence compared with drivers without AD, the crash rate among drivers with AD was still within the range deemed acceptable for other age groups, especially young drivers (88). Therefore, the authors argued that older drivers with AD are no more a hazard on the road

than other segments of the driving population and may be unfairly targeted.

Only one study suggested no differences in crash involvement between drivers with AD and normal controls (89). This study reported that the frequency of crashes within a group of drivers with AD, compared with a group of controls without dementia, was no different for either pre- or postdiagnosis periods of driving. The authors also reported that the drivers with AD drove significantly less (i.e., had less driving exposure than the controls); thus, reduced exposure may have mediated the similar crash rates of the two groups of drivers in this study. In summary, most studies implied that older drivers with AD are more likely to be involved in a crash than are controls (without dementia).

Instead of stereotyping older drivers with AD as having a high crash risk, many have argued that a functional evaluation of driving skills—using assessment tools with proven validity—is the only fair way to decide for or against the licensure of a driver (80, 90). An international panel of experts recently agreed that decisions on the fitness of at-risk drivers to continue driving should be based on empirical observations of performance, because age or medical diagnosis alone are often unreliable (79). In the absence of objective criteria, physicians and other caregivers often must rely on intuition to restrict driving. Such decisions may unfairly restrict mobility or unwisely sanction driving in those who are crash prone.

As discussed earlier, driving is tied to personal independence and self-worth. The removal of the license from a person with AD without objective evidence of impaired skills is viewed by many as unreasonable. However, there seems to be little consensus among health care professionals and driving experts on how to advise patients with dementia in the early stages of the disease on whether to drive or not. These issues highlight a serious public health problem that cannot be ignored (91). Further efforts to address these critical issues are clearly needed. The challenge is that a functional evaluation approach is difficult to implement because there are no accepted standard protocols for evaluating skills important for safe driving in people with dementia. Many authors have remarked on the need for prospective studies to evaluate cognitive abilities and driving performance and the need for the ultimate development of a cognitive battery to use in conjunction with an on-road evaluation (76, 78, 92–97).

### Physical

Controlling a vehicle safely depends on the successful execution and continuous monitoring of physical behav-



iors. Several important aspects of motor ability for the driving task are strength; coordination (both gross and fine); and range of motion of head, neck, arms, and legs, including the overall flexibility of the extremities, balance, and gait (e.g., to get in and out of a vehicle and sit stably behind the wheel). As Marottoli and Drickamer (98) summarized, most striking about the area of physical function and driving in older adults is that relatively little is known about how physical function deficits affect driving safety and behavior in the elderly. Little to no information is available about what minimum levels of physical functioning are necessary for safe driving. Reductions in strength could be a problem in turning the steering wheel or shifting the gear lever; however, most new vehicle controls are designed to accommodate a range of driver strengths and facilitate ease of operation. Retchin et al. (99) found a bivariate association between grip strength and driving frequency among older veterans, suggesting that some older adults with impaired strength might avoid driving.

Range of motion with respect to the head and neck is especially important when checking for vehicles, pedestrians, and other obstacles in the roadway environment. It has been shown that older drivers with a restricted ability to turn their heads, for example, from arthritis, are limited in the distances at which approaching traffic can be brought into the central visual field for inspection (61). It also has been shown that limited neck rotation is a risk factor for future crash involvement (10). Gait and balance may be especially problematic when getting in and out of a vehicle and may hamper a person's use of a vehicle, even though the person may be safe behind the wheel. This also is an issue worthy of study.

In terms of lower-extremity problems, foot abnormalities in older adults are associated with the occurrence of crashes and moving violations in older drivers (14), implying that these problems may hamper their ability to maneuver between the accelerator and the brake. Capabilities associated with physical activity also are related to older adults' driving safety. Older drivers involved in a crash or violation walked fewer blocks on an average day (14), reported difficulty with physical activities—such as walking a mile, opening a jar, and doing yardwork or light housework—and were more likely to have a history of falls (100, 101) in comparison with older drivers who were not involved in a crash or violation. These data imply that physical difficulties with other instrumental activities of daily living may serve as markers or warning signs that a person also may be having problems driving. It is known that reaction time to a visual stimulus is increased in older adults compared with younger adults when measured in a laboratory setting; however, slow reaction time is not consistently identified as a risk factor for older adults'

crash involvement. This may be because of compensatory behaviors such as driving more slowly and avoiding heavy traffic areas, although these potential coping strategies deserve further investigation in terms of their role in minimizing crash risk among the elderly.

## SELF-AWARENESS

Older drivers with eye conditions and visual impairment often report driving difficulty and avoidance of challenging driving situations; when visual deficits are severe, some even decide to stop driving (22, 23, 25, 26, 102–105). This self-awareness of driving performance problems and of associated cutbacks on driving exposure suggests that interventions to promote self-regulation may be effective. There is still concern about visually impaired drivers who are not cognizant of their visual problems and about those who are unaware of the ramifications of their visual deficits for safe driving, because these drivers would not know that self-regulation was needed. It is not known how prevalent these drivers are in the population. However, a recent study of visually impaired older drivers (106) indicated that these drivers did not see a link between their visual problems and the potential for crash involvement and driving difficulty. Some visual problems are not always obvious to the person (e.g., peripheral field restriction), and other visual problems are not screened for routinely in eye clinics and, thus, would rarely be clinically identified and communicated to the patient (e.g., slowed visual-processing speed, poor visual-attention skills).

Self-awareness of cognitive impairment is a more complicated situation because cognitive impairment, if serious enough, may prevent a person from clearly understanding that driving skills are compromised and compensatory strategies or cessation are needed to preserve safety. Drivers with mild to moderate cognitive impairment tend to report driving performance difficulties and reductions in driving exposure (22, 26). However, once again, it remains to be determined whether appropriate coping strategies are actually implemented by this population and whether these compensations are effective in preserving road safety. The studies summarized earlier indicated that crash risk is elevated in people with visual and cognitive impairment and suggested that self-regulation among people with impairments is not sufficient for preserving driver safety and that all people with impairments do not self-regulate.

## INTERVENTIONS

There are several potential strategies to minimize the impact of visual, cognitive, and physical impairments

on driver safety among older adults. A serious research challenge for the next decade is to demonstrate that these interventions actually make a difference—that is, that they will enhance safety and mobility.

One potential way to minimize crash risk because of vision impairment is to treat eye conditions so that vision impairment is reduced or eliminated. Chronic eye conditions in the elderly are often treatable, and highly effective treatments are already available for refractive error and cataract. Despite their availability, these treatments are not always sought out by the elderly or are not always covered by insurance, or both. As a result, the elderly often live with vision impairment, which is otherwise reversible, and this can have far-ranging effects on their lives, including a negative impact on driving.

With respect to cognitive impairment, there has been much discussion about the potential role that cognitive training could have in improving the performance of everyday activities and enhancing quality of life. One activity that could be improved is driving. Cognitive training protocols were designed for improving processing speed, memory, and problem-solving skills. Laboratory research showed that improvements are indeed possible (62, 107–111). Some studies further suggested that improving cognitive and perceptual abilities is associated with improved performance on everyday activities of critical importance to independent functioning, such as driving and medication recall (112, 113). Tasks for future research are to evaluate the extent to which improvements in these cognitive skills generalize to improvements in the performance of everyday tasks, such as driving, and to explore whether these training benefits endure. With respect to physical impairments and driving, as discussed earlier, there is a comparatively weaker understanding with respect to physical risk factors for unsafe driving in older adults. Yet it would be worthwhile to determine if physical training or exercise programs, or both, have behavioral and psychological benefits that also positively affect driving performance.

Educational programs in the form of seminars and workshops were designed for older drivers to decrease the impact of functional impairments on driving. Driver programs, as discussed by Staplin and Hunt in this volume (pp. 69–94), present material about how the aging process affects vision and other aspects of functioning and how these changes may affect driving. In addition, coping strategies and compensatory mechanisms are discussed. Although these courses appear to impart knowledge effectively about safe-driving practices to older people (114, 115), research has not demonstrated that the courses can improve safety in terms of the reduction in the chance of a crash—an issue worthy of further study. Educational programs for older drivers may prove to be most beneficial if they are targeted for

high-risk older drivers. A recent study (106) showed that older drivers at risk because of vision impairment and previous crash involvement had high self-efficacy in their ability to self-regulate and use alternative driving strategies to avoid challenging driving situations.

When making medical diagnoses and identifying functional problems during a clinic visit, physicians and other health care providers are in a position to identify potentially high-risk older drivers. This important role was emphasized by the American Medical Association's Council on Ethical and Judicial Affairs in a formal report urging physicians to accept ethical responsibility and report patients to the state's motor vehicle administration when the physician believes a patient is a clear risk to road safety (116). In-service education and continuing medical education programs should cover the rapidly growing field of older driver assessment and rehabilitation. Physicians and health care providers should be aware of the many referral services available, such as driving assessment clinics, driving rehabilitation services, and educational programs for older drivers, as discussed above.

## FUTURE WORK

Many areas are in need of focused work addressing driver capabilities if significant progress in enhancing the safety and performance of older drivers is to be made. Some initiatives overlap with other areas discussed in these proceedings.

1. During the past decade, the field has made great progress in identifying special visual and cognitive risk factors for unsafe driving and performance difficulties in older drivers. It is not too soon to use this information to evaluate promising screening tests to identify at-risk drivers in the field. Many complex issues implicit in such an enterprise need to be confronted openly, such as what is identified with these tests and, after identification, what actions are taken to meet the dual goals of safety and mobility? Which tests or combinations of tests are the best predictors? Sensitivity, specificity, and determination of cutpoints must be addressed throughout the process. Public health science could be enormously helpful to transportation scientists by addressing these questions. Screening tests must be evaluated in population-based studies, incorporating the best methodological designs addressing bias, chance, and error.

2. With vision, it is time to publicly recognize that an acuity test must be supplemented by tests of higher-order visual-processing skills in the screening of at-risk older drivers. Many older drivers with good acuity have slowed visual-processing speed and attentional skills—

both of which elevate risk. However, these at-risk drivers remain undetected by an acuity test. It also is time to acknowledge that even among visual-sensory tests, the measurement of acuity under high-contrast, high-luminance conditions is not the best way to identify older drivers with visual-sensory impairments that threaten road safety.

3. With cognitive domain, little is known about the rate and pattern of how cognitive impairment progresses in older adults in the earliest stages of dementia and at what stage these impairments become a threat to safe driving.

4. Within the physical domain, it would be useful to know if other physical difficulties in everyday life activities serve as markers for physical difficulties in operating a vehicle safely and proficiently. Further, after the physical risk factors for driving problems in older adults are better identified, how can vehicles be better designed to minimize or counteract the physical challenges of the aging body?

5. The next few decades of research should focus on evaluating interventions to reduce crash risk in older drivers. Focusing on reversing or minimizing the implications of visual, cognitive, and physical impairments seems a fruitful strategy because the research to date clearly indicates that these main factors underlie older adults' driving problems. It is not enough to develop an intervention that appears to have merit. Research must be carried out to evaluate the intervention in a controlled, systematic fashion. Potential interventions can take a variety of forms, as discussed above, such as medical treatments (e.g., eye care and treatments for dementias, cognitive training, and educational programs aimed at older drivers, health care providers, families, law-enforcement officials, and the general public).

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# Age-Related Disease, Mobility, and Driving

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**T**he interface between public health and the mobility of older people has been neglected. The dialogue also has been dysfunctional because much of the literature has concentrated on safety at the expense of mobility. Not only is this an inversion of older people's priorities, but it also does not reflect their safety record. Developing a dialogue among the disciplines of transportation research, public health, geriatric medicine, traffic psychology, and the other disciplines involved will require time, open minds, and opportunities to work in concert. The metaphor of the blind man describing the elephant has never been more appropriate.

## HEALTH PROFESSIONALS

Even within medical disciplines, there is a wide spectrum of perceptions. The public health doctor and the family physician deal with populations that are predominantly healthy, but people who are referred to medical directors at the Division of Motor Vehicles (DMV) suffer from what is known in public health terms as selection bias. In other words, the referral arises from a behavioral or health abnormality that causes individuals to stand out from their peers. By definition, members of this group no longer represent their peers. A similar process occurs when the more complicated cases undergo referral to specialist care. These patients have capabilities and problems that are different from the average experience of people with illness. A classic example of this process is the original stricture

on driving for people with diabetes mellitus, which came from specialist practices and was interpreted by the insurance industry as an indication that diabetes represents an extra risk to safe driving. A community-based study subsequently showed that any additional risk from diabetes is small in the general population (1). Physicians' roles are contrasting and complementary.

## Public Health

The public health specialist assesses the impact of the determinants of disease on the whole population and anticipates and measures positive and negative impacts of interventions. A classic example is mass medical screening of older drivers—a program that appears reasonable to laypeople but so far has been shown to be either ineffective, with no increase in crashes when withdrawn (2), or harmful, with no reduction in in-car fatalities but an increase in pedestrian and bicyclist fatalities (3).

## Family and Specialist Physicians

The family physician sees a wide range of older people, and it is likely that problems with mobility and safety are not prominent in their consultations. Specialist physicians see a more select group of older people and are more likely to meet those who find their mobility or safety, or both, compromised by age-related disease. These older people may have more access to support ser-

vices such as occupational therapy and neuropsychology, although the services may not be specifically centered on driver assessment. Both types of physicians represent the first line in diagnosis, assessment, and remediation. Currently, both undergraduate and postgraduate education in this process is lacking. Full assessment is hampered by a failure of health care agencies to recognize and fund driving assessments as integral to the maintenance of the health and well-being of older people.

### Medical Advisers to DMVs

Medical advisers see a very select population of older drivers and, to some extent, may have access to a range of facilities to help clarify driving ability. Their goals may be more precisely defined as supporting the responsibility of DMVs to keep drivers on the road as long as they are safe. Ideally, more links should be forged between this group and practicing clinicians. The development of the Maryland model project demonstrates an enlightened way to promote such an enabling approach.

The most significant development between *Special Report 218* and this update is the recognition that the major impact of age-related disease is to curtail mobility (4). A more measured sense of perspective has allowed a previous emphasis on risk to be reviewed. Clearly, older drivers are among the safest group of drivers on the road on the basis of a population-based rate. The positive aspects of aging are often underappreciated, and the literature on aging and mobility could benefit from a greater emphasis on the beneficial aspects of aging, including wisdom, strategic thinking, and less risk taking. As the most striking proof of this benefit, the older population has the lowest crash rate per licensed driver in any age group, despite the highest prevalence of disabilities postulated as relevant to driving abilities. Even within the small proportion of crashes caused by drivers in this age group, the contribution of chronic disease to the crash risk is modest (5). Older drivers' achievement is all the more compelling when considering that compensatory strategies place them in situations that at all ages usually add to a higher crash risk—that is, more urban and rural roads and lower mileage (6). Faced with these odds, older drivers' safety records point to superior strategic and tactical skills. If these skills were more widely applied, the qualities would enhance mobility and safety for all age groups.

### DISEASE AND DISABILITY

Along with the positive aspects of aging, there is an age-related increase in the prevalence of disability. The rate

of disability in activities of daily living among older people in developed countries is between 15% and 20% (7). The biological basis of loss of function in later life is usually rooted in disease, although this basis may be unrecognized. The original equation by the World Health Organization (8) of the link between disease and loss of function as

disease → disability → handicap

has been replaced with

disease → impairment → activity → participation

The second equation is preferable because it emphasizes that good health optimizes participation and hopefully social inclusion. A consequence of this equation is that instead of a prosthetic model of intervention (compensation for the disability), a multilayered process can be initiated. This process seeks to remedy or modulate the underlying diseases, remediate impairments, and compensate uncorrected deficits. The good news for the future is that there appears to be a slight but appreciable diminution in age-related disability in the last decade (9).

The underlying causes of disability tend to be multifactorial, relating not only to genetic susceptibility but also to the presence of several disease processes and self-care patterns. Most health surveys in later life focus on function, self-report, or a more detailed assessment of one aspect, for example, cognitive function.

Although it is known that 5% to 12% of older people have dementia and the same percentages suffer from the residual effects of stroke, it is likely that a considerable number suffer from both, reducing the overall total number suffering from dementia and stroke. It is difficult—if not impossible—to assemble the illnesses of the population into a hierarchy. Although the most commonly reported disability relates to rheumatological conditions, significant disability probably relates to neurological conditions, in particular stroke and dementia. Sensory impairments are common comorbidities, and the presence of multiple problems in older people who have driving problems has been recognized in the Established Populations for the Epidemiological Study of the Elderly and elsewhere (10).

Unfortunately, most studies of older drivers were not multifactorial or dealt only with specialist populations, making it difficult to estimate the causes of functional loss relevant to mobility among unselected older people. It is therefore reasonable not only to use measures of function as a proxy for illness within the community but also to promote strategies that seek to define the causes of the loss.

At a certain level of function, abilities are lost to such an extent that activity and participation are reduced.

The pattern of response is heterogeneous and may involve seeking remediation or adaptation, or both. For functional loss and driving, there is considerable evidence of reduced mileage, altered driving patterns, and withdrawal from driving. As the functional loss increases, there are marked variations between patterns of disengagement from activities and participation. The ordering of functional loss is unclear, but it has been suggested that driving might be preserved ahead of socially useful walking or use of public transport (11). The latter is not surprising because in most countries in the developed world, public transport does not have the accessibility or flexibility to meet the mobility needs of older people with functional compromise. This information is supported by a study showing that when drivers with dementia stopped driving, they were unable to compensate with other forms of transportation (12).

### Health and Reduction in Mobility

Many older drivers cease driving for health reasons. It is possible that remediation strategies have been insufficiently explored in a portion of cases. In one study, one in four older drivers stopped driving during a 6-year period (13). Medical factors predicted the older people who would not drive and included neurological disease (Parkinson's disease or stroke) and cataract but not cognitive impairment. In Florida, health factors accounted for about half of the decisions to cease driving (14). European studies also highlighted the importance of health in driving cessation (15, 16). Older people with cataract are likely to restrict their mobility (17). However, older people and their health care providers—for example, nurses (18) and doctors (19)—do not share these concerns with each other.

The failure of older people and physicians to discuss health and mobility may stem from the negative phrasing and mentality of much of the driving and health literature, which appears to focus on who should not drive instead of enabling people with a disability to maximize their mobility. Although the American Medical Association's ethical position paper on driving and illness was welcome because it encouraged physicians to address driving as part of a health assessment, it unfortunately emphasized the physician's task in negative terms (20). It is vital to develop a remediation context. A wide variety of interventions have been proposed to maximize safe mobility among older drivers.

### Illness and Driving

The increase in the literature on disease and driving, although small, has been significant. Some is original

research, and some represents a synthesis of prevailing wisdom. In many areas, physicians have more information than they did 10 years ago. Examples of increased physician knowledge and information include the following topics:

- Implantable cardiac defibrillators—the risk of crashes because of a defibrillator is low (21).
- Syncope—people most at risk for syncope are predictable (22).
- Cataracts—older drivers with cataract experience a restriction in their driving mobility and a decrease in their safety on the road (17). Surgical intervention, however, can be beneficial in terms of subjectively improved visual function and distance estimation while driving (23).
- Arthritis—doctors fail to inquire about the impact of arthritis on mobility (19), and a rehabilitative intervention program may improve driving ease (24).
- Diabetes—increasing evidence demonstrates that the condition has little or no effect on crash risk among older drivers with no history of crashes.

In some countries, these advances were incorporated into physician guidelines with regular updates, for example, in the United Kingdom (25), Australia (26), and Canada (27). For each case, these guidelines can be accessed without cost on the Internet. Similar guidelines by the Association for the Advancement of Automotive Medicine are near completion.

### Dementia as Paradigm for Age-Related Disease

Dementia—a syndrome of memory and other cognitive losses leading to social or occupational dysfunction—is a good paradigm for age-related disease. This common yet functional loss is frequently ascribed to old age. Often dementia is not detected early in the course of the illness, and many laypeople and caregivers have a nihilistic approach to the disease. Vascular dementia, or Lewy-body disease, is increasingly common with advanced age.

Dementia is a progressive, incurable syndrome, as is the illness pecto diabetes mellitus. Symptomatic pharmacological treatment of Alzheimer's disease (AD), alleviation of causative factors in dementia such as vascular dementia, and treatment of comorbid conditions such as depression can improve cognitive function in some patients. Any description of the assessment of driving function must consider these steps as the beginning of an evolving process of dementia treatment. More therapeutic advances will alter the future assessment of drivers with dementia.

Although the importance of dementia as a medical factor when considering fitness to drive was first

noticed by Waller in 1967 (28), it was not until 1988 that Friedland et al. at Johns Hopkins University made a specific study of driving practices among patients attending a memory clinic (29). From this seminal study, important questions about the effects of dementia on driving and transportation can be traced:

1. How are the transportation needs of patients with dementia met?
2. Are there any differences in the impact of different dementias on driving skills?
3. Do patients with dementia represent a risk to themselves and other drivers on the road?
4. Are there tools to assess the driving ability of people with dementia?
5. Are there interventions that can improve the safety and comfort of driving for people with dementia?
6. What advice should doctors give patients who are assessed as fit to drive?
7. How do older drivers with dementia deal with driving cessation when driving is no longer possible?
8. What advice should doctors give patients who are assessed as unfit to drive?
9. Is screening for dementia at license renewal a realistic option?

Studies on drivers with dementia are few and vastly outnumbered by commentaries and case reports. Studies that are directly controlled are even fewer. The potential for research in this area is vast.

### Transportation Needs of Patients with Dementia

Relatively little is known about how the transportation needs of people affected by dementia are met. Between 17% and 20% of memory-clinic patients continue to drive but tend to limit their driving. Trobe et al. estimated that these patients drive slightly more than half the mileage of controls (30). Little is known about barriers to the use of public transportation or the role of family and caregivers in meeting transportation needs. Family and caregivers may meet this need to a certain extent (12). However, it is likely that the ability to use public transportation is lost at a relatively early stage, and a more personalized system of transportation, such as that organized by the Independent Transportation Network (31), may be required.

### Quantifying Impact of Dementia on Driving Skills

Intuitively progressive cognitive impairment leads to a degree of impairment of driving skills and ability.

However, because of predictive limitations from a purely cognitive model, the exact impact of a given decrement of cognitive function is difficult to quantify. Driving is an overlearned skill (32), and the role of experience has not been quantified in disease states. Behavior also is an important factor: the addition of behavioral measures—such as anticipatory braking, defensive steering, and behavioral manifestations of complex attention—to a neuropsychological test battery greatly increased sensitivity and specificity in a group of patients with acquired brain disease (33). The ability and predisposition to use compensatory measures also is important. Drivers with dementia are often less aware of their deficits.

The initial evidence from specialist clinics suggested an increased crash rate among drivers with dementia (29, 34, 35). However, much of these data were anecdotal and retrospective. The first relatively large controlled study showed that drivers with AD had the same number of crashes in the first 2 years as age-matched controls; however, this risk climbs steeply after the second year (36). A larger study showed no difference in crash rate between patients with AD and controls (30). It also showed that many drivers had stopped driving before the diagnosis of AD, and nearly 90% had stopped driving at an average interval of 2.6 years. The patients with AD drove at 40% lower mileage rates than the national average for elderly patients. Both these studies suggest that the public health risk from AD is relatively small. Crashes per mile driven were higher, but this statistic may be a better marker of risk to themselves than to other road users (37); in all likelihood, the increase in crashes per mile driven is a function of fewer miles driven (6).

This information must be balanced by a study by Johansson et al., showing that older drivers who died in single-vehicle crashes were more likely to have a higher plaque (tiny insoluble lumps of a protein called beta-amyloid) and tangle (insoluble threads of a protein called tau that build up in nerve cells) count than would be expected by international criteria (38). However, the study was notable because very few vascular stigmata were reported. A follow-up study of the families did not suggest that any of those drivers who crashed had had significant cognitive impairment (39).

Taken together, these studies indicate that the issue of driving and dementia cannot be clearly classified as a public health problem yet. Rather, the issue represents a problem for individual patients, medical directors of DMVs, and clinicians who are likely to see a select population of people with difficulties. The American Medical Association's policy document on driving and dementia applies to this audience (20). An analogy for this scenario is epilepsy and driving. Early studies were based on specialist clinics of patients with complicated

and poorly controlled epilepsy. A subsequent community study showed that the impact of epilepsy on driving safety was actually very small (1). In a population of people renewing their licenses in North Carolina, the lowest 10% in cognitive testing had a relative crash risk of 1.5 in the 3 years before the cognitive testing (40). It is debatable whether this population represents a fair comparison. A somewhat reassuring finding from this cohort is that people with the poorest scores for visual and cognitive function also drove less and avoided high-risk situations (40).

### Differences in Impact of Various Dementias on Driving Skills

Only one study specifically set out to look at the difference between AD and vascular dementia (41). No differences were found, but the numbers were so small that the results were unlikely to be statistically significant or have clinical significance. Because current models of driver assessment hinge on behavior and motivation as factors important in driving ability, theoretically dementia of the frontal lobe type is important in terms of a reduction in driving ability. Another issue to consider is the neurovascular deficits in patients with vascular dementia such as visual-field defects. However, neither of these theories has been adequately investigated.

### Best Practice for Driving Ability and Safety Assessment in Patients with Dementia

The first step is to catalogue whether the patient drives and whether the patient or caregiver is concerned about the patient's driving ability. Although this step may appear elementary, it is widely recognized that patients with illnesses relevant to driving—for example, syncope—are not specifically assessed on driving ability (42).

The major advance in this area is the understanding that a purely cognitive model of driving ability does not adequately reflect the complexity and hierarchical nature of the driving task. Driver behavior is complex; one of the simplest and most easily applicable models is Michon's hierarchy, which uses strategic, tactical, and operational factors (43). The strategic level is the choice of whether to travel; the tactical decision is whether to overtake; and the operational level is what to do when overtaking and faced with an oncoming car. The strategic and tactical levels are more important in terms of driving safety than the operational level. To a certain extent, the Galski driving model (44)—which adds a behavioral observational element to a battery of cognitive tests and a primitive simulator—applies Michon's

hierarchy to brain damage (head injury and stroke). A Belgian group showed success in applying this model of assessment (45).

The most common model for driver assessment involves a variable combination of physician, occupational therapist, neuropsychologist, specialist driving assessor, and social worker. Not every patient needs to be assessed by all of these team members. For example, a patient with severe dementia clearly cannot drive, so a referral to the social worker to plan alternative transportation is appropriate. Equally, a mild cognitive defect may require only a review by the physician and occupational therapist. The overall interdisciplinary assessment should attempt to provide solutions to both maintaining activities and exploring transportation needs. An on-road test may be helpful because it may demonstrate deficits to a patient or caregiver who is ambiguous about whether the patient should stop driving. At a therapeutic level, members of the team may be able to help the patients come to terms with the losses associated with driving cessation. The occupational therapist may be able to maximize activities and functions and help focus on preserved areas of achievement, while the social worker can advise on alternative methods of transportation. This approach should save time and valuable resources for the occupational therapist, neuropsychologist, and on-road driver assessors.

In addition to the usual workup, the medical assessment should include a driving history from the patient and caregiver. Although Hunt et al. (46) demonstrated a poor correlation between caregiver assessment and on-road driving performance (two out of five cases), this single small study is insufficient to discount the collateral history. The Folstein Mini-Mental State Examination (MMSE; 47) is the most common choice of simple screening measures of cognitive impairment. A 1997 paper attempting consensus suggested that people who score 17 or less on the MMSE require further assessment in a formal manner (48). This low level is represented in the title of the paper: "Dementia and Driving: An Attempt at Consensus." In general, the use of the MMSE in isolation is inadequate.

Both occupational therapists and neuropsychologists have evaluated the next stage of testing. None of the studies has been sufficiently large to have a reasonable predictive value or to determine cutoff points on neuropsychological test batteries. This situation is paralleled in memory clinics, which use a wide variety of test batteries. The important elements of a successful assessment are the choice of key domains, the familiarity with the test battery, and the development of an understanding and close liaison among the team members. A wide range of tests has been correlated with driving behavior, but only a few of these tests are sufficiently robust to calculate cutoff points for risky driving. All of these



tests can be criticized for taking an overcognitive view of the driving task (49).

Specific tests that have shown correlation with driving ability in more than one study include the MMSE (50–52), the Trail-Making Test (40, 53, 54), and tests of visual attention (55–59). Other tests have been examined in single studies, for example, the traffic-sign recognition test (60)—a comprehensive review of this test is available from the National Highway Traffic Safety Administration (61).

In conjunction with the clinical assessment and collateral history, these tests help decide which patients require on-road testing and those who likely would be dangerous to test. Another interesting aspect is the possible disparity between scores on a test battery and the clinical assessment by the neuropsychologist. In a short paper by Fox and Bashford (52), the neuropsychology test scores and the neuropsychology prediction were not significantly associated, suggesting that the clinicians made their decisions on items not formally measured in the neuropsychology test battery.

At the moment, sufficiently sophisticated simulators are not widely available, but this situation may change in the near future with the advent of powerful laptop and desktop PCs. The main benefit of large, sophisticated simulators, such as the Iowa simulator, is to develop and understand neuropsychological and behavioral test batteries in a safe way and to correlate them with unsafe driving behavior and crashes. In a classic paper, Rizzo et al. showed that 29% of patients with AD experienced crashes in the simulator versus 0 out of 18 control participants (62). The drivers with AD were more than twice as likely to experience close calls. There also was evidence that drivers with mild AD did not crash and showed fair control of their vehicles, which is compatible with the idea that some patients with mild dementia should be allowed to continue driving.

On-road driver testing is the gold standard and should be offered to all patients who are not clearly dangerous when driving and are not disqualified from driving for other reasons. The assessor requires a full clinical report and may choose to use one of the recently developed scoring systems for on-road testing of patients with dementia. At least three road tests have been developed specifically for dementia, although the numbers of patients taking the tests have been relatively small, with only 27 patients taking the Sepulveda road test (51), 65 the Washington University road test (63), and 100 the Alberta road test (64).

The quantification, operationalization, and validation of these road tests need to be accomplished, and all tests need to be repeated in environments other than that of the test originators. An extra spin-off may be that just as the simulators provide information on which neu-

ropsychological tests are helpful in deciding the patients that are safe to drive, so too road test schedules may help in the development of neuropsychological tests. Psychological batteries have been developed for both the Sepulveda and Alberta road tests.

### Interventions to Improve Driving Safety and Comfort for People with Dementia

The only study that showed benefits from an intervention is the Bédard et al. work, which demonstrated that patients who drove with a companion were less likely to have accidents than those who drove alone (65). It is reasonable to suggest that patients with dementia should not drive alone. However, in the absence of further studies, this cannot be an absolute. It also would be good to review the patient at an appropriate time—for example, 6 months or sooner—for any significant deterioration. Unknown interventions include the removal of medications; however, it is unclear whether the underlying illness or the medication—particularly benzodiazepines, tricyclic antidepressants, and neuroleptics—is responsible for reported crash-rate increases.

### Medical Advice for Patients Assessed as Fit to Drive

If the assessment is positive, the decision to continue driving entails several components that include the following:

- Duration before review—because dementia is a progressive illness, it is prudent to make any declaration of fitness to drive subject to regular review, with an earlier reassessment if any deterioration is reported by the caregiver.
- Possible restriction—there is preliminary evidence from the state of Utah that drivers with a restricted driver's license have a lower crash rate (66). Patients should restrict their driving in heavy congestion, at night, and during inclement weather. They also should restrict their driving to familiar local areas.
- Driving with a companion—on the basis of the evidence that the crash rate is reduced if the driver is with a companion, it could be sensible to restrict driving exclusively to when there is someone else in the car, as in the copilot model (67).
- Licensing authority-reporting relationship—the patient and caregivers should be advised to acquaint themselves with local driver-licensing authority requirements, especially on disclosure. Except for jurisdictions that mandate reporting of drivers with dementia—such as California and some Canadian provinces—there is no



obligation for a doctor to break medical confidentiality in these cases.

- Insurance-reporting responsibility—the patient and caregivers should be advised to acquaint themselves with the insurance company’s policy on disclosure.

All of the above should be clearly recorded in the medical notes of the patient’s file.

### Dealing with Driving Cessation

There is strong evidence that drivers with dementia not only limit their driving or cease driving voluntarily but also are amenable to pressure from family and physicians. In one of the largest studies, 18% stopped driving of their own accord, 23% because of their physician, 42% because of family members, and the rest from a combination of interventions (30). Early data on how patients with dementia compensate for their transportation needs suggested that they are severely limited if they do not live with a family member who is a driver (12). Psychological adaptation to driving cessation may be helped by diagnosis and psychotherapeutic input, but this has not been tried in randomized, controlled trials. In a single case study, the patient’s feelings and fears about giving up driving were explored (68). The intervention was designed with the patient as collaborator—that is, by sharing the diagnosis, discussing its consequences, and dealing with the events at an emotional level, not an intellectual one. For example, a male patient was able to grieve about the disease and specifically about his loss of the car. This ability in turn enabled him to redirect his attention to other meaningful activities that did not involve driving. Although this approach may be hampered by the deficits of dementia, it reflects a more widespread trend toward sharing the diagnosis of dementia with the patient.

### Medical Advice for Patients Assessed as Unfit to Drive

If the assessment supports driving cessation, patients and caregivers should be advised of this development. Advice from a social worker also may be helpful. Driving cessation can have a considerable effect on a patient’s lifestyle. Most elderly drivers accept that a physician’s advice is influential in their decision to cease driving (69), and many patients with dementia respond to advice from families or physicians.

If the positive approach is not successful, confidentiality may have to be broken for some patients. Most professional associations for physicians accept that the

principle of confidentiality may be limited by a common-good principle of protecting third parties when direct advice to the patient is ignored (20). Removal of the driver’s license is not likely to have much effect on these patients, and the vehicle may need to be disabled and all local repair service shops warned not to respond to calls from the patient.

In the event of a decision to advise driving cessation, it may be helpful to seek assistance from a medical social worker for planning alternative travel strategies. But alternative strategies may be difficult to find because adequate paratransit—that is, tailored, affordable, and reliable assisted transportation that is acceptable to older adults with physical or mental disability, or both (31)—is lacking in many locales. Paratransit is expensive but may be beneficial to improve quality of life and avoid or at least delay institutionalization.

### Screening for Older Drivers with Dementia

Despite the lack of convincing evidence, ageism policies in many jurisdictions have led to screening programs for older drivers (70). In the absence of reliable and sensitive assessment tools, this approach is flawed, as illustrated by data from Scandinavia (3). Finland has regular age-related medical certification for fitness to drive, whereas Sweden has no routine medical involvement in license renewal. There is no reduction in the number of older Finnish people dying in car crashes, but there is an increase in the number of those dying as pedestrians and bicyclists, possibly by unnecessarily removing drivers from their cars.

A more minimalist and less medical approach using simple measures, such as a vision test and written skill examination, may be associated with a small reduction in deaths among older people by car crash (71). Unfortunately, this approach also is associated with a reduction in the number of older drivers—a possible negative health impact (72). Another approach is opportunistic health screening of older drivers with traffic violations (73). It remains to be seen whether these screening policies and others reduce mobility among older people—a practical and civil rights issue of great importance.

Some professionals occasionally may refer to off-road assessment procedures as screening maneuvers. In public health terms, it is more appropriate to use the phrase “screening maneuvers” when considering the assessment of unselected populations and the phrase “off-road assessment” for the increasing body of literature on behavioral, occupational therapy, and neuropsychology assessments of older people when there is cause for concern, such as drivers seen by the DMV or a specialist physician.

## BARRIERS TO A POSITIVE HEALTH APPROACH FOR AGE-RELATED DISEASE AND MOBILITY

There are several barriers to developing an enabling approach for older drivers with age-related disease. Despite increasing recognition of the importance of maintaining mobility, Medicare and other health care providers do not fund a comprehensive assessment and remediation process as outlined in Table 1. Doctors, specifically specialists in the health care of older people (74), have an inadequate knowledge of traffic regulations. The negative thrust of the literature, the lack of interdisciplinary support, and the paucity of alternative transportation may explain this lack of knowledge. Courses on traffic medicine are virtually nonexistent in medical schools. Moreover, older people with age-related diseases may not share a sense of moderate optimism that remediation is feasible.

Overcoming these barriers requires actions on several fronts. The development of literature on fitness to drive that emphasizes enabling strategies and barriers to driving would be an important first step (75). Courses in assessing fitness to drive for specialists dealing with older people having a disability—offered in some Australian states—should be required. The development of specialist centers allied to departments of geriatric medicine and psychiatry could serve as a catalyst to the development of the necessary skill base. Health care insurers need to be lobbied to provide for interdisciplinary driver assessment. Research that establishes the validity and effectiveness of the process would be extremely helpful. Linking medical sections of the DMVs with public health and medical specialists dealing with older people, as well as with area agencies on aging, also could further a positive agenda and ensure that local guidelines are both evidence based and enabling when possible. Access to adequate, affordable,

and acceptable alternative transportation must underpin these other developments.

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TABLE 1 Diseases and Appropriate Assessment and Remediation

Category	Disease
Neuropsychiatric	Stroke—driving-specific rehabilitation (76)
	Parkinson's disease—maximizing motor function, treatment of depression, assessment of cognitive function (77)
	Delirium—treatment and resolution
	Depression—treatment: if antidepressant, choose one with least potential of cognitive/motor effects (78)
	Mild dementia—assess, treat depression, reduce/eliminate psychoactive drugs, advise not to drive alone (79)
Cardiovascular	Syncope—advice pending investigation: treat cause (80)
Respiratory	Sleep apnea—treatment of underlying disease (81)
Vision	Cataract—surgery, appropriate corrective lens, and advice about glare (23)
Metabolic	Diabetes—direct therapy to avoid hypoglycemia (82)
Musculoskeletal	All arthritides driving—specific rehabilitation program (24)
Iatrogenic	Polypharmacy—rationalize medications (83)
	Psychoactive medication—rationalize, minimize (83)

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# Driver Programs

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# Driver Programs

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The approaching, unprecedented surge in the population of older Americans deserves thoughtful anticipation, with innovative programs that satisfy two apparently contradictory social imperatives. The continuing mobility of seniors in their 70s, 80s, and older must be assured. Emphasis must be placed on keeping older people driving as long as they safely can and providing safe, convenient, desirable, and dignified transportation alternatives when they cannot. At the same time, the increasing likelihood of decline in the various functional capabilities needed to drive safely—an undeniable consequence of normal aging plus a higher incidence of chronic and acute medical conditions—makes it a public health priority to identify and assess individuals who pose risks to themselves and others by continuing to drive. Progress on developing and integrating initiatives in these areas and promising future directions are discussed below.

Central to the discussion of emerging driver programs is the lifelong need for safe mobility. Seniors suffer a profound loss of quality of life when their mobility becomes significantly restricted, with cascading costs to families and to society. Because the personal automobile remains the dominant form of transportation, retaining driving privileges is the strongest determinant of mobility and will be for the foreseeable future. Hence, the inherent conflict for practitioners is to balance quality-of-life issues for the individual with public safety considerations. Also, it becomes apparent that program initiatives must extend beyond the determination of who is and who is not fit to drive. As improved methods are developed and validated for early detection of

at-risk seniors, the need for complementary program elements becomes more urgent, to provide remediation, rehabilitation, counseling, or retraining for seniors who can benefit; in this way, the best mobility solutions equaling the level of functional capability and the desire to keep driving can be found.

Key elements are program integration and coordination. To administer the diversity of program activities to meet the goals above will involve many organizations at many levels. Legislators and policy makers must be attuned to what works in the community. Professional and lay caregivers must have access to effective tools that are appropriate for their clients and customers. Private-sector and social-service organizations emerging as locations of choice for seniors to confront fit-to-drive issues without fear of immediate repercussions for their license status should be linked to the regulatory agencies, respecting individual privacy and serving the greater mandate for public safety. A range of educational activities aimed at the medical–health care, social service, and law-enforcement communities; older drivers themselves; their friends; and their families must be undertaken to dispel myths and promote solutions for maintaining safe mobility for senior drivers. The scope of this discussion includes the following principal components:

- Goals and techniques for the assessment of driver capabilities;
- Remediation of older drivers with known impairments and counseling of such people and their caregivers to help find the best transportation options available to meet their mobility needs;

- Current programs and promising directions for licensed older drivers; and
- Recognition that although older drivers do not present a greater risk to other road users than middle-aged drivers do, they are at greater risk to themselves because of their greater fragility; their activities may be limited by self-imposed restrictions, which they place on their driving as well.

## IDENTIFICATION AND ASSESSMENT OF HIGH-RISK OLDER DRIVERS

### Deciding What to Measure: Functional Impairment

The primary goal in this area is to determine which older drivers pose the greatest risk to themselves and others. Seniors as a group may be a problem because the curve relating fatality rate to driver age turns sharply upward as seniors age into their 70s and older. Also as a group, they may be overrepresented in certain types of crashes. But the collective goal can be achieved only by discerning the individuals who are capable of driving safely. On all psychometric tests, the range of performance for older-age cohorts dramatically exceeds the range for younger ones (1); as the distribution of abilities flattens and elongates with advancing age, characterizing an individual in terms of a group average becomes more prone to error. Thus, the use of a person's chronological age alone as a surrogate for driving risk has been fairly and consistently criticized. But this raises the question, what are the key indicators for impaired driving—that is, what should be measured?

A core premise guiding the development of assessment programs is that the driving task can be broken down into different component processes—for example, detecting hazards, making decisions, judging gaps in traffic, and executing physical movements to manipulate vehicle controls. The successful execution of component processes typically leads to the successful performance at the operational level of driving (2). Conversely, it is believed that the failure to execute even one component process significantly increases the likelihood of impaired driving and crashes.

Caution is required. Safe driving also depends on performance at tactical and strategic levels, particularly when such things as route planning and choices about when and under what conditions it is safest to drive come into play. In an often-cited study, Salthouse (3) illustrated how older people who demonstrated deficits in each of several component processes showed no losses in whole-task performance because superior tactics and strategy allowed them to compensate for their declines at the operational level. Still, the notion is compelling

that a minimal degree of capability to perform each component process will result in safe driving. In other words, compensatory strategies likely will prove ineffective beyond the level of degradation of driving skills. So the question of what to measure can be rephrased: what kinds of measures tell when and to what extent a person will experience declines in the component processes of driving that are the most critical for safety?

This question can be answered with reasonable reliability and a high degree of confidence: differences in the performance of critical driving skills can be accounted for in terms of a set of underlying functional capabilities. With other things equal, intact functional abilities lead to superior on-road performance and fewer at-fault crashes, while diminished functional capabilities translate into impaired driving skills and higher risk. Of course, other things often are not equal. Situations can arise when many things go wrong at once, necessitating emergency responses that would test the skills of even the best-trained, most-fit professional driver. Aggressive behavior or attitude that leads to a disregard of traffic-control messages and warnings can overwhelm any skill ability.

These influences—plus the fact that many individuals with the greatest declines in functional ability already have been selected out of the driving population at any given point in time—make direct links between diminished capability and crash risk difficult to prove, although evidence is mounting. Significant correlations between functional loss and crash involvement have been reported with increasing frequency in the technical literature (4, 5), and meta-analyses give an indication of the correlations' relative importance (6, 7). Epidemiological studies using case-control methods describe risk ratios that indicate a significantly higher likelihood of a driver having been involved in a crash if he or she is functionally impaired but with unrestricted driving privileges. These drivers contrast with drivers who are matched in terms of impairing condition and whose driving is restricted (8). The findings—with the common sense that tells people they cannot drive as well as they used to if they cannot see as well, or react as quickly, or remember where they are going—make a convincing case that early identification of high-risk older drivers can be achieved through screening and assessment of specific functional capabilities.

Before an attempt to pin down which capabilities are most important to measure and how best to measure them, the key distinction between functional ability and medical diagnosis needs to be made. An individual diagnosed with a medical condition may or may not suffer measurable functional decline. For example, a person with diabetes may suffer pronounced visual impairment (e.g., diabetic retinopathy), while another with a different form or stage of the disease suffers little or none.

Also diabetes affects systems other than vision. The disease—more prevalent among older people—may result in circulatory problems, including a loss of feeling in the hands and feet. Heart disease and stroke are two to six times more common in people with diabetes (9). Therefore, the loss of functional ability is at issue, not the diagnosis or medical condition.

Functional changes at the center of identification and assessment programs now undergoing pilot testing in the United States and abroad are briefly described:

- Reduced visual acuity—the aspect of vision used to resolve fine detail, for example, to see roadway targets with high brightness, or color contrast to the surrounding background area, or sharply defined edges, such as letters on road signs.
- Reduced visual-contrast sensitivity—the aspect of vision used to see targets that do not differ greatly in brightness or color from the surrounding background area or that have fuzzy or ill-defined edges, such as the edge of the road where there is a worn, faded, or missing edge stripe and the color of the shoulder is similar to that of the paved surface.
- Increased susceptibility to glare or slower glare recovery—stray light entering the eye masks or interferes with focal vision for a longer time, so that roadway targets cannot be seen as well as they were before the glare.<sup>1</sup>
- Reduced sensitivity to changes in angular size and motion—judgments of how far away an object is and how fast it is moving (e.g., an approaching car as the driver waits to turn left at an intersection).<sup>2</sup>
- Poorer visual-pattern perception and visualization of missing information—the ability to extrapolate from the scene's visual elements and construct a whole image from only partial information, which may be required to recognize a sign, other traffic-control devices, or obstructed hazards.
- Less efficient visual search—the speed with which people can direct their gaze from one location to another when experience dictates that information important to the task at hand will be found (e.g., when a driver scans the roadway scene ahead to look for a sign, landmark, or other directional information).
- Reduced area of visual attention—the portion of the overall visual field when a person is not only capable of seeing an object but also likely to pay attention to, recognize, and respond to the object in a brief

enough period of time to avoid a crash if the object is a traffic hazard.<sup>3</sup>

- Impaired selective-attention ability—the ability to filter out the less important events and information on a continuing basis while driving and to focus on the things most critical to safety at each instant.<sup>4</sup>
- Less efficient divided attention or slower attention switching—the ability to monitor and respond effectively to multiple sources of information at the same time.<sup>5</sup>
- Less efficient working-memory processes—a driver's ability to think about and recall information while driving, which will be needed at a later time, without any lapses in safely controlling the vehicle (e.g., being able to remember and apply while driving a simple set of navigational instructions memorized before a journey).
- Loss of limb strength, flexibility, sensitivity, or range of motion—for example, quickly shifting the right foot from the accelerator to the brake when needed and applying correct pressure for appropriate speed control to maneuver the car safely around obstacles.
- Reduced ability to rotate head and neck—drivers' physical ability to focus their gaze in each direction from which a vehicle conflict may occur in any given situation, including the familiar left-right-left check before crossing an intersection and looking over the shoulder before merging into traffic or changing lanes.

The functional abilities above—all of which decline as a consequence of normal aging—are a logical starting point in the development of screening and assessment programs to detect high-risk drivers. Although certain diseases, pathology, or trauma can cause or accelerate the loss of a given aspect of functioning, the normal aging process leads to a functional decline for all adults but at rates that vary widely from one individual to another. With the dramatic increases in the number and proportion of older people in the United States, there will be an associated increase in the number and proportion of drivers who are functionally impaired. The challenge is to identify and accommodate the needs of as many people who experience such decline as possible, at a cost individuals and society can afford.

<sup>1</sup> This glare usually occurs at night from oncoming headlights or headlights seen in the rearview mirror, but sun glare can produce similar problems during the day.

<sup>2</sup> The accuracy of such judgments depends on how quickly and accurately the brain can interpret changes in the size of the image formed on the retina at the back of the eye when the person's gaze is focused on a distant object.

<sup>3</sup> The risk of colliding with vehicles, pedestrians, and bicyclists entering from the side of the road or at an intersection increases significantly as the area of visual attention shrinks.

<sup>4</sup> Although not conducted on a conscious level, this action is necessary for the anticipation of and effective response to hazards so an avoidable conflict does not become an emergency.

<sup>5</sup> For example, a driver entering a freeway must track the curvature of the ramp and steer appropriately, keep a safe distance behind the vehicle ahead, and check for gaps in traffic on the highway, while accelerating just enough to permit a smooth entry into the traffic stream.

### Balancing Resources Against Testing Objectives: A Multilevel Approach

Ideally, a functional assessment procedure is developed that can identify every impaired driver and, at the same time, not mistakenly identify individuals who are fit, functionally intact, low-risk drivers. The first attribute characterizes the most sensitive test; the second attribute signifies the most specific one. In actual practice, the likelihood that any one procedure could satisfy both objectives is very small. Criterion issues confound the task. Because functionally intact drivers crash for reasons unrelated to impaired driving skills, while functionally impaired drivers may escape crashes by strategically reducing their exposure or through the defensive actions of other drivers, a variance in crash involvement will remain unexplained by any assessment of functional status.

Policy considerations demand an assessment approach that maximizes both sensitivity and specificity. If many drivers with significant impairments were missed, public health and safety would suffer unacceptably. If many individuals were restricted unnecessarily from driving or were compelled to spend large amounts of time or money to retain their driving privileges, a backlash would be expected against the entities performing the assessments and the administration that authorized them.

Even for individuals who reliably demonstrate a significant functional decline in a particular area, there is the practical matter of determining why the decline has occurred. Without diagnostic information about the source of impairment, it is difficult to judge the potential for remediation and the necessary understanding of any condition that indicates that a progressive decline will be absent.

The amount of time to complete an assessment and the various costs associated with implementing the procedure are determined by the sophistication of the test. For example, a common condition that can be diagnosed by a nurse practitioner requires a smaller investment of resources either from the patient or the insurer than would magnetic resonance imaging or ultrasound—both of which must be administered by highly trained technicians, using complicated and often expensive equipment, and the results must be interpreted by a specialist. Of course, some individuals are referred for the sophisticated assessments to pinpoint reliably the exact nature of the problem, but such procedures are administered only after the need is identified through previous screening.

An analogous, although not identical, approach holds promise to detect functionally impaired drivers at a cost society can afford. Namely, a first-tier screening activity could be designed as brief and inexpensive to administer

but also could have clear limitations in its sensitivity and specificity. The screening content would be composed of test procedures that are valid indicators of functional status for the key driving abilities noted earlier but that lack precision in measuring the extent of loss or in pinpointing the underlying conditions. A fundamental outcome of this tier of assessment must be a preliminary sorting of drivers who are at significantly higher risk of crash involvement because of functional driving impairments from drivers who are not. Certainly, the number of people in the latter group would be expected to exceed those in the former group, but the relative proportions would be expected to shift with increasing driver age. A more ambitious goal of first-tier screening, which relies on the findings of studies under way in several jurisdictions, is to permit discriminations within the group deemed to be at significantly higher risk, to identify individuals with impairments who pose a danger to themselves and others if they continue to drive.

The priority on detection of the most serious driving impairments using a first-tier screen is reflected in the Gross Impairments Screening (GRIMPS) Initiative, implemented on a pilot basis in Maryland. Secondary outcomes of the screening activity that may prove valuable in promoting safe mobility among the senior driving population also include (a) guidance and referrals for follow-up examinations in a specialty area, which in turn can open up possibilities for remediation of declining skills; and (b) a heightened knowledge of current functional status measured against requirements for safe driving, providing a baseline against which future changes in abilities can be tracked by individuals and their friends and family members.

The GRIMPS screen is actually a battery of brief procedures spanning the range of critical functional abilities. Each procedure is based on research that has shown an association between poor performance on an included measure and a higher likelihood of crash involvement or other indication of driving impairment. Specific methods are tailored for early implementation in a short time, using inexpensive materials by staff with minimal training (nonspecialists). The entire battery, including instructions, can be administered in less than 15 min. Measures of functional ability in GRIMPS are shown in Table 1, with time of administration and summary of procedures.

A rationale for the physical measures included in GRIMPS begins with the work of Marottoli et al. (10), who reported that performance on the timed rapid-pace walk correlated most strongly with motor-vehicle crashes, traffic violations, and police stops for driving problems, among several functional measures in the year following testing. Slower times for the foot tap test were associated with an increase in the adverse driving events in the same study. Hu et al. (11) linked

TABLE 1 GRIMPS Battery

<i>Functional Ability</i>	<i>Measurement Procedure</i>	<i>Time</i>
<i>High- and low-contrast (static) visual acuity</i> required to read road signs and detect roadway features and hazards under good visibility conditions, at dawn or dusk and in rain or fog.	<i>Vision Test Cards</i> —A 5.5-in. <sup>2</sup> test card [from the American Association for Retired Persons (AARP)] contains six lines of three letters each, for acuities of 20/30, 20/40, 20/50, 20/60, 20/80, and 20/100 at 5-ft viewing distance. High- versus low-contrast letters are used on opposite sides of the card. Smallest line read without errors is the acuity score.	2–3 min
<i>Intact scanning pattern</i> as required to rule out neglect of one side of the visual field (hemianopia) while driving—a deficit associated with recovering stroke–CVA patients.	<i>Symbol Scan Chart</i> —This 5.5- × 8.5-in. test chart contains 10 common symbols arranged in two rows of five columns each. With chart placed at arm's length and eye level, the examinee must identify the shapes without turning his or her head (i.e., by moving eyes only). Verbal report indicates normal scanning pattern versus hemineglect.	1 min
<i>Visualization—understanding of spatial relationships</i> as required to identify objects when only part is in view and anticipate unseen hazards.	<i>Motor-Free Visual Perception Test: Visual Closure Subtest</i> —Examinee chooses which one of four incomplete figures may be completed to match a whole figure presented on the same test page. Correctness, not time, is scored for the 11 test items.	3 min
<i>Visual search and sequencing: information-processing speed, divided attention, and attention switching</i> as required to respond effectively and without undue confusion to the continuously changing priorities in information-rich, visually complex (e.g., urban–suburban) environments.	<i>Trail-Making Test</i> —Examinee uses a pencil to connect a sequence of integers, or a mix of integers and letters, in ascending order as quickly as possible. Part A contains only numbers; Part B contains numbers and letters that must be connected in an alternating fashion. Performance is timed. Errors are pointed out during the test, and examinee continues from last correct connection without stopping the clock. Time-to-complete all items, or number of items completed within a fixed interval, defines scoring criteria.	4–6 min
<i>Immediate memory and working memory</i> as required to remember the meaning of traffic-control devices and follow directions, while continuing to perform essential driving tasks.	<i>Cued and Delayed Recall</i> —Three short words are presented to the examinee, who must repeat them back immediately; a probe set may be repeated as required. The same memory set must then be recalled later, after a number of intervening procedures in the test battery. Performance is scored in terms of the number (if any) of items omitted.	45 s
<i>Lower-limb mobility</i> (strength, endurance, and coordination) required to sustain pedal control without fatigue and to move between accelerator and brake pedals quickly and accurately.	<i>Rapid Pace Walk and Foot-Tap Test</i> —Examinee walks along a 10-ft path, turns, and returns to the starting point as quickly as possible. Then while seated, he or she touches the right foot to the floor five times, alternately on each side of a 2-in.-tall barrier, moving the foot laterally from one side to the other on every tap, as quickly as possible.	1 min
<i>Upper-limb mobility</i> as required for maintenance of steering control and for emergency responses.	<i>Arm Reach</i> —Examinee is asked to raise each arm as high as possible over his or her head. To pass, the arm must be raised so that the elbow is above shoulder height.	15 s
<i>Head–neck flexibility</i> as required to look over one's shoulder to detect conflicts during turns, merges, and lane changes.	<i>Head–Neck Rotation</i> —The examinee, who is in a chair and wearing a seat belt, must turn and identify a high-contrast stimulus (e.g., clock face) placed 10 ft behind him or her. With belt fastened tightly, the head, neck, and torso may turn but not the lower body parts.	30 s



poor performance on the arm reach measure to a twofold increase in crash risk for women age 65 or older, while “difficulty reaching out” significantly predicted at-fault crash involvement in a study by Sims et al. (12). Stewart et al. (13) found a highly significant correlation between bursitis and traffic crashes in the Florida Geriatric Research Program Longitudinal Study. Marottoli et al. (14) found limited head and neck mobility (range of motion) independently associated with an increase in adverse driving events in multivariate analyses adjusted for driving frequency. Reduced head and neck flexibility resulted in significantly slower decision times at intersections for older (but not younger) drivers in a study by Hunter-Zaworski (15).

Vision tests of GRIMPS acknowledge that a de facto national standard of 20/40 binocular-static acuity exists for licensure—regardless of the mixed research record in this area—and provide a familiar eye-chart assessment using high-contrast optotypes to allow for the confirmation of or deviation from this level of capability. The measurement of acuity using low-contrast stimuli reflects findings reported by McKnight and McKnight (16) and others of significant correlations with on-road performance. In addition, difference scores between measures using high- and low-contrast acuity targets are useful to identify people who increase their risk the most when driving during low-luminance (dawn or twilight–dusk) conditions (17). Next, the need to screen for gross deficits in visual scanning reflects the increased incidence of cerebrovascular accidents (CVAs) among older people. People recovering from stroke often have a hemianopic loss, causing the neglect of one side (usually left) of the visual field. Szlyk et al. (18) found that such losses in older patients with CVAs were associated with more lane-boundary crossings and variability in lane position in a driving simulator and were predictive of real-world crashes.

Hu et al. (11) identified impaired immediate memory as a risk factor for crash involvement of older men. In a case-control study, Johansson et al. (19) showed that subjects in a group with driving suspensions and crashes scored significantly lower on an immediate memory task compared with matched controls. McKnight and McKnight (16) reported a strong correlation between delayed recall and safe driving. Hunt et al. (20) found a highly significant correlation between driver performance on the logical memory subscale of the Wechsler Memory Scale, which assesses immediate and delayed recall, and outcomes on a road test.

Difficulties with the visualization and comprehension of spatial relationships have been linked by Keyl et al. (21) to impaired driving skills for both Alzheimer’s and control subjects in a simulator study based on visual closure subtest scores of the Motor-

Free Visual Perception Test. Poorer performance on this same measure correlated significantly with errors on a driving test in research by Tarawneh et al. (22). Marottoli et al. (10) found that poor understanding of spatial relationships, as manifested by the difficulty of reproducing an intersecting pentagon design (23), most strongly correlated with adverse driving events. Problems in copying a complex geometric figure from the Rey–Osterrieth Complex Figures Test—a measure of visuoconstructional ability independent of memory function—were the most significant predictor of crashes in a high-fidelity driving simulator study by Rizzo et al. (24).

A cluster of perceptual–cognitive skills, including divided attention, attention switching, information-processing speed, and visual search and sequencing, are included in the common neuropsychological Trail-Making Test (25). Highway safety researchers investigated these skills extensively. Tarawneh et al. (22) reported that worse performance on Trails B showed the highest correlation of all factors studied (visual, cognitive, and physical) with problems on a driving test. Tallman et al. (26) found that performance on this measure correlated significantly with steering deviations in a driving simulator. Stutts et al. (27, 28) found a highly significant correlation between poor Trails B performance and crash involvement. Rizzo et al. (24) reported that Trails B performance significantly predicted simulator crashes. Finally, Odenheimer (29) found significant correlations between road-test performance and both parts (A and B) of the Trail-Making Test in a sample of older drivers, including older drivers with and without dementia. The rationale provided by these and additional independent research findings to adopt this measure or a construct-valid derivative of the Trail-Making Test in GRIMPS is compelling.

A kit containing the materials and instructions needed for manual administration of the screen was prepared under a National Highway Traffic Safety Administration (NHTSA)–sponsored research project (30), and efforts to automate the battery are under way. To reiterate, however, GRIMPS provides only a coarse filter, designed to detect gross impairments in people with the functional abilities needed for safe driving. The use of GRIMPS for finer discriminations of functional status sufficient to trigger other programmatic actions in the multilevel approach recommended here remains to be demonstrated in the pilot tests now under way. A second tier of diagnostic procedures is essential to assess more precisely the extent of functional loss or to determine the underlying causes for the decline observed in a screening activity.

Many diagnostic assessments can be accomplished using conventional techniques performed and interpreted by specialists in such fields as ophthalmology

(glaucoma, cataracts, and age-related macular degeneration), neuropsychology (dementia), internal medicine (organ failure and systemic diseases), and physical medicine (musculoskeletal problems and arthritis). Often the critical event is getting the older driver to go for an examination. Unfortunately, there may be no perceived need by the individual to be seen or no perceived benefit from the knowledge of health status that results. The belief that visits to specialists should be encouraged or initiated through the GRIMPS process is currently under study, as noted above.

Another concern at the diagnostic level of assessment is the extent to which a specialist can relate a patient's test outcome to driving. Although major efforts to establish the association between defined degrees of severity (or disease progression) for specific pathologies and an increasing risk of crash involvement have been undertaken in recent years (8), much work remains to be done. Further, do the practitioners who are in a position to advise their patients about the consequences of their diminished capabilities for safe driving, and the appropriate steps they should take to reduce their risk, know of the information available in this area?

At least two activities hold promise to enhance substantially the diagnostic assessment of driving impairment. First, recently developed tools, through considerably more sophisticated methods than performed at the GRIMPS level, can more precisely discriminate an individual's crash risk associated with particular types of functional loss. Second, a professional niche specializing in this activity has evolved that offers generous employment opportunities in the decades ahead.

Evidence of the sophistication to assess driver functional capabilities began with the computer-based measures of visual attention—that is, the Useful Field of View Test developed and studied throughout the 1990s, most extensively through the work of Ball and colleagues (31–35). These studies' findings quantify the relationship between a person's functional visual-attention loss and intersection crashes, linking measured deficits in visual attention to specified increases in crash risk. In a related area, fine discriminations of crash risk associated with information-processing difficulties and restrictions in channel capacity were investigated by Cantor (36). These fine discriminations serve as the basis for paper-and-pencil and computer-based instruments. In the area of dementia and driving, Dobbs et al. (37) produced a pioneering, computer-based assessment protocol to sort individuals into a three-way classification of functional status. For people in the middle with ambiguous cognitive status, a tailored road test was designed to focus on the particular problems most commonly manifested by drivers with dementia. Finally, the most comprehensive approach may be reflected in the

automated psychophysical test, as described by McKnight and McKnight (16). This test measures the full array of sensory, attentional, perceptual, cognitive, and psychomotor abilities in 1 h through an automated, self-paced examination on a desktop PC.

Next, the already substantial—and in the future potentially much greater importance of—clinical and on-road assessments performed by certified driving rehabilitation specialists (CDRSs) cannot be ignored when discussing the diagnosis of driving impairment. These practitioners are drawn principally, although not exclusively, from the ranks of occupational therapists (OTs). Most CDRSs' professional status provides access to confidential medical records, and they are already an integral part of the medical hospital managed care organizations that deliver health care services. In theory, combined with an in-depth understanding of the functional requirements for driving and insights about the extent to which clients depend on this activity to meet their needs for everyday living, these attributes define a professional niche ideally suited to evaluate fitness to drive but also identify and provide referrals for specialized treatments or appropriate rehabilitation–remediation programs. CDRSs often evaluate the need for and prescribe adaptive equipment for people with disabilities to drive and then train the driver to use the adaptive vehicle controls safely. Further, CDRSs counsel changes in driving habits when nonremediable deficits are demonstrated. OTs without CDRS credentials are implementing this role on a pilot basis in Maryland (38).

With this acumen and repertoire of skills, CDRSs could be integral to the design of innovative driver assessment, rehabilitation, and mobility counseling programs. But serious barriers to large-scale program implementation still exist. Few practitioners (fewer than 250) hold CDRS certification in the United States, and no uniform criteria for granting certification exist, nor does a standard curriculum or structured training program to prepare for the certification. With the correction of these programmatic deficiencies and the development of in-service and practicum–internship opportunities, OTs and, conceivably, certified occupational therapy assistants (COTAs) could assume prominence in performing driver assessments at the diagnostic level.

One final resource for diagnostic assessment of driving skills that deserves mention is simulation. Advances in computers, image processing, and display and sensor technologies in the last decade have created interactive simulation devices that are capable of rendering plausibly realistic driving environments at a reasonable cost. These devices could be used as assessment tools by public- and private-sector concerns (39). The driver is confronted with a range of believable scenarios for the evaluation of key driving skills; brake, accelerator, and

steering inputs are scored on objective criteria. Besides evaluating driver responses to events that may be too risky for the driver and the evaluator to experience in a road test or—as in many precrash scenarios—that occur too rarely to be encountered, a simulator-based assessment facilitates the standardization of test procedures and the development of norms. A realistic, interactive test in which results can be reviewed and mistakes explained may have great value for effective remedial treatments and acceptance of and compliance with subsequent restrictions of driving privilege.

### Disseminating Effective Tools and Procedures

As jurisdictions prioritize local and regional issues relating to seniors' mobility needs, ready access to information on assessment procedures and program options will be vital for implementing the best feasible solutions. Program planners and administrators should learn the extent to which a given assessment procedure has been

validated, under what conditions, against which criteria, and for what number and type of older drivers.

Table 2 presents a sampling of programs with demonstrated practical value. These programs offer a range of driver assessment activities. Not intended as an exhaustive list, Table 2 provides insight into the diversity of practices and techniques for conducting driver assessments, introduces program delivery options, and may stimulate inquiries for more in-depth information from the sources.

An annotated compendium of research findings on driver assessment is found in Staplin et al. (30). This 120-page report represents the product of a literature search and synthesis sponsored by NHTSA. Studies included in the compendium met two criteria: (a) older drivers were included in the study sample and (b) either crash data or performance measures commonly accepted as crash surrogates served as outcome variables. The authors, location, methodology summary, and key finding overview are reported for each study in the compendium.

TABLE 2 Sample of Programs Providing Driver Assessments and Related Services

<i>Program Name and Organization</i>	<i>Scope of Activities</i>
<i>Getting in Gear</i> Tampa Bay Regional Planning Council, Area Agency on Aging, St. Petersburg, Fla.	<i>Driver Assessment:</i> Mini-Mental State Examination (MMSE), Automated Psychophysical Test, Useful Field of View (UFOV), GRIMPS Initiative, on-road driving test. <i>Driver Education and Training:</i> National Safety Council's Coaching the Mature Driver Program. <i>Case Management–Social Agency Referrals:</i> Alternative transportation, Meals on Wheels, adult day care, Lighthouse for the Blind, physician examination.
<i>Older Driver Evaluation Program</i> Office of Geriatrics & Gerontology, Ohio State University, Columbus	<i>Driver Assessment:</i> Self-report questionnaire (health status and behaviors, adaptive aids, driving habits, living arrangements, caregiving responsibilities, etc.); pharmacological review; hearing screening; MMSE; Trail-Making Test; vision screening; range of motion, balance, strength, and endurance; reaction time (RT); driving simulator; on-the-road assessment. <i>Case Management–Social Service Agency Referral:</i> Recommendations for driver retraining or adaptive equipment prescriptions, alternative transportation information, and help with alternative living arrangements; referral to physician, OT, or physical therapist; physician examination.
<i>Mature Driver Retraining Workshops</i> Traffic Improvement Association of Oakland County, Bloomfield Hills, Mich.	<i>Driver Assessment:</i> (Voluntary) psychophysical tests (simple RT, visual acuity and depth perception, visual attention–UFOV), on-road driving evaluation where instructor indicates problems in driving behavior and offers suggestions for improvement. <i>Driver Education and Training:</i> American Automotive Association (AAA) Safe Driving for Mature Operators Program.
<i>Community Mobility and Driving Rehabilitation Program</i> Maryville University, St. Louis, Mo.	<i>Driver Assessment:</i> Referrals from physicians, Alzheimer's Association, and family members receive clinical assessment of visual acuity and contrast sensitivity, visual attention (UFOV), Trail-Making Test, cognition (Short Blessed Examination), posture, strength, endurance, and range of motion. Road tests for drivers without significant cognitive impairment include progression into traffic and complex driving environments.

(continued)

TABLE 2 (continued) Sample of Programs Providing Driver Assessments and Related Services

Program Name and Organization	Scope of Activities
	<p><i>Driver Training:</i> Teach familiarity with adaptive driving devices, then reassess. No training for cognitively impaired.</p> <p><i>Counseling:</i> Driving needs and problems discussed with family members; alternative transportation information provided to drivers when entering program.</p> <p><i>Reporting:</i> Reports are sent to physicians, and drivers who do not pass the tests are reported to DMV.</p>
<p><i>You Decide: Senior Driving Awareness Program</i> Area Agency on Aging 1-B, Southfield, Mich.</p>	<p><i>Driver Assessment:</i> Program provides information supporting self-assessment only.</p> <p><i>Driver Education and Training:</i> Two-part monthly meetings based on the Driving Decisions for Seniors Program, developed by Ethel Villeneuve from Eugene, Oregon. The first part is directed toward assisting seniors facing driving restrictions, imposed by either themselves or others, and helping current drivers prepare for the day when they can no longer drive. Group bus trips are organized to teach seniors how to use the local mass transit system. Instruction is provided on planning a trip, using a bus schedule, boarding a bus, transferring between routes, and treating mass transit use as a positive experience. In general, this program focuses on how to improve or self-assess driving skills, when to consider restricting driving, how to cope with the emotional aspects of driving restriction or cessation, what public and alternative transportation options are available, how to participate in transportation planning efforts and public forums, and what to consider when planning for future mobility needs.</p> <p><i>Counseling:</i> The second part of the monthly meeting is a support group where older people or family members discuss issues of relevance to the older driver. Group trips are also arranged to help older people who have never used or are uncomfortable using public or alternative transportation.</p> <p><i>Case Management–Social Service Agency Referral:</i> In-progress information and referral database includes a variety of mobility resources for older drivers including current defensive or driver improvement courses; physician assistance and medical evaluation; retraining programs; and connections to counseling resources, public and alternative transportation resources, and other peer-support programs.</p>
<p><i>Older Driver Safety Project</i> DeGraff Memorial Hospital, North Tonawanda, N.Y.</p>	<p><i>Driver Assessment:</i> Visual acuity testing (day and night), RT testing, cognitive testing; hearing tests, rules of the road knowledge, and on-road driving assessment.</p> <p><i>Case Management–Social Service Agency Referral:</i> Referral to special vehicle modifiers, driver specialist for on-road remediation, medical personnel, driver retraining programs (AAA or AARP), support group–counseling for driver (and family) who is advised to cease driving, and counseling on options–alternatives to driving.</p>
<p><i>Getting Around—Seniors Safely on the Go</i> Howard County Office on Aging, Columbia, Md.</p>	<p><i>Driver Assessment:</i> Peer volunteers conduct older driver GRIMPS Initiative in the senior center.</p> <p><i>Education and Counseling:</i> Feedback on GRIMPS is provided by OT who also provides information relating to physical fitness and nutrition to better (driving) health and materials about alternative transportation in the region.</p> <p><i>Referral:</i> OT suggests follow-up appointments with ophthalmologist or other medical specialists and provides information about programs to remediate physical impairments and directions to DMV for an on-road driving evaluation.</p>
<p><i>Senior Health Center</i> Senior Health Center, St. Mary’s Hospital, Richmond, Va.</p>	<p><i>Driver Assessment:</i> Driving history and fitness to drive are assessed as part of the health assessment, which includes a review of driving record, family interview on observances of unsafe driving behavior, physician review of medical record, geriatric depression screen, and cognitive and functional tests (MMSE, clock draw, set test, review of activities of daily</p>

(continued)

TABLE 2 (continued) Sample of Programs Providing Driver Assessments and Related Services

Program Name and Organization	Scope of Activities
<p><i>DriveWise</i> Beth Israel Deaconess Medical Center, Boston, Mass.</p>	<p>living, tests of mobility, gait, and coordination). The assessment outcomes are categorized as follows: (a) clearly safe to drive, (b) clearly unsafe to drive, and (c) possibly safe with intervention but needs more testing.</p> <p><i>Case Management–Referral:</i> Referrals to additional disciplines (ophthalmologists, physical therapists, or neuropsychologists) for more in-depth testing or to DMV for knowledge and on-road testing. For clients who are deemed clearly safe to drive, a recommendation is made to the client’s family to ride with the driver frequently to keep track of the client’s performance and to notice cognitive changes over time. For those who are deemed unsafe to drive, a “no driving” prescription is written and the client is reported to DMV, which will revoke the license. The Senior Health Center does not perform driving evaluations.</p> <p><i>Counseling:</i> The center counsels families of clients who are judged unsafe to drive about what to expect from the client (anger, depression, etc.) and tips on how to keep a cognitively impaired client from driving. Alternative transportation options are also explored, including public transportation, connections with volunteers, paid private drivers, and a consideration of moving to an assisted living community that provides transportation is suggested.</p> <p><i>Driver Assessment:</i> Interview by clinical social worker (what role driving plays in the individual’s life, what it would mean to restrict or cease driving, and what types of alternative transportation are available); assessment by a neuropsychologist to determine concentration, organizational skills, reasoning, judgment, and speed of information processing; assessment of mobility, vision, and brake RT by an OT; 45-min on-road driving evaluation by a driving instructor and the OT.</p> <p><i>Counseling–Referral:</i> Findings of assessment presented to participant and family members by clinical social worker. Educational materials about driving are provided, as are arrangements of transportation alternatives and referral to training programs to improve driving skills. If driving cessation is recommended, practical and emotional support is provided to the individual and family members by the clinical social worker, and alternative methods of transportation are identified. If the participant does not follow the recommendation to stop driving, the team may report their findings to the Registry of Motor Vehicles.</p>
<p><i>Adaptive Mobility Services, Inc.</i> Orlando, Fla.</p>	<p><i>Driver Assessment:</i> Physical, visual, perceptual, and cognitive evaluation, plus vehicle (car and van) needs for adaptive equipment, on-road/in-traffic assessment, and clinical assessment by OT.</p> <p><i>Driver Training:</i> Fitting for adaptive equipment and training in its use, car and van evaluation programs, classroom instruction, and training in vehicle operation provided for new and experienced drivers.</p> <p><i>Counseling–Referral:</i> Client and family education for vehicle purchases, alternative transportation options, referral to other services for specialized treatment, visual or cognitive training, and occupational or physical therapy.</p>
<p><i>Driving Assessment Clinic</i> University of Alabama at Birmingham Health System</p>	<p><i>Driver Assessment:</i> In-clinic battery (vision screening, cognitive assessment, UFOV, review of medical conditions and medications, driving needs, driving habits, social support and knowledge about the rules of the road, and safe driving practices); evaluation of on-road driving performance in the clinic’s specially equipped vehicle. Recommendations about the patient’s fitness to drive can take a variety of forms: for example, the patient has adequate skills to continue driving; the patient has significantly deficient skills, so he or she should refrain from driving; or the patient should avoid driving in certain situations—night, peak traffic, and inclement weather.</p> <p><i>Counseling–Referral:</i> counseling on alternative transportation services and strategies.</p>

(continued)



TABLE 2 (continued) Sample of Programs Providing Driver Assessments and Related Services

Program Name and Organization	Scope of Activities
<p><i>Driver Evaluation and Training Program</i> Sinai Rehabilitation Center, Baltimore, Md.</p>	<p><i>Driver Assessment:</i> Upper extremity range of motion, strength, coordination, and sensation; lower extremity range of motion, strength, coordination, and sensation; ambulatory status; sitting balance and endurance; vision screening (acuity, peripheral vision, sign recognition, depth perception, phoria, night vision, color recognition); Motor-Free Visual Perception Test; Block Design; Trail-Making Tests; auditory attention tests; driver situation problem solving scenarios; RT; and behind-the-wheel (BTW) evaluation.</p> <p><i>Driver Training:</i> Training in the use of adaptive equipment. The duration of the training program varies according to a person's weaknesses and targeted training areas; duration of training estimates are discussed after the BTW evaluation and at the end of each session. Training is ceased when the driver can complete the BTW evaluation driving exercises and the designated testing route safely with no significant errors.</p>
<p><i>Adapted Driving Program</i> Bryn Mawr Rehabilitation Hospital, Malvern, Pa.</p>	<p><i>Driver Assessment:</i> Medical history; driving history; visual assessment (acuity, fields, tracking, saccades, depth perception); physical assessment (range of motion, strength, coordination, sensation, cervical range of motion, trunk balance, ambulation status); RT; traffic-sign recognition; simultaneous attention; and spatial perception (Motor-Free Visual Perception Test, Hooper Visual Organization Test, Trail-Making Test); and BTW evaluation.</p> <p><i>Driver Training:</i> Training may be recommended if the deficits observed could be overcome with training. Lessons and retesting with the Pennsylvania Department of Transportation for license coding are required if the person needs adapted devices. Trial lessons are recommended for questionable candidates that appear to have the potential to drive. Lessons are not recommended for people with advanced dementia or severe neurological deficits that will not be overcome with training.</p> <p><i>Counseling:</i> If a driver fails the evaluation and is not a candidate for any follow-up driving services, extra time is spent reviewing the results and counseling the person and family to help them adjust to this significant life change. The person is given reprints of articles concerning driving cessation, and alternative transportation options are discussed.</p>
<p><i>Driver Evaluation and Training Program</i> Geisinger/Pennsylvania State Medical Program, Pennsylvania State Rehabilitation Center, Hershey</p>	<p><i>Driver Assessment:</i> Visual and perceptual skills, RT, cognition, attention, dexterity, judgment, and on-road examination.</p> <p><i>Driver Training:</i> Instruction and remediation in driving theory, regulations, and law; BTW training; training in the use of adaptive equipment; and accompaniment to licensing center.</p> <p><i>Counseling:</i> Information on alternative transportation services is provided to people who are judged as unfit to drive.</p>

### Rehabilitation and Counseling for Impaired Drivers: Practitioner Perspectives

In this section, current issues are explored that affect the provision of counseling and remediation to drivers with a range of impairments from the perspective of the practitioners who administer the interventions. What approaches are pursued with which clients, how the choice of rehabilitation and training options follows from clinical assessments by driving evaluators, and what are the major difficulties standing in the way of progress in this critical area are addressed below.

During the 1999 annual conference of the Association for Driver Rehabilitation Specialists, a workshop was held on the topic of enhancing community mobility of older adults (40). The workshop attendees all worked in driving programs and consisted mostly of registered OTs and driving instructors. From discussions throughout the day, five main issues surfaced where uniformity was not in practice: (a) counseling, (b) using and interpreting clinical assessments and road tests, (c) depending on the physician to guide the recommendations provided to the client, (d) training and rehabilitating, and (e) reporting results to



licensing agencies. Further insight and selected research findings on these key issues follow.

### *Counseling*

Few driving programs begin the evaluation by exploring options for alternative transportation; most wait until the end. The belief is that alternative transportation is not an issue unless the client does not pass the evaluation. But when that occurs, the therapist loses the client. Typically, older clients are agitated, tired, and angry after failing their driving test. Trying to find alternatives to independent mobility usually is not well received or fruitful.

A better approach is first to discuss driving as a function of the client's lifestyle. OTs understand that people use a vehicle to interact with their physical and social environments. The vehicle is the means from which productive living stems. People are able to engage in activities that bring meaning to their lives because of the independence provided by mobility. For example, older people may not go to the grocery store just to buy food; they also may go to see people, buy a newspaper, look for new products, or get exercise. In small communities, going to the grocery store may be essential to getting the news and seeing friends. Older people are seen out and about, which confirms that they are okay. Going to the store takes on a contextual meaning. Grocery shopping becomes a by-product of achieving other goals.

Hunt et al. (41), supported by General Motors, conducted focus groups with participants from a rehabilitation driving program. Three 90-min focus groups were conducted: one with individuals unable to drive safely and two with individuals able to drive safely. The mean age in years was 76.5 ( $SD = 6.0$ ). Participants lived in the St. Louis metropolitan area. Participants offered the following comments on alternative transportation:

- "Some family member will always take me to the doctor. It is a necessity."
- "I can always call a church member for a ride."
- "There is no doubt we [a married couple] will go out less together to socialize."
- "I'd rather stay home than bother a family member unless it was critical, only something I had to do."
- "I feel hurried when I ask a family member for help; they have their own commitments to keep."
- "Without my driving, all my activities would be limited."

When asked to name the two top alternatives to driving, participants wanted transportation provided by family members and friends. The least favorite options were taxis and buses for the following reasons:

- "Taxis are so expensive, even for short distances."
- "Buses are not flexible enough in their schedules to reflect our needs."
- "They only provide curb service, which doesn't accommodate people who live on hills or have long driveways."

One approach may be to fill out a weekly planner with the client. By recording and analyzing weekly and monthly activities, needs and solutions may become more apparent. For example, neighbors and friends may be able to help with grocery shopping and social trips. The family may want to become more involved by taking an older relative to the physician. Grandchildren who drive could provide alternative transportation. Families need to rethink what time together means. Instead of perceiving it as a burden, viewing it as an opportunity to be together may have more success. Taxis can be used as a backup.

When families live in separate cities, social agencies (e.g., home care) may need to provide assistance. Often, an older person who does not drive may need other services, such as medication monitoring, housecleaning, or self-care assistance. Unfortunately, these services usually are not covered by ongoing medical insurance and must be obtained through private pay. Often OTs are knowledgeable about these additional services and can recommend agencies to contact.

When people must stop driving because of cognitive impairments, it is important that health care professionals assure them that the alternative transportation is escorted. Cognitively impaired individuals need reminders about their appointments; otherwise, they will not be ready when the driver arrives. Most important, if cognitively impaired individuals are dropped off at a medical building, they may not be able to find the medical office or their way back for the return ride. Van drivers often complain that passengers with dementia do not wear seat belts and attempt to move around while the van is moving. The multiple problems with alternative transportation add to the crisis of being told that one cannot drive. Therapists who attempt to provide solutions to clients report few options.

### *Using and Interpreting Clinical Assessments and Road Tests*

OTs and other evaluators use many different assessments in driving programs. Most striking is how therapists use the information they collect. Standardized cognitive assessments are designed to screen for impairments. When clients perform poorly on these tests, impairment is a possible reason.

Some driving programs base their decision for drive fitness only on the road test and discount clinical test results. But therapists believe in the ecological validity of the road test, and assessing individuals on the actual activity is the philosophy of occupational therapy. Research shows, however, that for a variety of reasons, an impaired person may pass a road test depending on the length of the test, the environmental conditions of the test, and fluctuations in the disease (39). Even so, OTs performing on-road assessments may not rely on neuropsychological assessments to determine driving fitness. Because OTs validate clients' abilities through actual performance, they may use the on-road assessments as the only testing criteria. Future research of cognitive performance on neuropsychological assessments in correlation with driving ability may provide the evidence, so that if an individual is cognitively impaired, actual road testing may not be warranted. OTs often hear families and physicians say that they need to prove the impairment to the drivers. These clients insist that the impairment can be determined only through the ecological validity of an on-road test; this is why a client is referred to an OT.

There are strong arguments for the opposing point of view. Clients usually prefer to demonstrate their driving ability through a road test instead of clinical evaluations. Generally, they do not understand the relationship between clinical tests and driving. Of course, clients usually disagree with a recommendation to stop driving even if they perform poorly on the road test. Common excuses include that they are not driving their own vehicle or the driving instructor–evaluator was at fault, not them. The analogous argument for clinical testing is what does this have to do with driving?

Still, some of the more safety-conscious driving evaluation programs refuse to test a person on road if clin-

ical tests demonstrate significant impairments. Some therapists believe that the evaluation should stop when cognitive problems are identified in the clinic. Often therapists question why a client comes to them with a known diagnosis of dementia. They believe that the physician should notify the licensing agency, not refer the person for a driving evaluation. Therapists state that the safety issues and cost of an evaluation outweigh the use of the evaluation to remove the person from the road. Very few clients ever agree with the results of a failed driving test. Even with state licensing agencies, people with impairments often take the test more than once to prove that they can drive.

### *Training and Rehabilitating*

From the evaluation of a retraining program, Hunt (40) reinforced the view that clinical measures can be important predictors of on-road performance. The 75 older participants had either stopped driving or were still driving but their driving ability had been questioned.<sup>6</sup> The medical history of 25 participants included stroke. The reasons given for not driving included weakness, restricted movement, decreased sensation, restricted endurance, and pain. No one reported vision or cognitive problems. Two participants had significant visual-field loss in each eye yet reported no problems with vision. One participant was referred to the driving program by an ophthalmologist, the other by a daughter. Table 3 shows on-road testing and training results. Because the program was funded by a grant, Hunt pro-

<sup>6</sup> Age = 76.5 years; *SD* = 6.0; range = 66–90 years; females = 34; minorities = 9; 63 = high school education or higher.

**TABLE 3 On-Road Testing and Training Outcomes Related to Cognitive Test Scores**

<i>Training Participants Who Passed Clinical Evaluation</i>	<i>Training Participants Who Failed Clinical Evaluation</i>	<i>Discrimination Between Pass and Fail Groups (t-Test)</i>
41% passed with no training.	37% were considered too dangerous because of visual or cognitive problems to take an on-road test.	Trail Making A (time) $p < .005$
Remainder had 2–9 h of training before being released with the okay to drive.	26% failed the on-road test.	Trail Making B (time) $p < .05$
Average amount of training = 3.3 h.	Reminder had 2–20 h of training before a recommendation not to drive.	Trail Making B (errors) $p < .05$
	Average training = 3.2 h (excludes outliers)	Short Blessed Examination score $p < .001$

vided extensive training to evaluate if individuals with cognitive impairment could respond to driver training.

The driver training program also showed that participants who performed poorly on Parts A and B of the Trail-Making Test were able to be retrained either with the use of adaptive controls equipment or with time behind the wheel. When providing training for adaptive controls or equipment, the evaluator must give special consideration. Driving with new equipment becomes a divided-attention task. Practice time must be given so that the driver's use of the equipment becomes habitual. Hunt found that the average training time was 3.3 h, with a range of 2 to 9 h.

Another type of training involves the speed of processing. A series of studies has shown that training improves visual-processing speed in older adults by up to 300% (42–44).<sup>7</sup> This magnitude is found for a variety of speeded-attention tasks and composite measures of performance. Studies demonstrate that training generalizes to novel targets and faster speeds of processing. The factors affecting training gain were the level of impairment at baseline<sup>8</sup> and the presence of dementia.<sup>9</sup> But the maintenance of training effects has not been evaluated extensively. In the original training study (42), training effects persisted over a 6-month period. Participants in the older age group (65 years or older) performed at the same level after training as the middle age group (40–59 years) did at baseline. At the 6-month follow up, the magnitude of effects had not changed from the immediate posttest value. In the subsequent study (45), training effects persisted over 18 months and remained significantly better than baseline. However, the magnitude of the training effect decreased from an effect size of 2.5 *SD*, relative to a social-contact training group, to an effect size of 1.5 *SD*.

Improvements in a participant's speed of processing resulted in improved braking times in a driving simulator, significantly less dangerous maneuvers during an on-road driving test, and maintenance of the scope of driving space over an 18-month period, relative to the decline in driving space for two control groups (45). The speed of processing intervention, through improved or maintained cognitive function, may help continue a person's independence and quality of life through reduced vehicle crash involvement, reduced injuries, and improved or maintained mobility and cognitive activities of daily living.

Hunt (40) provided a driving rehabilitation program to 25 older adults who had experienced a stroke.<sup>10</sup>

Results showed that of the 5 participants who were driving after the stroke, only 1 passed the road test. After having a stroke, 20 participants had stopped driving, 7 passed the training program and the road test, and 13 did not. Approximately 30% returned to driving after being evaluated and trained in a rehabilitation driving program. The training consisted of the use of adaptive equipment (e.g., spinner knobs, hand controls for braking and accelerating, leg lifters, mirrors, and time behind the wheel to practice driving maneuvers). Participants reported that they were unaware of driving rehabilitation programs before their involvement. This finding points to the physician's role in the rehabilitation of drivers with impairments.

### *Relying on Physician Referrals*

Most hospital-based driving programs rely on physicians as a referral source. Sometimes the physician wants the OT to report back on the client's driving test results, and then the physician notifies the client; others prefer that the therapist report directly to the client and family. Some driving programs are not solely dependent on physicians for referrals. Referrals may come from the client or family directly or another health care provider. Many therapists see themselves as consultants to the physicians. The reality is that few individuals know about driving rehabilitation.

Fisk et al. (46) explored this idea and determined that many stroke survivors are making decisions about their driving capability without professional advice or evaluation. A sample of 290 stroke survivors were surveyed regarding driving status following the stroke, driving exposure, amount and type of advice received about driving, and evaluation of driving performance. The stroke survivors were 3 months to 6 years poststroke. Results showed that 30% of the stroke survivors who drove before their stroke resumed driving afterward. Health care professionals often informed stroke survivors poorly about driving: 48% reported that they did not receive any advice about driving, and 87% reported that they did not receive any type of driving evaluation. Almost one-third of the poststroke drivers had high exposure, driving 6 to 7 days or 100 to 200 mi per week.

### *Reporting Results to Licensing Agencies*

Some driving programs explain that participants identified as unsafe drivers will be referred to the Department of Motor Vehicles (DMV) for further evaluation. Many programs do not evaluate a client who will not sign a statement that the program can send the test results to the state. Programs have these rules to avoid liability if a person with

<sup>7</sup> The magnitude of training effects across studies was between 1.0 and 3.5 *SD* immediately after training.

<sup>8</sup> Lower scores are associated with larger training gain.

<sup>9</sup> Poorer training gains are associated with dementia.

<sup>10</sup> Mean = 76 years; *SD* = 6.3; number of males = 16.

an impairment continues driving and becomes involved in a crash. Also, OTs are aware that they have a role in public health and safety. This awareness has fostered the active involvement of OTs in innovative licensing programs, such as the pilot program in Maryland.

## Current Programs and Promising Directions for Licensing Older Drivers

### *Should Age Alone Trigger Mandatory Retesting?*

The reaction to program initiatives with the design or the potential to affect the licensing of older drivers often can be gauged in terms of a single attribute—namely, if age dictates what actions are required. In 1999 the programs that had been proposed through legislation or that existed on either a continuing or pilot basis represented a range of options on this issue. At one end of the spectrum, legislation introduced in June 1999 in the California State Assembly (S.B. 335) would have required all residents age 75 and older to pass written and road tests for license renewal and full driving privileges. Spurred by a tragic incident—a negligent older driver struck and killed a 10-month-old boy who was being pushed in a stroller by his mother—this measure failed to pass into law and was revised to require retests only when triggered by previous crashes and violations, as well as qualified referrals. Sadly, even if the more severe version of the proposed California law had been enacted before the precipitating incident, the baby's life likely would not have been saved. That same day, the offending driver had failed his driving test.

The states with laws that require drivers to take a periodic behind-the-wheel test at a specific age (75 years or older) include New Hampshire, Washington, and Illinois. But bills that would have toughened requirements for older drivers to renew their license recently failed in Texas and Florida.<sup>11</sup> A blended policy that stops short of mandatory retesting based on age alone but that factors age into the determination of when to trigger a sanction for a given number of driving infraction points was recommended by Gebers and Peck (47). Several states took age into account in the decisions about when to require in-person versus mail-in license renewal and when to reduce the interval between successive renewals (48). These legislative initiatives beg the question of whether it is fair and reasonable to test drivers based on age alone.

To reach an informed decision on the merits of age-based licensing programs requires an awareness of certain myths and facts about aging. Even though with

reasonable certainty there is an age at which everyone suffers functional declines that result in significant driving impairment, marshaling the evidence to justify a particular age at which all individuals should be required to undergo functional screening presents serious problems. Simply put, it is a myth that aging makes all older people high-risk drivers. Although specific abilities such as vision, memory, physical strength, and flexibility needed to drive safely may suffer declines, the rate of change varies dramatically across the population of older individuals. Many older people do not differ significantly in their driving skills from their middle-aged counterparts, who statistically are the safest group on the road based on mileage. Not only are arguments for new licensing programs triggered by age alone questionable on scientific grounds, but there also are formidable cost and feasibility barriers to implementing mandatory, across-the-board testing if comprehensive evaluations, including road tests, are required for all license renewals of a targeted age group.

The solution for retesting that restricts the fewest possible people while serving the greatest good in terms of public health and safety arguably lies in a multilevel approach. According to this model, licensing authorities would apply methods that are cost-effective and that enjoy broad acceptance by the public to ensure that most drivers meet minimal qualifications but would test rigorously a smaller group who performed poorly on a functional screen. If screening applies to all drivers or begins at an age young enough that more drivers are included in the program than are exempt,<sup>12</sup> then potential charges of discriminatory practice become moot. Inevitably, some older drivers and others deserving restrictions will be missed. The best success comes when a multilevel assessment program is integrated with efforts outside the formal licensing system that (a) strengthen awareness of functional decline and impaired driving, (b) promote self-regulation and informal regulation by a trusted health care professional, (c) provide access to remedial treatments when medically appropriate, and (d) facilitate the transition to alternative transportation options in the community.

### *Nature and Frequency of Contacts with Older Drivers for Licensing Purposes*

In North America, contacts between older drivers and licensing offices generally come from the renewal process, augmented by referrals from physicians, law enforcement, family, friends, and others, as well as by the direct obser-

<sup>11</sup> Personal communication, K. Milton, American Association of Motor Vehicle Administrators consultant on public policy, June 29, 1999.

<sup>12</sup> For example, in Pennsylvania drivers may be required to undergo reexamination for license renewal through random selection within age cohorts beginning at 45 years.

vations of licensing personnel when an older driver appears at a field office to transact business. The nature and frequency of the contacts provide the framework for recommendations on program enhancement.

License-renewal requirements that make distinctions based on driver age are summarized by jurisdiction in Table 4 (4, 48–50). As shown in the table, various actions are triggered in different states with an age range from the 40s to the 80s. Studies evaluating the efficacy of the various requirements for license renewal show mixed results. Lange and McKnight (51) found that in states requiring age-based, on-road driving tests for renewal (Indiana and Illinois), tested drivers evidenced significantly lower relative involvement in crashes (7%) than their counterparts in neighboring comparison states (Ohio and Michigan). Although age-based testing

appeared to lower the rate of crashes for older drivers, it did not lower the proportion of single-vehicle crashes. Further, Rock (52) noted that Illinois recently dropped a testing requirement that may have had a lingering effect, thus potentially affecting the Lange and McKnight study findings. Rock explored changes made to the Illinois renewal requirements for older drivers and found that eliminating the road test for drivers age 69–74 did not lead to an increase in crashes. In addition, shortening the renewal term from 4 years to 2 years for drivers age 81–86 produced clear benefits.

In contrast, an evaluation of Pennsylvania's ongoing Older Driver Reexamination Program concluded that clear safety benefits were demonstrated (53). For the study, each month 1,650 drivers over age 45 were selected for retesting at license renewal. Drivers were

TABLE 4 Licensing Requirements: Distinctions for Older Drivers

<i>State or Province</i>	<i>Licensing Requirements: Distinctions for Older Drivers</i>	<i>Age</i>
Alaska	No renewal by mail, vision test required	70
Alberta	Medical report every 2 years at age 70, every year at age 80	70, 80
Arizona	Reduction of interval between renewal (from 12 years to 5 years at age 55), no renewal by mail for age 70 or older	55, 70
British Columbia	Medical report at age 75, every 2 years at age 80	75, 80
California	No renewal by mail, vision test required, written knowledge test required	70
Connecticut	Reduction of interval between renewal from 4 years to 2 years	65
District of Columbia	Medical report plus reaction test; optional knowledge, and road tests at age 75	70
Hawaii	Reduction of interval between renewal from 6 years (age 18–71) to 2 years	72
Idaho	No renewal by mail	69
Illinois	Reduction of interval between renewal from 4 years (age 21–80) to 2 years (age 81–86); reduction of interval between renewal to 1 year (age 87 or older); no renewal by mail, vision test required, and on-road driving test required (age 75 or older)	75, 81, 87
Indiana	Reduction of interval between renewals from 4 years to 3 years, required on-road driving test.	75
Iowa	Reduction of interval between renewal from 4 years to 2 years	70
Kansas	Reduction of interval between renewal from 6 years (age 16–64) to 4 years	65
Maine	Reduction of interval between renewal from 6 years to 4 years at age 65; vision screening test at renewal for age 40, 52, and 65; every 4 years after age 65	40, 52, 65
Manitoba	Medical report for renewal	65
Maryland	Medical report for new drivers over age 70	70
Montana	Reduction of interval between renewal from 8 years (age 21–67) to 6 years (age 68–74) and to 4 years at age 75	68, 75
Nevada	Vision test and medical report required to renew by mail	70
New Mexico	Reduction of interval between renewal from 4 years to 1 year	75
New Hampshire	Road test at renewal	75
Newfoundland	Medical report every 2 years at age 70, every year after age 80	70, 80
Ontario	Medical report for renewal	65
Oregon	Vision screening test every 8 years (every other license renewal)	50
Pennsylvania	Random physical examinations for drivers age 45 or older; most are over age 65	45
Quebec	Medical report every 4 years at age 70, 2 years at age 74–80, and every year at age 80	70, 74, 80
Rhode Island	Reduction of interval between renewal from 5 years to 2 years	70
Yukon	Medical report and renewal every 2 years at age 70	70
Wisconsin	No renewal by mail	70



selected randomly within each 5-year age cohort, with the selection algorithm weighted heavily toward the oldest drivers. The weighting resulted in the selection of very few drivers (proportionally) in the younger cohorts but almost every driver over age 85. Each selected driver was required to undergo both vision and physical examinations. Any licensed physician could conduct the medical evaluation. A physician, eye care specialist, or driver's license center performed the vision screening at no charge. If the driver chose to be screened at a driver's license center and a vision problem was found, an examination by a specialist was required. As a result of this program, approximately 30% of the drivers selected for retesting were not able to renew their license. This group included drivers who had already stopped driving and drivers who surrendered their license voluntarily in lieu of completing the examinations. Less than 1% actually failed the medical or vision examinations.

An additional one-quarter of the drivers already had restrictions placed on their driving privileges; 99% of these restrictions were related to vision or hearing problems. If warranted by the results of the medical examination, the selected drivers were required to complete an on-road driving test successfully. The Pennsylvania Department of Transportation (DOT) found that a driver's test was warranted for less than 1% of the drivers. In an evaluation of this program, Freedman et al. (53) found that the program was effective in discovering medical and visual conditions that require remediation, restrictions on driving, or withdrawal of operating privileges, especially among drivers age 60 and older. However, they also found that on the basis of the data on new restrictions, failures, crash data, and other reasons for loss of license, little was gained by requiring drivers younger than age 60 to undergo retesting.

A key statistic in the program was the number of people who voluntarily stopped driving and surrendered their license. This impetus toward self-regulation, following a notice that retesting was required, may signify a more potent variable than any of the specific differences between jurisdictions regarding renewal interval or procedures. A concern must be raised that a percentage of seniors, who are fit and capable of driving safely, will retire from driving prematurely and suffer unnecessary or exaggerated restrictions to their mobility. Effective public-information campaigns that reassure older people who continue to drive safely and provide information about counseling availability on remediation options and adjustments in driving habits to preserve mobility will mitigate the unintended consequences of a program designed to screen for unfit drivers.

The Pennsylvania DOT experience underscores the potential value for a screening program that requires in-person—not mail-in—renewals for drivers of all ages.

As reported by Fields and Valtinson (48), 28 states currently require that all drivers appear at a DMV office to renew their license. Cobb and Coughlin (54) conducted a telephone survey of 51 DMV line examiners in the 50 U.S. states and the District of Columbia. Most respondents revealed that the most important criterion for identifying an impaired driver was how the person looked coming through the door. However, the survey also found that the legal requirement to appear in person before a licensing official was not used by many states because of the heavy reliance on the skill and judgment of an examiner or counter personnel to determine a driver's fitness. Petrucelli and Malinowski (50) reiterated, "The examiner's personal contact with the applicant is the only routine opportunity to detect potential problems of the functionally impaired driver. This opportunity should not be lost because of inadequate training." The authors documented 14 jurisdictions that provide some orientation enabling examiners to observe and recognize potentially hazardous signs and symptoms.<sup>13</sup> For example, two chapters in the *Florida Examiner's Manual* deal with the identification of driver restrictions, incorporating materials on what to observe and ask, as well as on the degree of impairment signified by a physical condition or verbal answer.

In a recent report, Janke and Hersch (55) highlighted the feasibility of prescreening renewing drivers using a structured set of questions to target individuals with suspected impairments. Staplin and Lococo (56) asked whether it would be feasible to "implement a referral mechanism for functional screening or evaluation in which DMV counter personnel use a checklist to record a brief, structured set of observations or question-and-answer responses for members of the driving public who appear before them." The questionnaire was distributed to driver license administrators in all 50 states and 12 (at the time) Canadian provinces; 64% responded yes, and 36% responded no.

Inevitably, one or more jurisdictions using procedures during in-person renewals that single out individuals for more stringent examination to retain their driving privileges have been challenged on legality. As an instructive example, Wisconsin DOT included a chapter, "Evaluating Medical Conditions or Disabilities," in the *Safe Mobility for Older People Notebook*, informing their field staff about how to determine a customer's functional ability by visual inspection. The notebook defined functional ability and provided the standard, so that employees would know the benchmark. A person who does not meet the standards and whose license is not properly restricted

<sup>13</sup> British Columbia (Canada), Connecticut, Florida, Indiana, Iowa, Maryland, Missouri, Montana, North Carolina, North Dakota, Oregon, Prince Edward Island, and Washington.



may be required to take a driving skills test or to file a medical report, or both (30).

In 1994 an Americans with Disabilities Act (ADA) suit was filed by an out-of-state male driver in a wheelchair who went to the Wisconsin DMV for a license transfer. He did not have any restrictions on his out-of-state license. On the basis of visual inspection, the Wisconsin DMV required him to take a road test. The driver thought that the action was discriminatory because the person (not in a wheelchair) behind him in line who was also out-of-state did not have to take a road test. However, the Wisconsin Supreme Court found that the operation of motor vehicles is a privilege, not a right, and is subject to reasonable regulation. Accordingly, a state can require a road test from any individual for the purpose of assuring highway safety. Similar to U.S. DOT, the state DMVs have a legislative mandate to protect public safety and maintain safe highways. Wisconsin DOT's practice was therefore not considered discriminatory, and the driver did not win the suit. No comments were issued about improvements needed in Wisconsin DOT's practices under the ADA. The driving evaluation was found to be related rationally to the achievement of public safety, not based on prejudice, stereotypes, or unfounded fear. The Wisconsin experience serves as a precedent. Innovative licensing programs may be developed with a degree of assurance that they are not in violation of the spirit or letter of the ADA to conduct a special evaluation, "as may be necessary to determine if a person adequately compensates for a medical condition or functional impairment to safely operate a motor vehicle with or without license restrictions" (30).

On a broader scale, this issue leads to the subject of physician reporting. According to Petrucelli and Malinowski (50), 14 states or provinces require and another 10 states permit physicians to report to the licensing authority patients who have potential driving impairments. Jurisdictions with mandatory reporting requirements grant the physician immunity from legal action by the driver. Most jurisdictions with voluntary reporting laws also grant the physician immunity from legal action except Ohio, North Dakota, and Alberta (Canada). Other jurisdictions allow physicians to report the driver only after the driver has been informed of an impairment and has refused to disclose the impairment to the licensing authority. Potentially impairing conditions covered by existing statutes also vary from jurisdiction to jurisdiction. Although conditions such as epilepsy, which may cause loss of consciousness, are near universal as triggers for reporting, only California identifies dementia among the conditions physicians are mandated to report (55).

By far the most extensive body of physician report data on driver medical conditions is from Pennsylvania

DOT. The Pennsylvania Vehicle Code (Section 1518) requires a physician to report any condition that may impair a person's ability to drive safely for anyone older than age 15. A medical advisory board (MAB) formulates the medical conditions. Physicians have immunity from civil and criminal liability because reporting is mandatory. Failure to report can result in a physician being held responsible as a proximate cause of a crash resulting in death, injury, or property loss caused by his or her patient. Also, physicians who do not comply with their legal requirements to report may be convicted of a summary criminal offense.

Physician reports are confidential and may be used only for driver's licensing decisions. Physician reporting reached a level of 10,000 referrals by 1990. In 1992 Pennsylvania DOT conducted an information campaign to 46,000 physicians emphasizing the consequences of failure to report. The result was 40,000 reports in 1994. This number has increased by approximately 2,000 each successive year.

When a report is made, restrictions to the person's driving privileges may be added or deleted, the person's license may be recalled or restored, the person may be required to provide more specific medical information or to submit to a driver's test, or no action may be taken. The *Physician Reporting Fact Sheet* stated that approximately 72% of referred individuals have medical impairments significant enough to merit temporary or permanent recall of their driving privileges; 51% of the recalls are due to seizure disorder, and 16% are due to other neurological disorders.<sup>14</sup> An additional 9% of physician reports result in restrictions on the individual's driving privileges; 60% of these restrictions involve special equipment needs. The reports cross the age spectrum, with 51% of drivers younger than age 45.

The effectiveness of reporting programs is indicated in a study of Saskatchewan crash data for the 1980s (56). A minority of drivers diagnosed with various conditions, including alcohol or drug dependence, cardiovascular disease, stroke, coordination-muscular control diseases, diabetes, seizure disorders, and visual disorders, participated in the province's Medical Review Program. The majority were diagnosed but had not been reported. In the program, each participant's driving was restricted on a case-by-case basis, as deemed appropriate by the provincial licensing agency. The participants demonstrated a lower incidence of at-fault crashes compared with diagnosed but unreported drivers, matched on age, gender, place of residence, license class, and periods of driving for all conditions, except

<sup>14</sup> The *Physician Reporting Fact Sheet* is published and updated by the Bureau of Driver Licensing, Driver Qualification Section, Pennsylvania DOT. Copies may be obtained from the bureau at P.O. Box 68682, Harrisburg, PA 17106-8682.

coordination–muscular control disorders (57). The authors attributed the anomalous finding for drivers with muscular control disorders to self-awareness and better self-management and concluded that a significant benefit in crash reduction for drivers with medical problems can be realized from reporting programs.

Their expertise and position of trust places physicians, eye care specialists, and other health care providers in a key role to diagnose likely driving impairments. Because seniors rely most heavily on their health care providers for information and advice about when they can safely continue to drive (58), it is important to protect the confidentiality of these physician–patient discussions. Physicians may be reluctant to report a patient with whom they have held a long-term relationship, knowing the devastating impact on the patient’s quality of life that will result. At the same time, professionals bear an ethical and, in many jurisdictions, a statutory responsibility to alert licensing officials when they judge that an individual poses a public health risk. Resolving this dilemma requires new options and innovative approaches. A partnership between medical specialists and specialists in driving evaluation may hold the greatest promise.

### *Incorporating Knowledge About Limited Capabilities into Driver-Licensing Decisions*

A review of current options is examined and applied to the licensing of older drivers with declining abilities. How feasible is it to modify or expand the options? One state integrated the full range of assessment, remediation, and counseling activities discussed earlier with a public information and education campaign to pilot a model program for safe mobility. This integration is explored below.

One way licensing agencies accommodate drivers with age-related diminished capabilities while still carrying out the mandate for public safety is to impose restrictions that either ameliorate the functional deficits or restrict the exposure of these individuals, effectively and gradually retiring them from driving. Such restrictions of driving privileges, particularly when a restriction is disputed, are administered through MAB in most states. Although procedures vary across jurisdictions, Maryland serves as a useful example. If the Maryland Motor Vehicle Administration (MVA) has reason to believe conditions exist that might impair a person’s driving ability, the applicant is required to submit certain medical information and authorization for release of records and information from physicians and hospitals that have treated the applicant for that medical condition. MVA’s administrative staff then summarizes the information and sends a report to MAB for review,

along with the applicant’s case history. The board also has access to the driver’s crash and violation records. Most drivers under review must appear in person before MAB. The board has the authority not only to interview the applicant but also to require all tests deemed necessary to evaluate the driver’s functional capability and driving skill, up to and including a road test.

Licensing agencies use a wide range of restrictions. Petrucelli and Malinowski (50) indicated that all jurisdictions issue at least one type of restricted license. The most common restriction is the requirement to wear corrective lenses. Other license restrictions address age-related diminished capabilities and pertain to time of day, geographic boundary, trip type, class of vehicle, speed limit, and special equipment. An example, excerpted from the *Wisconsin Examiner’s Manual* (59), is shown in Table 5. The information emphasizes the many options for accommodating older people’s mobility needs over a span of potential years of functional decline.

In the future, even more options and options that are more finely tailored to specific functional deficits are anticipated; multiple levels of low-vision restrictions and restrictions tailored to perceptual and cognitive deficits will be featured most prominently in this group. However, the essential precondition for administering an enhanced program of licensing restrictions, including revocation, that is fair to individuals and effective from a public health perspective focuses attention on licensing authorities’ willingness and ability to innovate.

In 1997 a questionnaire was developed by NHTSA and distributed by the American Association of Motor Vehicle Administrators (AAMVA) to licensing officials in all 50 states and 12 Canadian provinces. The questionnaire asked for feedback regarding innovative practices from the standpoint of legal, ethical, or policy issues and resource constraints that could affect implementation in their jurisdiction (56). Responses obtained from 47 states, the District of Columbia, and Canadian provinces are summarized below. Together these data help to define the possibilities in the licensing arena when new programs aimed at enhancing safety and mobility for seniors are envisioned.

The starting point of the NHTSA–AAMVA survey was a question asking licensing officials to indicate whether new or expanded screening procedures should be applied to all drivers over a specified age—that is, could qualifications procedures for license renewal that are purely age based (not tied to any measures of declining performance or indices of risk) be implemented in their jurisdiction? Only six affirmative responses were received. This response suggests that in more than 90% of states and provinces in North America, new programs affecting the licensing of older people will continue to take factors, such as crash and violation data, medical data, and information from referral sources, into

TABLE 5 Common Restrictions Applied to Licensed Drivers with Functional Limitations (59, Section 350: Restrictions for Physical Disabilities)

<i>General Restrictions</i>	<i>Specific Restrictions</i>		
	<i>Area and Speed</i>	<i>Special Equipment</i>	<i>Time of Day</i>
Code 1: Corrective glasses or contact lenses	“Home area” only (a defined radius that includes the driver’s residence)	Steering knob or power steering	Daylight driving only (e.g., driving restricted to between 9 a.m. and 3 p.m.)
Code 2: Hearing aid or vehicle equipped with outside rearview mirror	No freeway or interstate highway driving	Hand-operated dimmer switch	
Code 3: Automatic transmission	County or town roads only (e.g., no driving on Florida Avenue in the city of Tampa)	Power-assisted brakes	
Code 4: Automatic turn signals	No driving in a specific city	Rearrangement of pedals or controls	
Code 5: Daylight only (doctor’s recommendation required or based on driving evaluation given at night)	Within city or village limits only	Artificial arm, hand, or foot	
Code 7: Proof of financial responsibility	Highways with a particular mile per hour speed limit or less only	Foot brake extension	
Code 9: Complete hand controls	Between residence and work only	Specially equipped vehicle (must specify make, year, and identification number)	
Code 10: Left outside mirror			
Code 11: Right outside mirror			
Code 12: Adequate seat adjustment			
Code 14: Vehicle under 10,000 lb			
Code 99: Special restriction card			

account in the determination of whether individuals are qualified to retain full driving privileges. The derailed efforts to pass legislation in 1999 in California mandating age-based testing of older drivers reinforced this conclusion. The survey data do not, however, indicate that novel screening techniques applied to segments of the driving population, including but not limited to older people, will prove unacceptable. The long-standing reexamination program in Pennsylvania, which applies to drivers as young as age 45, is a solid precedent. Finally, Wisconsin DOT’s experience of withstanding an ADA challenge indicates that there may be significant latitude on the use of drivers’ physical and behavioral attributes as triggers for screening and evaluation activities.

An overview of the findings from the NHTSA–AAMVA survey of licensing officials most pertinent to

this discussion follows. In each case, the respondents were asked if the practice in question would be feasible to implement, considering current priorities and policies:

- 85% said that the vision-test procedures could be expanded to include abilities other than static acuity that have been shown to relate significantly to crash risk.
- 72% said that the visual-acuity criterion (20/40 binocular acuity in most jurisdictions) could be modified so that individuals with lower levels of functional ability would not necessarily lose all driving privileges but could be accommodated with restrictions such as “daylight only.”
- 78% responded affirmatively to the adoption of criteria for functional abilities other than vision as

grounds for licensing action, including measures of attention, perception, memory and cognition, decision making, and situational awareness.

- 97% said that tests of functional ability and consequent licensing actions can be conducted at any time an individual's (potential) impairment is brought to the attention of the licensing authority, regardless of when this occurs in an individual's renewal cycle.

- 92% said that the nature and frequency of functional testing requirements could be tailored to specific medical conditions, as identified in a physician's referral to the licensing authority.

- 78% said that on-road test procedures could be individually tailored so that test content focuses on the specific aspects of functional decline, as indicated in a previous screening or clinical evaluation.

- 90% said that the screening–evaluation of drivers, with the potential for subsequent licensing action, could be performed without a physician's diagnosis for individuals who are referred to the licensing authority by family, friends, and health care or social service professionals.

The results of the NHTSA–AAMVA survey further indicate that slightly less than half (45%) of state and provincial licensing officials expected that all driver screening and evaluation activities would be carried out by the DMV. When allowed to check multiple responses in this category, 63% of the licensing officials replied that their departments should carry out some screening and evaluation activities, while others should be privatized. Only one respondent indicated that all screening–evaluation activities should be privatized. A large majority (85%) of the respondents also said that public education and community outreach activities to provide information on aging and safe driving practices would accompany new screening–evaluation programs in their jurisdictions, including the key components of techniques for self-evaluation, strategies to compensate for loss of ability through changes in driving habits, and information about transportation alternatives in the driver's area.

If these data help define the realm of what licensing authorities can do, attention ultimately must turn to what licensing authorities will do after all technical, administrative, budgetary, and political factors are taken into account. To succeed in this area will require programs that

- Serve the public health mandate to restrict and revoke the license of impaired drivers, while treating seniors in a fair and dignified manner that avoids penalties based solely on age;

- Foster opportunities for remediation and rehabilitation for individuals who have experienced temporary or reversible decline in their functional abilities related to driving safety; and

- Support a shift to alternative transportation to preserve the mobility of people who no longer can or who no longer want to drive.

All of these program elements are essential as well as the coordination that allows them to mesh together effectively, working across institutional and jurisdictional boundaries while appearing as nearly seamless as possible to the general public. No single solution is likely to emerge. But a model program under the sponsorship of NHTSA has been devised for driver screening and evaluation, with links to the full array of service providers needed to carry out the actions above. In fact, many of the key elements, diagrammed in Figure 1, were piloted in Maryland in 1999.

Under the Maryland model, drivers enter screening and evaluation program activities on either a referral or nonreferral basis. The majority consists of nonreferrals who go to a field office or mobile unit of MVA for license renewal. During the pilot implementation, people 70 years or older at selected MVA field offices were asked to participate in a battery of screening measures. They were not penalized if they refused to participate, and all received their renewal before the request was made.

By contrast, all motorists who used the convenient on-site license renewal, titling, and other services at the retirement community Leisure World, where a mobile unit periodically visits, were required to take a screening after completing MVA business. Planned comparisons of accepting and declining drivers approached at the field offices and the sample obtained at Leisure World will influence the state's eventual policy on an age trigger for mandatory screening. Other potential influences may stem from structured observations by counter personnel and self-reported medical conditions on renewal forms.

The screening measures performed under the Maryland pilot presently address the range of gross impairments discussed earlier, plus a specialized assessment of visual-attention ability from a brief version of the Useful Field of View Test. MVA line personnel who received supplemental training in the required testing and record-keeping procedures conduct the tests.

As indicated in bold in Figure 1, MVA's MAB plays the central role in coordinating activities to detect and intervene with functionally impaired drivers. With technical assistance provided through NHTSA research funds, MAB selects screening measures, oversees training, and supervises the staff that carries out these activities. MAB also originates, develops, and distributes flyers, brochures, news releases, and other public information materials to notify the public about the program and its purpose.

Consistent with its traditional role in the Maryland licensing system, MAB's advisory function continues in

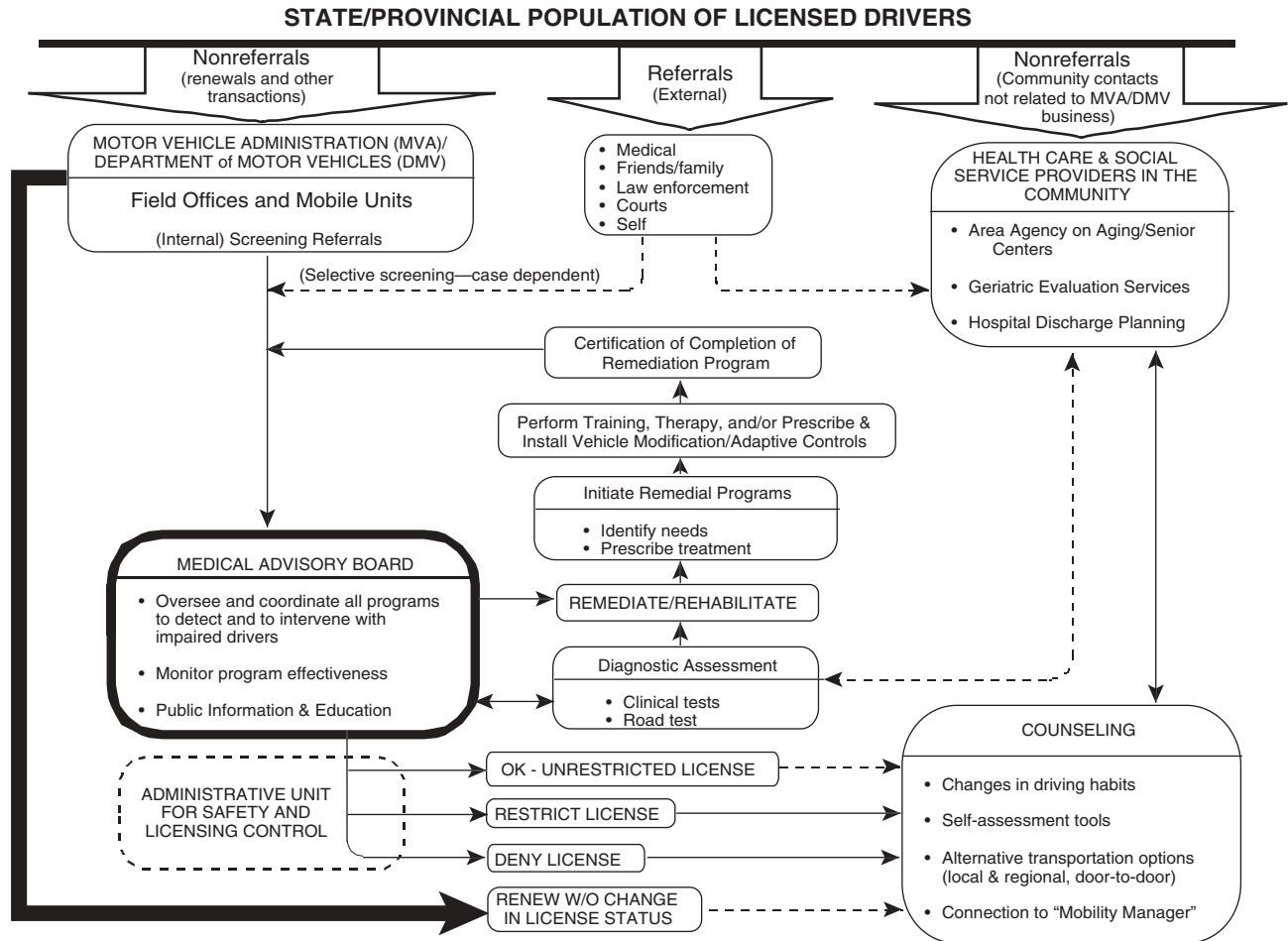


FIGURE 1 Model program for driver screening and evaluation.

the control of drivers with suspected impairments. Specifically, MAB provides recommendations to an administrative unit of the agency responsible for the safety of all drivers referred to the board for evaluation. Four recommendations for license control actions are possible: restrict license, deny license, remediate then reexamine to determine license status, and no action (unrestricted license). Before issuing a recommendation to the administrative unit, MAB may require one or more diagnostic assessments, including a clinical examination by a physician, eye care specialist, or others; a road test may be required as well. Understandably, these assessments are tailored to the suspected type of impairment. Computer-based assessments and road tests specialized to detect drivers with dementia also are included in the pilot.

Perhaps the most critical role of MAB in the Maryland pilot program's evolution was to organize and provide logistical support for an interagency forum, the Maryland Research Consortium (MRC). MRC effectively served as a task force to foster alliances in the state between stakeholders seeking

safety enhancements and the preservation of mobility and quality of life for seniors. These stakeholders included the Departments of Transportation, Health, and Aging; private health care providers and health maintenance organizations; community action groups and social service providers; and law enforcement. An array of academic and professional organizations seeking a better understanding of the validity, effectiveness, and administrative feasibility of assessment and intervention practices also were brought into this cooperative alliance. An infrastructure for communication among multiple parties was developed through periodic meetings of MRC, which would prove crucial in overcoming institutional, jurisdictional, and technical barriers to implement the Maryland pilot program.

Returning to the mechanisms through which drivers are referred to MAB, few are referred by law-enforcement personnel who observe negligent or erratic driving or by courts, physicians, or friends and family members who are concerned about an older driver. In the case of friends and family, full disclosure of the specific reasons is required. These referral avenues have the potential to



change the license status of the affected older driver and are common in many other states.

Unique to Maryland is the one additional mode through which older drivers are referred for functional screening and evaluation of impairments. Drivers may use community social service providers to learn more about aging and driving impairments, receive advice and assistance on safer practices, and find other mobility solutions. Specifically, senior centers administered by the area Agency on Aging at the county level advertise and offer the identical GRIMPS performed at MVA facilities. As a further incentive, an OT with special training in the effects of functional impairments on safe driving is present at the senior center to help older drivers interpret the screening results, answer questions related to health and driving, and provide counseling to modify their driving habits. The OT also can prescribe and assist in scheduling visits to a physician or specialist when a potentially significant impairment is revealed during screening. Also in the works is the expansion of these services to other community-based organizations and institutions.

A primary thrust of the activities at senior centers is public information and education. To instill confidence in older drivers that their difficulties in achieving safe mobility can be addressed without fear of any immediate formal actions by the licensing authority, screening results are not reported to MVA. Using age peers to conduct the GRIMPS provides a comfort factor as well. Thus, individuals who suspect they have an impairment and seek confirmation (or reassurance) without a pending threat of licensing action can do so privately.

To some this exception may raise questions about the effectiveness of screening in community settings as a public health measure, but several other considerations weigh on this issue. Except for cases of significant cognitive impairment, many recent reports show that most seniors effectively self-regulate their driving (26, 60–62). This self-regulation requires the knowledge that a problem exists and a strategy for what to do about it. Fisk et al. (46) provided a case in point concerning poststroke patients. Even though some older drivers may find that they remain within the normal functional driving limits, they still learn about the levels of functional decline that serve as a red flag, and they also establish a baseline against which to interpret and act on future assessments.

Further, while honoring the commitment to hold an individual's screening results in confidence from the licensing authority, the OT may make known to physicians and family members the status of a driver at risk because of functional impairment. The physician or family member in turn can initiate a referral to MAB. This program element provides greater discretion for an individual or personal caregiver in addressing driving

problems, while establishing a shortcut to remediation or skills enhancement if this option is viable. It is perhaps most critical that actions or adjustments affecting exposure are encouraged sooner instead of later. Individuals and their caregivers have the information they need to mitigate risk instead of waiting months or years until the next license renewal cycle.

In the Maryland pilot program, the availability of screening through the participating area Agency on Aging is advertised to older people and their adult children through diverse media, including television, radio, newsletters, and flyers. The service also is informing the law-enforcement and medical communities about the referral option as an alternative course of action when cases of potential impairment are encountered but undiagnosed (for law enforcement and the courts) or are borderline (for the medical community).

The range of remedial or rehabilitative treatments envisioned in the Maryland pilot program is large. The treatments encompass adaptive equipment in vehicles and training for its use; traditional physical therapies and exercise programs designed to restore strength, flexibility, and range of motion; instruction in the road-sign-and-knowledge aspects of driving, as offered by various national organizations; and still-experimental perceptual-cognitive retraining techniques designed to improve attention, visual search, and scanning for safety threats while driving.

Finally, counseling is an indispensable component of the model, which must be closely integrated with driver screening and assessment. Counseling may be performed in community settings, licensing agencies, or wherever providers with an understanding of functional impairments and driving can access up-to-date information on other mobility resources. Because some older people inevitably will suffer functional decline that makes it unsafe for them to continue driving while others will retire from driving as a lifestyle choice, an appraisal of local and regional options for alternative transportation and exhaustive information about how to use the options will be provided in the Maryland pilot program. More broadly, the counseling activities in the model are designed to help older people assess their mobility needs and talk through such issues as social isolation and fear of dependence on others.

The impact of Maryland's pilot program is expected to be widespread. Besides influencing subsequent policy and procedures within the state, the pilot program will help other states define the costs of innovative older-driver licensing approaches and quantify the benefits in terms of enhanced safety and mobility. The problems experienced in program activities administration will be instructive to other jurisdictions. Identified strengths and weaknesses will support the necessary revisions of the model before additional,



federal-sponsored field tests, as envisioned in NHTSA's strategic plan, are initiated in other locations.

## CONCLUSION

The justification for bold initiatives in the licensing of older drivers derives from the many social and economic rewards of safe mobility for life and extends beyond the greater public-health interest to the priorities of older people. *Parade Magazine* recently published the results of a survey of people 65 and older conducted by a health maintenance organization in California (63). Asked to name their top worries, survey respondents keyed on personal security issues, including fear of robbery and assault, and financial security—for example, a loss of health insurance for themselves and their children. Health-related issues were mentioned even more frequently, including health of spouse, of children, and of oneself. But at the top of the list of What Seniors Fear, ahead of cancer, stroke, or loss of vision or memory was loss of ability to drive. To allay the fear, fair and effective licensing programs in the 21st century must identify people who cannot safely continue to drive because of age-related functional decline and assist them with a transition to alternative transportation. When capabilities instead of age become the criterion for licensure, the best possible outcome in the complex and often contentious area will be at hand.

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# Mobility Solutions

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# Mobility Options for Seniors

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To live full and independent lives, people need access to a range of goods, services, activities, and other people. This access often involves travel, although now many goods can be ordered for home delivery and many services can be booked by telephone or through the Internet. By definition, mobility means being able to travel where and when a person wants, being informed about travel options, knowing how to use them, being able to use them, and having the means to pay for them (1). In reality, mobility always is limited to some degree, but for daily local travel, the private vehicle comes the closest to full mobility. Alternative means of mobility tend to be more attractive and acceptable the closer they approach the characteristics of the automobile. Thus, if taxis are available and affordable, they almost can replace the automobile, as can walking for short distances. But a rural bus offering once-a-week round trips to the local market, while valuable to the users, offers far less flexibility.

With the aging U.S. population, a growing concern is driving cessation for the baby boomers—a generation that grew up with the personal automobile. What can be done to help this group maintain independent mobility as they reduce their driving so that they do not need to drive beyond their capabilities? All drivers need mobility alternatives, especially when a person would prefer not to drive and when an older person stops driving. People of all ages have repeatedly shown their preference for driving, both for the activity itself and for the freedom the automobile provides to go wherever and whenever, with protection from the weather and destinations in

control. As people age, physiological changes make driving more difficult. The aging process is far from uniform among people, and age alone does not determine ability. Individuals' transition away from driving can be helped by mobility planning and counseling, enabling individuals to identify mobility requirements and try various alternatives before having to use them.

Mobility alternatives to the private automobile initially are needed for trips that older drivers prefer to avoid—for example, nighttime driving, congested areas, and peak times. These options help seniors to maintain their dignity, independence, and choice for as long as possible (2). Rosenbloom (3) showed the strong preference of seniors for the private automobile. However, in general, North American transit provides the poorest match to the automobile. Patterns of land use, growth of services such as the Internet for shopping and social interaction, and direct delivery of goods will affect the acceptability and viability of transit alternatives.

The importance of mobility continues with increasing age and retirement (4). Table 1 lists the number of journeys per year made by people in Britain by age. Number of journeys reduces with increasing age, as does length of the journeys, but this trend mainly reflects a changing pattern of activities by emphasizing the difference between traveling and having the ability to travel. Seniors who remain active and mobile live longer, while seniors without alternatives may suffer from loneliness and depression. The freedom to move is life itself (5).

For policy makers and transportation providers, “gray power” is a force to be reckoned with. The



TABLE 1 Journeys per Person per Year in England, 1996–1998

	Age Group								All Ages
	25–49	50–54	55–59	60–64	65–69	70–74	75–79	80+	
Men	1,199	1,210	1,223	1,102	1,071	936	810	540	1,070
Women	1,270	1,137	958	879	822	750	600	403	1,034

SOURCE: National Travel Survey 1996–98 (8).

seniors of tomorrow will be more affluent, more vocal, and increasingly used to claiming their rights (6). Because they likely will be more active than previous generations in their retirement, shopping, banking, and recreation trips will continue, and health-related trips are expected to increase (4). The number of older people is increasing, particularly the number of people age 80 or older. Transportation providers cannot afford to ignore this growing travel market segment.

## PROBLEM AND APPROACH

Often a senior's mobility problem starts with a lack of suitable transportation as an alternative to driving. Most seniors perceive transit to mean only buses and trains (2), and many seniors lack the knowledge or confidence to use traditional public transportation. The infrequent use of public transportation by seniors—in the United States typically 1% to 2% of all their trips—may be because public transportation does not match their needs, or public transportation is too difficult to use physically, or psychological factors predispose seniors against public transportation.

Transit planners generally are unaware of what the growing population of older people needs (6). Stated that “our transportation system does not meet the mobility needs of normally aging people,” Freund's solution is to provide “a transportation system that does” (7). In Britain buses generally are easier to use—in terms of schedules, location of stops, and design of buses, for example—than in the United States and the percentage of trips by bus for people in their 60s (8%) is double that for people age 30–60 (4%); for people in their 70s, the percentage is more than triple (14%) (8). Furthermore, despite increasing car ownership and use, in the past decade the number of bus trips per year increased for people age 75 and older—the only age group for which this was the case.

Making transportation meet the mobility needs of aging people is easier said than done. The traditional transportation planning philosophy tends to be supply (operator) oriented. That is, given the types and levels of transportation service available, how can society persuade older drivers to switch to transit when they can no longer drive? Few planners ask about the difficulties seniors have when using transit services and what can

be done to overcome the difficulties. However, several transit organizations are introducing more service options beyond the traditional fixed-route and para-transit services. If alternative means of mobility complement and then replace the car for drivers as they age, the mobility options must include more variants than those usually provided by transit operators.

European experts have warned that it is not enough to extrapolate current trends because future developments will be on a new scale (6). Novel approaches better matched to the demand (user) side of the equation, such as user abilities and preferences, need to be developed. For example, the recent shift in focus to a customer-driven mobility management concept is a step in the right direction (9). Burkhardt et al. (10) examined how various mobility options match the requirements of older drivers. The mobility needs of seniors are complex, with no one solution of alternative mobility for all people in all areas or even for one person in one area. European countries favor a family of transportation services to provide mobility options.

Many communities in North America also are moving to provide a range of transit service options, from accessible fixed-route transit services to service routes, subsidized taxis, dial-a-ride, volunteers with cars, and a high-quality pedestrian infrastructure (11).

## MOBILITY OPTIONS FRAMEWORK

Mobility for obtaining access to the goods, services, activities, and people that make independent living possible depends on where a person lives. In dense urban areas, most activities can be reached on foot or by transit, if the service is easy to use. In the suburbs, where activities are dispersed and journeys longer, there are few alternatives to the car or taxi. Residence area affects not only the geographic location of activities and the amount of travel required but also the transportation services and available infrastructure. In addition, regardless of area, the abilities of the individual may limit mobility options. For example, some older people are restricted in the distance they can walk without a rest or in their ability to climb the steps of a bus and to stand while the bus is in motion. These issues are discussed below.

Several factors influence the effectiveness of an option: the ability and willingness of seniors to use

and to pay for the option, the psychological barrier of moving from the driver's to the passenger's seat, and personal mobility planning of options and budgets for the degree of mobility required. Perhaps the most important factor is the degree to which an option matches the characteristics of the car to provide door-to-door travel, protection from the weather, space for luggage or shopping, and freedom to decide where and when to travel.

**Traveler Abilities**

The abilities of the elderly traveler determine the transportation options. The functional, physical, mental, psychological, and budgetary demands placed on users determine their role in travel as driver, passenger, or pedestrian. Table 2 lists the ability demands placed on users according to the mode of transportation and the geographic area of the activity.

**TABLE 2 Ability Matrix**

<i>Geographic Region</i>	<i>Ability of User</i>	
	<i>Functionality: What Must Seniors Be Able to Do?</i>	<i>Knowledge: What Must Seniors Know?</i>
<b>Urban</b>	<b>Motor Vehicle Passengers</b>	
	-Walk to vehicle pickup under all weather conditions.	- Service options and schedules
	-Board, remain standing, or be seated	- Service for point of origin and the destination of choice
	-Handle fare payment plans, rules, and options	- Eligibility requirements
	-Grasp stanchions or carry packages	- Service booking
	-Recognize directions, landmarks, and destination	- Time for total journey
	-Comprehend spoken or written directions and recognize destinations	- Safety of service
	-Hear directions and announcements	- Nearest pickup point
	-See vehicle route number signs and destination	- Safety of pickup point
	-Transfer between vehicles and modes	- Transfer needs
-Manage crowded conditions at stops and in vehicles	- Time frame if advanced booking is required	
-Enter and exit the vehicle rapidly	- Where to get off	
-Stand at pickup point for long periods	- Where to acquire information on service or change	
	- Travel substitution alternatives (e.g., shop via Internet or use delivery service)	
	- Availability of travel training and counseling	
	<b>Motor Vehicle Drivers</b>	
	- Drive an automobile or motorcycle, especially after dark	- Best route for safe travel, especially for scooter
	- Drive an automobile or motorcycle in heavy traffic	- Alternative routes to avoid congestion
	- Drive a scooter/powerd wheelchair	
	<b>Nonmotorized Vehicle Operators or Passengers</b>	
	<i>Cyclist</i>	<i>Cyclist</i>
	- Cycle long distances and maintain balance	- Safe routes for bicycles and wheelchairs (bike paths)
	<i>Pedestrian</i>	<i>Pedestrian</i>
	- Walk along crowded sidewalk or road if no sidewalk	- Safe route for walking, especially at night
	- Cross major thoroughfare safely	- Condition of sidewalk or road
	- Manage complex urban travel environment and stimulus	
<b>Neighborhood (Local)</b>	<b>Motor Vehicle Passengers</b>	
	Same as above except, in some cases, effort required may be less strenuous than in urban conditions	Same as urban

(continued)

TABLE 2 (continued) Ability Matrix

Geographic Region	Ability of User	
	Functionality: What Must Seniors Be Able to Do?	Knowledge: What Must Seniors Know?
	<b>Motor Vehicle Drivers</b>	
	<ul style="list-style-type: none"> <li>- Drive an automobile, especially after dark and in local streets with poor lighting</li> <li>- Drive an automobile in congested, heavy traffic</li> <li>- Drive a golf cart, scooter, or powered wheelchair</li> </ul>	<ul style="list-style-type: none"> <li>- Best route for driving</li> <li>- If it is safe to drive golf carts, scooters, or powered wheelchairs</li> </ul>
	<b>Nonmotorized Vehicle Operators or Passengers</b>	
	<p><i>Cyclist</i></p> <ul style="list-style-type: none"> <li>- Cycle or tricycle and maintain balance within the neighborhood</li> </ul> <p><i>Pedestrian</i></p> <ul style="list-style-type: none"> <li>- Walk safely on streets without sidewalk</li> <li>- Cross arterial and local streets safely</li> </ul>	<p><i>Cyclist</i></p> <ul style="list-style-type: none"> <li>- Location of bike paths</li> <li>- If bicycling or tricycling is safe</li> </ul> <p><i>Pedestrian</i></p> <ul style="list-style-type: none"> <li>- Condition of sidewalks</li> <li>- If neighborhood is safe for walking</li> </ul>
<b>Suburban</b>	<b>Motor Vehicle Passengers</b>	
	<p>Same as urban conditions except:</p> <ul style="list-style-type: none"> <li>- Perhaps walk longer distances to the vehicle pickup point</li> <li>- Less crowded conditions</li> <li>- Perhaps wait longer for vehicle pickup because of uncertainty of vehicle arrival</li> </ul>	Same as urban
	<b>Motor Vehicle Drivers</b>	
	<ul style="list-style-type: none"> <li>- Drive an automobile especially after dark and in suburban streets with poor or no lighting</li> <li>- Drive an automobile in peak hour traffic</li> <li>- Drive a golf cart or scooter on suburban roads</li> </ul>	<ul style="list-style-type: none"> <li>- Best route for driving</li> <li>- If it is safe to drive golf carts/scooters</li> </ul>
	<b>Nonmotorized Vehicle Operators or Passengers</b>	
	<p><i>Cyclist</i></p> <ul style="list-style-type: none"> <li>- Cycle/tricycle and maintain balance on suburban roads</li> </ul> <p><i>Pedestrian</i></p> <ul style="list-style-type: none"> <li>- Walk safely on streets without sidewalk</li> <li>- Cross arterial and local streets safely</li> </ul>	<p><i>Cyclist</i></p> <ul style="list-style-type: none"> <li>- Location of bike paths</li> <li>- If bicycling or tricycling is safe</li> </ul> <p><i>Pedestrian</i></p> <ul style="list-style-type: none"> <li>- Condition of streets</li> <li>- If it is safe for walking</li> </ul>
<b>Rural</b>	<b>Motor Vehicle Passengers</b>	
	<ul style="list-style-type: none"> <li>- Walk for a long distances on rural roads without shelter and in inclement weather to and from vehicle to the point for pickup</li> <li>- Board and be seated in a vehicle</li> <li>- Handle fare payment</li> <li>- Grasp stanchions and carry packages</li> <li>- Recognize directions, landmarks, and destination in a rural setting, especially at night</li> <li>- Comprehend spoken or written directions</li> <li>- Hear directions and announcements</li> <li>- See vehicle route number signs and destination, if any, especially in poor light conditions or no light</li> <li>- Disembark from the vehicle</li> <li>- Get in and out of the vehicle</li> <li>- Wait for vehicle pickup which may be more uncertain, especially in inclement weather</li> </ul>	<ul style="list-style-type: none"> <li>- Same as urban, except that the information available may be simpler and easier to grasp as less options are available</li> </ul>

(continued)

TABLE 2 (continued) Ability Matrix

Geographic Region	Ability of User	
	Functionality: What Must Seniors Be Able to Do?	Knowledge: What Must Seniors Know?
	<b>Motor Vehicle Drivers</b>	
	- Drive, especially after dark and in rural areas with no lighting	- Rural route for safe travel
	<b>Nonmotorized Vehicle Operators or Passengers</b>	
	<i>Cyclist</i> - Cycle and maintain balance on rural roads for long distances and in inclement weather	<i>Cyclist</i> - Safe route for nonmotorized vehicles
	<i>Pedestrian</i> - Walk safely on rural road conditions without light, sidewalk, or shelter from inclement weather and traffic	<i>Pedestrian</i> - Lighting and surface conditions of rural roads
	- Cross rural road intersections safely	- If it is safe for walking

Functional demands include the individual’s ability, for example, to find and walk to a vehicle pickup point, climb the steps, handle a fare-based payment system, stand on a moving vehicle, travel alone, and carry parcels. The functional requirements for travel are best described in terms of the journey chain from door to door: home to curb, curb to vehicle, ride in vehicle, transfer, vehicle to curb, and curb to door (6). Accessible vehicles only serve one role—albeit an essential one—in an accessible transportation service.

Accessible pedestrian infrastructure and links between modes and within terminals, information before and during travel, and—perhaps most important—trained staff all play essential roles in accessible service. Accessible vehicles must be easy to use for people who walk with difficulty, are in wheelchairs, have shopping or luggage, or have babies in strollers. Universal design means designing for the whole population to remove the barriers to public transportation for many people.

Older people likely will have more difficulty walking, balancing, and climbing steps. Their walking ability may be restricted, and they prefer ample time for actions such as boarding, paying a fare, and finding a seat. In Britain about 12% of seniors age 60–74 and 28% of seniors age 75 and older cannot walk more than 200 m or climb more than 12 steps without resting (12). Seniors have overriding concerns for safety—especially a fear of falling—and for personal security from theft and assault while traveling (13).

People who walk with difficulty often are more restricted in the distance that they can travel than are people in wheelchairs (14). To make an informed choice of travel modes, an individual must have knowledge of available transportation options—namely, booking

procedures, schedules, routes, fares, location of stops, and help when needed. Because seniors have failing eyesight and hearing, the size of the transit schedule print and the audibility of travel announcements pose particular concerns. Similarly, the ease of use and the legibility of travel information are important because signage, information kiosks, and web-based systems often create a challenge for the elderly traveler.

With the onset of the information age, smart or intelligent transportation systems (ITS) are being designed and added to cars, to transit vehicles, and at stops and stations. These systems have the potential to help, but seniors have to master the technology and ITS must be user-friendly, or the complex procedures and tasks of the new technologies could reduce the benefits for seniors.

An individual’s financial ability also restricts the mobility options available. Seniors who previously drove may be willing to devote a larger budget to transportation services than their transit-dependent counterparts. Ability demands (Table 2) can be used to explain the decision criteria of modal choice based on the user’s abilities and restrictions, but mobility options for seniors must be designed to pose as few problems as possible.

### Geographic Location

Patterns of land use and mobility requirements and options vary according to geographic location. The population and land use characteristics within urban areas, neighborhoods, suburban areas, and rural areas are all different, as is the availability of senior transportation services in these areas.

Walking emerges as the second most used travel mode for seniors, after the private automobile, in all

geographic locations. Safety of elderly pedestrians is an issue, especially in urban areas with heavy traffic. In suburban and rural areas, sidewalks may not exist and road lighting may be poor.

A traditional urban area likely has a strong concentration of social and economic activities and a more diverse and dense population. When an economically active downtown area survives, the area contains major trip generators and may be the focus for transit routes. In urban areas, the more numerous mobility options vary by transit mode, level of service, and geographic coverage and usually are less costly. However, despite the abundance of public transit services, seniors in urban areas only use transit about as frequently as they use taxis.

Trip lengths tend to be shorter in urban areas and neighborhoods than in suburban and rural areas because of activity concentration. The transportation infrastructure tends to be better developed in urban areas, with traffic signals, streetlights, transportation terminals, bus shelters, sidewalks, and crosswalks. In rural areas, roads are sometimes unpaved; streetlights, sidewalks, and crosswalks are rare or nonexistent. All these rural conditions create further travel barriers for seniors.

It is not surprising that mobility options for seniors—and the general population—tend to diminish and costs increase in the transition from urban areas to neighborhood, suburban, and rural areas, with lower density, less demand for service, and more remote destinations. In these lower-density areas, informal transportation provided by families or volunteers continues to be an important resource. Unconventional services, such as transit-cum-ambulance, -school bus, and -postal van service; voluntary carpools; or mobility clubs, have developed to fill the transportation gap. Some of the community-based solutions have the potential to meet the travel needs of seniors for spontaneous and unplanned trips, but others require advance planning. Table 3 lists multiple mobility options for seniors.

### Service Options

Many organizations provide seniors with transportation services, including public agencies, the private sector, hybrid organizations (a combination of public and private), volunteer groups, family members, and the individuals themselves. Burkhardt et al. (10) provided a description of these various options.

Services range from traditional fixed routes provided by public transit systems (rail and bus) to less traditional, more accessible, and more innovative services, such as flexible routes, community-based services, and paratransit. Other possibilities include a volunteer car

service and personal modes, such as walking and bicycles. All of these options need to be supported by mobility counseling. Table 4 lists transportation service options by provider type. The following section focuses on transportation for daily living. Because of space restrictions, long-distance services, such as intercity coach, rail, air, and maritime services, are not addressed.

### Public Transportation Services

Public transportation refers to a transit system for the general public, usually delivered by the local or regional government.<sup>1</sup> Public transportation is provided through a variety of service-delivery options, ranging from traditional fixed routes to more responsive services, such as flex route and route deviation, service route, paratransit, community transit, and community bus.

**Fixed Route** This service operates on a schedule with predetermined stops along a defined roadway or tracks. Fixed-route services typically include bus services, subways, light-rail transit, and commuter rail. Some seniors can use subways, light-rail transit, and commuter trains, but many find the amount of walking within these systems too strenuous. Many seniors have trouble negotiating the stairs and escalators. Some subways (Metro in the District of Columbia), extensions to old systems, and light rapid-transit systems (Skytrain in Vancouver, British Columbia, Canada) are accessible to passengers in wheelchairs; these access features also benefit elderly travelers. Ståhl et al. (15) found that the problems for people with mobility difficulties using Swedish urban rail services involved getting to and from the station, around the station, and on and off the train.

The transition from an inaccessible fixed-route system to one with accessible vehicles, stops, and stations can take many years. In the interim, the transit system will be partially accessible. During this period, decisions must be made about the distribution of accessible buses and other vehicles throughout the fixed-route system. Early experience suggested that the transit operator should assign new accessible buses to the most appropriate routes, so that all buses on one route are accessible, including any spare vehicles, before starting to allocate accessible buses to the next route.

Several reasons justify this strategy. First, many bus stops need work to make them accessible. It would be easier to concentrate this work along selected routes instead of trying to cover the whole system. Second, low-floor buses often are introduced as part of a qual-

<sup>1</sup> In Britain and most of Central and South America, private companies provide most public transportation.

TABLE 3 Mobility Options Matrix

<i>Transportation: What Options Are Available?</i>	<i>Information: What Do Seniors Need to Know?</i>	<i>Affordability: How Much Does It Cost?</i>
<b>Motor Vehicle Passengers</b>		
<ul style="list-style-type: none"> <li>- Fixed-route rail: metro, light rail, commuter rail, and bus with low-floor or kneeling buses or wheel chair lift-equipped vehicles</li> <li>- Paratransit: curb-to-curb, door-to-door, door-through-door, on demand subscription, or feeder service</li> <li>- Community transportation: service route, community bus, flex routes</li> <li>- Demand-responsive transit: dial-a-ride</li> <li>- Independent Transportation Network</li> <li>- Taxi with or without shared ride</li> <li>- In neighborhood areas, golf carts, neighborhood electric vehicles, and mobility clubs are additional options.</li> </ul>	<ul style="list-style-type: none"> <li>- Information on schedule</li> <li>- Type of stops (bus stop or hail stop)</li> <li>- Type of access and egress: sidewalk, crosswalk, overpass, or tunnel</li> <li>- Route and destination</li> <li>- Distance and journey time</li> <li>- Service options and transfers</li> <li>- Advance booking and demand-responsive service</li> <li>- Shared ride arrangements</li> </ul>	<ul style="list-style-type: none"> <li>- Flat fare</li> <li>- Discount fare</li> <li>- Subscription fare</li> <li>- Monthly pass</li> <li>- Fare based on eligibility</li> <li>- Fare based on distance traveled</li> <li>- Voluntary contributions or no cost</li> <li>- Membership</li> </ul>
<b>Motor Vehicle Drivers</b>		
<ul style="list-style-type: none"> <li>- Private automobile</li> <li>- Motorcycle</li> <li>- Scooters, powered wheelchair, neighborhood electric vehicle, golf cart</li> </ul>	<ul style="list-style-type: none"> <li>- Type of access and egress: sidewalk, crosswalk, overpass, or tunnel</li> </ul>	<ul style="list-style-type: none"> <li>- Fixed cost of vehicle</li> <li>- Operating costs of vehicle</li> </ul>
<b>Nonmotorized Vehicle Operators or Passengers</b>		
<ul style="list-style-type: none"> <li><i>Cyclist</i></li> <li>- Bicycle or tricycle</li> <li><i>Pedestrian</i></li> <li>- Walking</li> </ul>	<ul style="list-style-type: none"> <li><i>Cyclist</i></li> <li>- Type of access and egress: sidewalk, crosswalk, overpass, or tunnel</li> <li><i>Pedestrian</i></li> <li>- Type of access and egress: sidewalk, crosswalk, overpass, or tunnel</li> </ul>	<ul style="list-style-type: none"> <li><i>Cyclist</i></li> <li>- Minimal</li> <li><i>Pedestrian</i></li> <li>- Negligible</li> </ul>

ity package, along with bus-priority measures, new livery, retrained staff, and extensive publicity. For successful implementation, all vehicles and aspects of the route must be high quality. In Britain the introduction of low-floor buses increased ridership by about 10%. In the city of Leeds, where the full quality package was introduced in one corridor, ridership increased 70% in 2 years. Third, the vehicles and infrastructure must be easy to use for elderly people, people who have difficulty walking, and people in wheelchairs. The successful experiences in Europe, particularly with low-floor buses in urban and suburban areas, could be applied to the United States and Canada.

Fourth, designating only certain routes as accessible restricts travel options for seniors and people with dis-

abilities (16). An on-call service allows individuals to call in advance and request that an accessible bus be placed on a particular route at the time they wish to travel. This system also may be offered as a supplement to paratransit services or can be integrated with paratransit operations (16). Although offering the benefit of expanded opportunities using a fixed route, on-call programs provide a lower level of service than either fixed-route or paratransit systems. On-call, accessible, fixed-route bus programs end up being a short-term and rather unsatisfactory solution to the problem. This program should be used as a short-term service enhancement until accessible buses are available throughout the system (16). European studies have shown that accessible, mainstream public transit is the



TABLE 4 Service Providers

<i>Provider Type</i>	<i>Services</i>
<b>Public</b>	<ul style="list-style-type: none"> <li>– Fixed-route rail (metro, light rail, commuter rail, and bus (with low-floor or kneeling buses or wheel chair lift-equipped vehicles))</li> <li>– Paratransit (curb-to-curb, door-to-door, door-through-door, on-demand subscription, feeder)</li> <li>– Community transportation (service route, community bus)</li> <li>– Demand-responsive transit (dial-a-ride)</li> <li>– Taxi (with or without shared ride)</li> <li>– Flex route (route deviation, point deviation, flag stop, request-a-stop)</li> </ul>
<b>Private</b>	<ul style="list-style-type: none"> <li>– Taxi (with or without shared ride)</li> </ul>
<b>Hybrid</b>	<ul style="list-style-type: none"> <li>– Mobility counseling and training</li> <li>– Mobility management</li> <li>– Coordination and brokerage service</li> </ul>
<b>Volunteer</b>	<ul style="list-style-type: none"> <li>– Private automobile</li> <li>– Independent transportation network</li> <li>– Mobility counseling and training</li> <li>– Carpool</li> <li>– Mobility club</li> </ul>
<b>Personal</b>	<ul style="list-style-type: none"> <li>– Friends' and relatives' automobiles</li> <li>– Private automobile</li> <li>– Motorcycle</li> <li>– Scooter</li> <li>– Powered wheelchair</li> <li>– Bicycle</li> <li>– Tricycle</li> <li>– Walking</li> </ul>

most effective mobility option, allowing older and disabled people to continue to live independent lives (17).

**Flex Routes** On request flex-route services deviate from the main route to pick up or drop off passengers. Delivery of a flex-route service includes route- and point-deviation, flag-stop, and request-a-stop services.

*Route-deviation service* combines the features of a fixed-route, fixed-schedule transit service with features of a demand-responsive, curb-to-curb service. Unlike in a traditional fixed-route service, a vehicle may be requested by customers either to pick them up or to drop them off at a specified location within a corridor instead of on the advertised route (16). The vehicle then returns to the point at which it deviated from the regular route. In the absence of any requests, the service operates on a traditional fixed-route system. Customers typically call a central dispatch or control center to request a deviation from the advertised route. Some systems require 24-h notice, while others can accommodate short notice (16).

Possible variations of this mode include general-public, client-specific, and site-specific route-deviation services (16). A general-public route-deviation service accepts requests from all riders. A rider-specific program targets the service to riders, such as seniors, who

have difficulty getting to or from an advertised route. The third and most popular approach offers a degree of route flexibility but limits the overall schedule. With the site-specific route-deviation service, an advertised schedule lists certain major trip generators or destinations, such as senior centers, and deviation requests are accepted for those specific sites only (16).

Issues to consider in the design of a route-deviation service (16) include maximum distance for deviations from the advertised route, selection of areas covered by the route deviation, and service and time restrictions for the route deviation (e.g., specific time of day or day of the week).

In a *point-deviation service*, a vehicle operates on a fixed schedule with specific stops but without a fixed route. Vehicles accommodate requests for pickups and dropoffs at locations other than specified stops as long as they can be accommodated within the fixed schedule. Customers can choose to meet the vehicle at a designated location or can call in advance to arrange to be picked up at a particular location within the service area (16). Point-deviation systems also have more complex designs. For example, in Hamilton, Ohio, the system combines several sectorized point-deviation routes with a timed transfer center. This system works better

in older, midsized cities with a radial street pattern (16). A simple point-deviation system works best in rural communities and suburban neighborhoods. Key implementation issues for the point-deviation service include capacity constraints, checkpoint locations, service area size, and advertised schedule (16).

A *flag-stop service* allows patrons to request a bus by waving it down anywhere along a route. In a *request-a-stop service*, a person can request a stop at any location along a route. Both of these effective services reduce walking distances to and from bus stops. Many rural and smaller urban areas have implemented flag-stop services (16).

**Service Route or Community Bus** These flex-route services are designed for older people specifically by reducing the walking distances to and from bus stops, using low-floor vehicles, and providing ample time for boarding and alighting. Usually also available to the general public, the services target seniors and people with disabilities. Typically smaller vehicles travel on narrow neighborhood streets and go to mall or hospital entrances (11, 16). Service routes are designed to bring fixed-route buses as close as possible to the residences and destinations of the target population. Sufficient time in the schedule allows for driver assistance and reduces the pressure on passengers to hurry when boarding and alighting.

Service routes can replace traditional fixed-route services with limited ridership and attract trips from paratransit services. An advantage of service routes is that reservations are not required, thus allowing for spontaneous travel (11, 16). The Madison (Wisconsin) Metro provides a modified service-route system by operating on a fixed-route timetable but allowing for the pickup of preregistered passengers within three or four blocks of the service route. The service provides transit for the general public and people with disabilities (18).

**Paratransit** Paratransit means “alongside transit” and includes all public and private mass transportation between the private automobile and conventional transit. Paratransit consists of demand-responsive modes and provides shared rides. Taxicab and livery services are included because of the similarity of their operations to other demand-responsive services and because taxis have historically served older people and people with disabilities—both markets traditionally served by paratransit (19). In practice, paratransit covers two areas: a specific type of paratransit required for compliance with the Americans with Disabilities Act of 1990 (ADA), called ADA complementary paratransit, and all other demand-responsive services (1).

The levels of paratransit service vary from curb-to-curb, to door-to-door, to door-through-door. A curb-to-

curb driver assists the rider from the curb in front of the trip origin to the curb of the destination, including assistance into and out of the vehicle, as well as wheelchair folding and storage. Door-to-door paratransit provides service from the door of the building at the point of origin to the door (or driveway) of the destination. If needed, drivers assist passengers from the door of the building to the door of the vehicle by pushing the wheelchair, extending an arm to steady passengers, or carrying passengers. Door-through-door paratransit service requires the driver to assist the passenger across the threshold of both the origin and destination buildings. Usually drivers assist passengers up and down steps and in and out of the vehicle. Although most paratransit services are directed at physically challenged transit users, seniors also may use the service. In rural areas, often a paratransit service is part of the general community transit services.

Problems with paratransit consist of restricted availability because of eligibility, scheduling constraints, and limited capacity. Usually provided as a subsidy to seniors, paratransit services’ escalating costs have prompted many systems to search for ways to shift users into a broader range of services, especially fixed-route services. Three major types of paratransit service provide public transit:

- *General-public dial-a-ride.* This type of service is demand-responsive, door-to-door, or curb-to-curb for the general public and people with disabilities; other names for this service are dial-a-bus, telebus, and call-a-ride. Dial-a-ride is the best known of the demand-responsive paratransit-type services and involves advance requests to be picked up and dropped off at a desired location. Dial-a-ride services take one of three forms:

- Many-to-one: transportation from multiple origins to one location;
- Many-to-few: transportation from multiple origins to a few designated destinations; and
- Many-to-many: transportation between any two points within a service area (20).

General-public dial-a-ride is particularly useful in low-density urban and rural areas where the service acts as part of intracommunity transportation and feeder services in a regional fixed-route system (20). To improve the productivity of a dial-a-ride service, many operators promote group trips by developing contracts with human service agencies to provide transportation services to a designated location for nutritious meals, workshops, or shopping, for example.

- *Feeder service.* Often part of a general-public dial-a-ride (20), this service uses paratransit vehicles to and from a fixed-route bus stop or train station. In most locations, the feeder service typically is limited to people

with disabilities who can use fixed-route services if they have appropriate transportation to the stop or station.

- *Subscription bus service.* Designed to meet the needs of specific groups or individuals, this prearranged service typically is provided as part of a paratransit program or of a system's fixed-route service. The vehicles tend to be accessible buses available during off-peak periods or spare accessible buses from a fixed-route service.

Transit Windsor (Ontario, Canada) provides a special subscription bus for seniors shopping on Tuesdays and Wednesdays. The Worcester (Massachusetts) Regional Transit Authority operates a senior shoppers' special bus service once a week in a particular sector of the city. The service includes regularly scheduled pickup locations, such as senior housing projects, and accepts phone-in requests.

### *Private Services*

Taxi and limousine companies, as private providers of transportation services, offer rides directly to the public. The companies often contract with public transit-paratransit operators and other community organizations to provide regularly scheduled rides. Taxis are either booked by phone or hailed on the street and have the flexibility to carry multiple passengers. Because of the high cost, however, seniors rarely use taxis.<sup>2</sup> Charges are based on mileage or zones. The cost is more affordable if a contract provides the service or if the local government provides a user-side subsidy to groups, such as disabled people or seniors. Taxis tend to be used more for medical or other essential services such as grocery trips.

### *Community Transportation and Hybrid Services*

Community organizations typically provide transportation for their clients. Recently, transit systems have worked with community organizations to coordinate services for their clientele and to use resources more effectively. Services range from bus routes to dial-a-ride to taxi-like provisions. Many community transportation providers specifically serve the transit needs of seniors by including

- Regular trips to senior centers, grocery stores, and doctors' offices;
- Special services for nursing homes and group outings;

- Neighborhood circulators to pick up people who live in the suburbs and drive them within neighborhoods or to major bus routes;
- Discounted transit fares; and
- Taxi or car setups provided by a mix of volunteers and paid staff.

Although the community transportation services tend to be client specific, they could serve a broader community need and become more efficient in resource use. In Boulder, Colorado, community-oriented transit replaced the services provided by the Regional Transit District's fixed-route system. A service such as the Hop and Skip bus routes "breaks the rules for traditional methods of transit design and operations by treating transit like a product that competes with the convenience, image and comfort of driving alone" (21).

Coordinated community transportation services usually are designed in a dynamic and often extensive public planning process. Collaboration and cooperation with the local transit and paratransit providers and alternative transportation resources in the community is vital, with a sincere willingness on all parts to make community transportation services happen. Other features of a coordinated system may include

- Multijurisdictional partnerships;
- Vehicle sharing;
- Fares geared to specific users;
- Pedestrian-scaled, eye-catching vehicles designed to compete with the car;
- User-friendly information system at stops;
- Drivers trained as community ambassadors; and
- More frequent and direct service.

The services allow community organizations that do not primarily provide transportation services to focus their efforts on their important role in support services, vocational rehabilitation, day programs, and so forth. A hybrid service offers a brokerage type of service, in which coordination occurs between public and private transportation operators. The service usually involves coordination through a central dispatching center.

Public transit operators and nonprofit or community organizations may provide accessible services to seniors for free or at a nominal cost. Most of the providers operate the basic transport service and subcontract to private operators, such as taxi companies, to provide for off-peak or feeder services from transfer points, transit centers, and rail-based systems. Drivers are volunteers or paid, and the cost of the dispatch center may be partially subsidized by the local government, charitable organizations, or user fees.

To allow for a coordination of service among providers, individuals must book in advance the desti-

<sup>2</sup> In Britain 1% of older people journey by taxi, compared with 7–13% by bus and 29–34% by walking.

nation and preferred time and date of departure. At the time of a booking, the client is told the fare and the approximate departure and arrival time. One of the largest brokerage systems, New Jersey Transit Authority, combines private and public providers through a centralized system of booking and dispatching. To overcome resistance to this integrated program, the transit authority enlisted travel trainers to help seniors and individuals with disabilities use the services more effectively.

In 1988 a nonprofit association in Minitonka (Manitoba, Canada) set up a transportation service for seniors and disabled people with a vehicle that can be used as an ambulance or van. Typically the vehicle is used for transit operation but also can be used as a nonemergency ambulance (22). Similarly, the post-bus service in the United Kingdom combines mail delivery and transit. The mail van also serves as a transit service for seniors in rural areas. In other rural areas, school buses are used by transit services to carry fare-paying passengers (23). Aroostock Regional Transportation in Presque Isle, Maine, is a private, nonprofit agency providing transportation services to older people, people with disabilities, low-income people, and the general public in a low-density county—a population of 87,000 in an area of 6,600 mi<sup>2</sup>. With a fleet of 25 vehicles, the system primarily offers a scheduled fixed-route service. Aroostock provides special fares to seniors, whose trips account for 47% of the system's use. According to a Transit Cooperative Research Program report, “a significant benefit of Aroostock's service is that elderly customers are assisted in staying in their own homes longer compared to the without-transit situation where institutionalization at a nursing home facility often is the only realistic alternative” (24).

The County of Lee Transit System (COLTS) was formed in 1992 to replace an uncoordinated group of overlapping transportation services in Lee County, North Carolina. Now the Lee County Senior Services Agency runs COLTS, which provides most of the transportation services for the county. COLTS offers a range of transportation services, including taking seniors for midday meals and shopping trips, which give seniors more independence.

### *Volunteer Services*

At the local level, seniors may obtain rides from neighbors and friends; however, seniors often dislike feeling the debt of gratitude. At the regional level, more extensive and organized transportation services use at least some voluntary contribution or labor or a voluntary ecumenical group.

The Independent Transportation Network (ITN) operates within a 25-km radius of Portland, Maine, and serves 600 seniors and 50 people with visual impairments. The service uses 4 company vehicles and the cars of 75 volunteers. The goal of ITN is to meet the mobility needs of seniors through an economically sustainable, nonprofit transportation service. The service was designed to incorporate the desirable characteristics of private cars. Customers pay for trips by the mile and choose to ride alone or with others. Discounts are given for advance trip booking and ride sharing. ITN offers membership to individuals who use the service frequently and to businesses that wish to support ITN through the purchase of preprinted stickers for their senior customers (25).

A mobility club is an organized carpool service. The volunteers who set up the dispatch center for coordination and management operate the club. The club enlists volunteer drivers, using their own cars, to provide transportation services for seniors (26, 27) as a way to enhance mobility, especially in rural areas.

When a senior has a disability, it is unlikely that a volunteer can provide an accessible vehicle. Therefore, a local church group or nonprofit organization often supplies a specially equipped accessible vehicle on loan to the senior for a specific trip. The senior must arrange for a driver and an attendant, if needed. The disadvantages of this service are the necessity to negotiate the availability of the vehicle and the purposes for which the vehicle will be used and then to obtain a driver.

Although not a transportation service, Driving Decisions for Seniors is an innovative approach being tested in Eugene, Oregon. This service provides mobility counseling to seniors trying to decide whether to stop driving. Mobility counselors assist seniors by working through the issues and provide an institutional mechanism to help identify and make the transition to alternative mobility options (1).

Another service for seniors, a free telephone information and referral mobility management system, inventories the transportation services available in a given area. Mobility counselors help seniors develop a detailed intake form of available services and then link seniors to a transportation service or package of services best suited to their needs, similar to creating a “transportation quilt.” One example is the Connect-a-Ride Program of the Jewish Council for the Aging of Greater Washington, D.C. This one-stop information and referral program on transportation serves seniors and people with disabilities in Montgomery County (Maryland) and Fairfax County (Virginia). Such programs help to sensitize seniors to mobility options before there is a crisis, because most services require lead time for enrollment, such as applying for eligibility and purchasing discount coupons.

### *Personal Transportation Modes*

Few seniors opt to drive motorbikes as a lower-cost option to an automobile, but because a driving license is needed for a motorbike, this option is not a true mobility solution. Personal transportation alternatives for seniors that do not require a license include walking, bicycles, adult tricycles, electric bicycles, powered wheelchairs, scooters, electric golf carts, and neighborhood electric vehicles (NEVs). These means of transportation provide the benefit of spontaneous travel but for shorter trips only. Seniors also avoid the debt of gratitude that many feel when a friend, neighbor, or family member provides transportation. But these options require rights-of-way such as sidewalks and special paths that are safe from traffic and do not pose a threat to other road users. An accessible and safe environment for pedestrians, wheelchairs, and scooters serves a vital role in an accessible public transportation system, as do powered wheelchairs and scooters. These links to an accessible transit system offer seniors the opportunity to travel without an automobile.

**Walking and Assisted Walking** For a fit senior, walking is ideal, provided that the distance is within the physical ability of the person and the weather is good. As able pedestrians or those with nonmotorized mobility aids, such as walkers, crutches, canes, or manual wheelchairs, seniors are concerned about personal security, safety, sidewalk conditions, road crossings, and availability of shelter and rest stops, especially in inclement weather.

Walking is the most frequently used means of transportation by seniors after the automobile. Transportation planners almost have forgotten this free and flexible mode of transportation. With the overemphasis on automobile transportation, little attention has been paid to support the needs of pedestrians, such as sidewalks, road crossings, and traffic signaling systems. Several best practices in this area come from Europe, particularly Scandinavia and the Netherlands, where walking and cycling are more prevalent (28). In Britain, people in their 60s make 29% of their journeys on foot and people age 75 and older, 34% (8). The value to seniors depends on the quality of the pedestrian infrastructure, especially in downtown areas and at activity locations. High-quality sidewalks and crosswalks are essential for seniors to retain independent, safe mobility.

**Bicycles and Tricycles** Cycling as a mode of transportation has been rediscovered by many because of the increasing popularity of physical fitness, environmental friendliness, and flexibility of travel. For local neighborhood travel, healthy seniors may opt for this viable mode. However, unless safe tracks and road crossings are provided, it can be dangerous, and elderly

people are very susceptible to accidents. In Finland there are high rates of deaths and injuries among seniors who cycle or walk after being forced to stop driving for medical reasons (29).

A beneficial addition to cycling, the electric bicycle can be operated with less exertion (30). The distance range is about 15-mi round trip on one battery charge, and the recharging takes about 3 h. Electric bicycles may be ideal vehicles for local trips, provided the weather is good, safe routes are available, and the agility and dexterity of the senior are not safety concerns. Kits are available to convert a regular bicycle into an electric one. Or an electric bicycle can be purchased for approximately \$600, which may be affordable to many seniors.

A relative to the bicycle, the adult tricycle is available on special order from several bicycle companies and can be used for local errands and other neighborhood trips. However, because of the prohibitive cost, tricycles have not been popular among seniors.

### **Powered Wheelchairs, Scooters, Golf Carts, and NEVs**

Two categories of personal vehicles—the powered wheelchair and scooter—also provide independent mobility for short local trips. About the size of manual wheelchairs and normally on four wheels, powered wheelchairs operate at 2–3 mph and have a range of a few miles. Scooters are small three-wheeled or four-wheeled vehicles (somewhat larger than a powered wheelchair) and normally operate at up to 4 mph, with a range of 10 to 20 mi. In Britain scooters can travel at 8 mph on roads and 4 mph on sidewalks. British scooters have lights and turn indicators and are used on roads in small numbers, but like golf carts, are not compatible with motor traffic on normal roads. Once a network of safe cycle routes is established, people using powered wheelchairs and scooters can share these routes with cyclists.

A specialized application of powered wheelchairs and scooters is as loan vehicles in shopping malls. Plans to provide this service in Britain are called shopmobility (31), which enables people with restricted walking ability to move about within large malls or pedestrian-only shopping areas; the malls and areas can be reached by transit, paratransit, or automobile.

The golf cart has become a popular vehicle for seniors, especially when living near a golf course. In Sun City (Arizona) and Palm Desert (California), the golf cart is a fashionable mode of transportation. The carts are relatively inexpensive, run on rechargeable batteries, and are suited for short local trips (32, 33). However, carts are restricted to bicycle paths or dedicated lanes on the sidewalk because they are not compatible with traffic on normal roads. The dexterity and agility of the senior also determine the possible uses of



a golf cart. An issue of concern for expanding the use of golf carts depends on safety. Because of the small number of carts produced and used for transportation, the National Highway Traffic Safety Administration (NHTSA) has not deemed it practical or economical yet to deal with issues of standards and specifications (2).

To fill the gap between the golf cart and the car, companies such as Bombardier sell a covered minicar or NEV to respond to the needs of aging baby boomers. The vehicle originally was aimed at the residents of gated communities in the U.S. Sunbelt. The NEV costs about \$7,000—twice as much as a golf cart—and can run up to 30 mi without a battery recharge. NHTSA introduced safety standards for this new category of low-speed vehicles in *Motor Vehicle Safety Regulations* (34).

The most important factors to determine how many seniors will use these personal transport modes are

- Health, stamina, and agility of the person;
- Disposable retirement income of the person;
- Capital and operating costs of the vehicle or equipment;
- Geographic area in which the person lives and length of the journey; and
- Quality of the infrastructure for pedestrians, cyclists, and users of powered wheelchairs, scooters, and golf carts.

## ISSUES AND CHALLENGES

The text above demonstrates the complexity of providing mobility options for seniors. The section below summarizes the mobility option issues and challenges faced by transportation planners and policy makers.

### Mobility Options

No one form of transportation can substitute for car travel either when older people prefer not to drive or when driving is no longer possible. In Europe a family of services is beginning to provide various mobility options, such as transit services, that are easy for everybody to use, including older people; people who find walking or climbing steps difficult; people with briefcases, carts, baby strollers, luggage, or mobility devices; shoppers; and people in wheelchairs. Other options include routes for people who can use transit if walking distances are reduced and more time is provided for boarding, paying the fare, and finding a seat; subsidized taxis; dial-a-ride for people who need assistance while traveling; and an accessible and safe infrastructure for pedestrians and people in wheelchairs.

### Improvements to Transportation Services

Significant improvements have made transportation services more accessible, particularly for seniors and people with disabilities. Transit stations have more accessible features, including elevator ramps, signage, and accessible communication devices such as talking signs. Traditional transit services are more accessible because of features such as low-floor buses to assist seniors when boarding and exiting. Designed for everyone, these features most help elderly people who have difficulty walking, climbing steps, and balancing on a moving bus; people with mobility aids, luggage, or young children; and people in wheelchairs. The introduction of community transportation, service routes, and paratransit services further improved the mobility options for seniors by providing flex-route, route-deviation, dial-a-ride, and accessible van and taxi services. How to convince and train seniors to use these improved transit services remains a challenge. There are hidden transportation resources in many communities, such as taxis, school buses, mail delivery vans, and ambulances. The efforts of mobility brokers or coordinators may prove promising to mobilize and manage the resources from school boards, hospitals, agencies, housing authorities, and private fleets to provide the needed mobility for seniors.

### Automobility

Personal vehicles still account for more than 90% of the trips made by older people. The use of a personal vehicle is the most important factor for seniors to maintain independent living (1). Seniors also take one out of five taxi trips, and the voluntary car program (e.g., ITN in Portland, Maine) has proved successful (2). To design mobility options that can achieve the level of service provided by the automobile, taxi, or “get-up-and-go automobility” (25) for longer trips remains an elusive goal. However, powered wheelchairs and scooters capable of up to 8 mph on specific paths away from pedestrians offer the possibility of independent mobility for short trips. The paths can be shared with cycles and form a network of safe cycle routes, but the paths must be separated from traffic because the alternative vehicles—such as scooters—are not compatible with general traffic on all-purpose roads.

### Mobility Budgets

The concept of a mobility budget is fairly rare but gaining in use. Mobility budgets for seniors who drive are different from those for seniors who do not. For drivers



who have to give up their vehicle, the money can be used to pay for alternative transportation services (2). For this group, affordability is less of an issue than finding a suitable alternative to the automobile. Affordability may be an issue for nondrivers. Planners need to design transportation services that match the user's mobility budget.

### **Economic Sustainability**

"To move forward into a transportation future, a transit solution to meet the needs of the aging population must be economically sustainable" (6), a European report noted. For service providers, achieving sustainability depends on developing the right mix of services and innovative funding plans (1), such as coordinating public transportation and human services transportation programs (Medicaid, etc.), and the integration of planning, funding, and operations. For people who are poor and elderly, mobility services may have to be paid for by user-side subsidies or private sources (e.g., friends and relatives), particularly in rural areas (2).

### **Rural and Suburban Mobility**

Mobility in rural and suburban communities remains an issue. At least 75% of seniors live in low-density suburbs. Seniors in rural communities are more isolated than their suburban counterparts and have few alternatives other than family and friends (2). Devising suitable transportation alternatives for long trips and dispersed origins and destinations is difficult. The construction of pathways in suburban areas would provide safe routes for pedestrians, powered wheelchairs, scooters, and bicycles. The routes would make independent travel possible for trips of 2 to 3 mi to the neighborhood center, church, and friends in suburban areas but the problem in rural areas persists.

### **ITS: The Two-Edged Sword**

ITS has much to offer seniors, as drivers and passengers of public and private transportation systems. The application of ITS in public transportation can improve the efficiency of transit operations and allow for the provision of multimodal trip-planning information. Real-time information can be provided at bus stops and stations, in vehicles, and in the home through the Internet and pagers. The application of ITS to guide seniors with a visual impairment is under way (1). However, seniors' acceptance of this new technology and its impact on travel behavior remain undefined.

The requirements of seniors must be incorporated into the development of ITS applications, including the presentation of electronic information (35).

### **Community Support Building**

Greater use of untapped community resources can be made, including volunteers as mobility counselors, attendants, and drivers. The challenge is to increase awareness and to build and mobilize community support to make this happen.

### **Transportation Manager and Front-Line Personnel Training**

Well-trained, sensitive, and helpful staff are as important as good, quality equipment and infrastructure and can make up for many deficiencies in the equipment. Transportation personnel often do not understand adequately the mobility needs of seniors or the mobility limitations and abilities of people with locomotive, sensory, or cognitive impairments. Sensitivity training and certification needs to be expanded to include transportation personnel (management, operations, and front-line staff) involved in the provision of services to the aging population. The training should be a part of an overall policy to pay more attention to the needs of all passengers. Through Easter Seals, Project ACTION has provided training to consumers and transit operators for over a decade.

### **Future Directions for Public Policy**

The need for policies and programs to address the issue of senior mobility will not go away. The population of older people is increasing. At least 75% of the next generation of seniors currently live in low-density suburbs and are independently mobile. As they age, driving will become more difficult, and eventually they will have to stop driving. Transit and paratransit in the suburbs do not currently provide a level of mobility to match that provided by the car, although these services could be improved substantially by using the experience of other countries.

The cost of publicly provided mobility is high, but the costs and quality-of-life penalties of not providing mobility are much greater (17). To comprehend the importance of these options, it is essential to understand the cross-sector benefit of mobility options for seniors. A 1994 British study (17) showed that the savings of health care and social service costs achieved by making transportation fully accessible to elderly people

and people with disabilities could be up to £37,000 (U.S.\$55,000) per 1,000 people per year, not including any additional transportation costs. These savings mainly came from the reduced number of domicile visits by home helpers, doctors, health visitors, podiatrists, and hairdressers. Being able to reach these services can help seniors maintain self-sufficiency and delay the need for assisted living arrangements. The potential for voluntary and privately provided services emerges particularly if incentives can be offered to the providers, and the potential for walking and for powered wheelchairs for local trips emerges if safe routes away from traffic have been established. Thus, developing safe routes in existing suburbs should be a priority.

## CONCLUSIONS

Throughout the world, populations are aging, and the number of people over age 80 is increasing the fastest. Disabilities increase with age, and eventually many people will have to stop driving because of health reasons, leading to greater pressure for alternatives to the car and for accessible transportation (1).

There is no one mobility solution, but a range of public, private, and personal mobility options is feasible. One strategy is to improve public transportation services. However, outside of densely populated urban areas, public transit and paratransit services cannot provide the spontaneity and independence desired by seniors, particularly current drivers. A broader range of services, including accessible fixed route, flex route, service route, dial-a-ride, and taxis, can provide seniors with alternatives to driving that may be acceptable in urban and denser suburban areas. Innovative third-party services, such as ITN's automobility, are proving to be popular and affordable in small to medium-size communities. Personal vehicles that do not require driving licenses—such as electric bicycles, powered wheelchairs, scooters, golf carts, and NEVs—offer seniors independent mobility for local trips (1) and will become increasingly viable, as will nontransit alternatives such as walking and cycling. To make these personal mobility options attractive, the design of intersections, sidewalks, road crossings, and bicycle-wheelchair paths must reflect the needs of elderly people (6) and may need to be retrofitted in suburban areas or added if missing.

The travel options for seniors need to be defined on the basis of functional ability, particularly of the very old. A great deal already is known about people's ability to walk and use transit. Human factors assessment could be used as an essential element of transportation planning, operational design, and service delivery of travel options for elderly people. More work and input

from seniors are needed to develop the appropriate criteria for the accessibility seniors require to sustain independent living (6).

It is important to examine critically seniors' travel needs and abilities from their perspective. Mobility counseling and training are required to define tailored and individualized outreach solutions. These solutions must take into consideration seniors' concerns about the safety and security aspects of their mobility options. The mobility management concept should be examined and further developed to address the needs of seniors.

Knowledge of mobility options is one of three deciding factors of mode choice. Transport providers and planners must appreciate the information needs of seniors, especially those with reduced vision and hearing, when presenting travel information and designing signage. Accessible information guidelines have been developed and implemented (36, 37) and should be followed up. A systematic approach to disseminating best practices and facilitating technology transfer also is essential to prevent duplication and to foster universal standards (1). Guidelines similar to the ones developed for disabled travelers in Canada and Europe could go a long way toward addressing U.S. seniors' mobility concerns (38–40).

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# Surviving Without Driving

## Policy Options for Safe and Sustainable Senior Mobility

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Most people think of transportation in terms of modes—airplanes, automobiles, bicycles, ferries, trains, trucks, and so forth. If cataloguing existing methods, the list is long and useful. But if analyzing the state of transportation alternatives so that the mobility needs of an emerging population—whose needs are not being met well by existing modes—can be better met, then more abstract thinking is necessary. Modes of transportation result in demand instead of cause; hence, manipulation of existing modes may produce marginal rather than profound change. If the mobility needs of an aging population grow as quickly as the demographics indicate, then profound change grounded in clear analysis will be required in both practice and policy.

This paper provides a practical approach to transportation planning for an aging population. The needs of older citizens are predictable, so accommodating them is possible. Policies and actions that encourage private investment, volunteerism, and advanced information technology are the keys to the successful design, development, and implementation of an effective and efficient transportation system that meets the needs and desires of the aging population in the United States.

With modes set aside and transportation reduced to fundamental components, two primary elements emerge: resources and logistics. Resources are the economic means, in any form and from any source, to fund a transportation process. Logistics refers to the arrangement and connection between and among the events in a transportation process. Two primary forces—technol-

ogy and policy—act on the two primary elements. The three kinds of technology are mechanical, energy, and information. Policy, of course, guides all the above. The action of the twin forces of technology and policy on the primary elements of resources and logistics, within the context of consumer choice, produces transportation. All transportation may be understood in terms of these two primary elements and two primary forces within this context. Change any one of these four components of the transportation framework, or change consumer choice through marketing, and some or all of the other primary elements and forces change responsively. In combination, they form a useful heuristic device, a conceptual framework with which to understand both advancements and barriers in transportation, historically and predictively.

### CONTEXT

An examination of transportation for older people begins with a discussion of older people as consumers (see Figure 1).

### Older People as Consumers

Transportation solutions succeed or fail in the context of consumer choice. Where do seniors live? What kind of transportation do they like? What can seniors afford, and what are they willing to buy? The answers to these and similar questions tell planners and policy makers



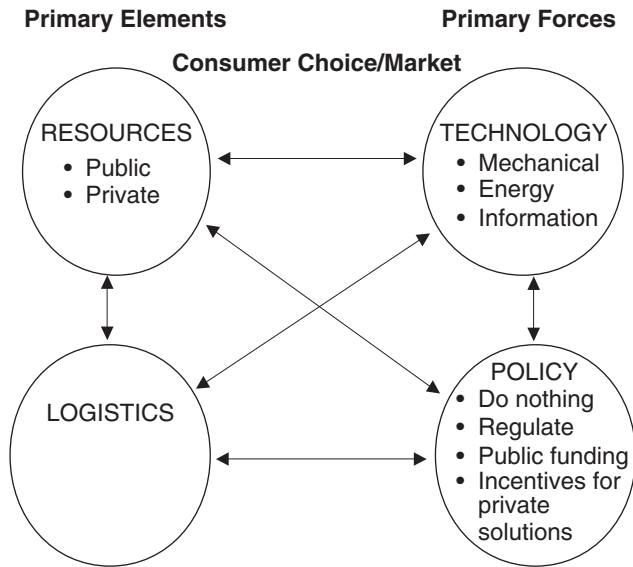


FIGURE 1 Basic components of the transportation process and system.

how to design transportation solutions that meet the needs of the populations they serve.

Three out of four seniors live in rural or suburban areas, where insufficient density does not support traditional mass transit. They take 9 out of 10 trips in private automobiles as either driver or passenger, and they are willing to pay a high premium for this convenience. Automobiles are expensive, and the cost per mile increases as the miles driven decline. Conversely, automobiles are personal, private, upholstered, air conditioned, and waiting in the garage, driveway, or at the curb. They go in any direction at any time. Consumers desire automobiles for the same reasons they desire cell phones, fast food, and the Internet—to eliminate the need for advanced planning, to provide multiple options at any time, and to bring instant gratification.

As travelers, older people are often frail and need assistance. They have difficulty walking to bus stops and are uncomfortable waiting in the cold or heat. People who rely on walkers or canes cannot easily carry packages or negotiate steps, and even if transportation is accessible for persons with disabilities, their homes usually are not. Seniors often fear falling and the crush of people on mass transit. Many older consumers need more than a ride: they need someone to open a door, carry a package, fold a walker, and offer a steadying arm.

A picture emerges of older transportation consumers as individuals with the same high expectations as the general population but with special needs. How can these needs and expectations be met? If they are not met, what are the consequences?

## Symbolic Value of the Automobile

Beyond the apparent consumer preferences and needs exists the less obvious but enormously powerful symbolic value of the automobile. In literature, people attach abstract meaning to concrete objects to create symbols. Advertising is the process of adding meaning to consumer products. In a commercial culture in which the average consumer is bombarded with 3,000 advertisements a day (1, p. 13) and almost everything has a meaning beyond its purported function, automobiles are the triumph of advertising. When a soft drink can identify a generation (Pepsi) and an ad campaign can make a milk moustache glamorous ("Got Milk?"), a lifetime of associating automobiles with individualism, status, power, and sexual attraction has created a compelling consumer preference. Television advertisements remove all subtlety from these campaigns, such as the message "driving = love" and a race car with "Viagra" in enormous letters.

No attempt to design a transportation service for older people will be complete or effective without penetrating this phenomenon. The personification of machines—cars with pet names and lovingly groomed—fills a need people have that goes beyond transportation. The affinity is neither good nor bad, and the affection people have for automobiles is neither good nor bad. But the affinity must be understood, or transportation planners will never know how to plan for an effective replacement when older people can no longer drive.

## PRIMARY ELEMENTS

### Resources

Collection methods distinguish the two kinds of resources: public and private. Public resources are gathered involuntarily through taxes, which means these resources are always scarce. A decision must be made on a rationale or justification for the acquisition and allocation of public resources, and the process through which such decisions are made includes public policy. The expenditure of public resources may provide for a public or common good such as education or safety, accommodate a market failure such as a lack of affordable housing, or compensate for a market externality—an unintended consequence—such as air pollution. Private resources are expended voluntarily as consumer purchases or contributions, which may be separated further into cash, goods, and services. Decisions regarding the allocation of private resources reside with the individual or the corporation, whether for profit or nonprofit.



### Public

Traditionally, public resources have funded alternative transportation services for seniors. At the national level, the Federal Transit Administration and the U.S. Department of Health and Human Services provide these funds. States also may contribute, and a local mill rate provides public resources in many counties and municipalities. However, 34% of people age 69 or older have no public transportation in their communities (2). If publicly funded senior transit does exist, rides typically are rationed by restrictions in service areas, trip frequencies, hours of operation, or advance-notice reservation requirements. These limitations almost always result from insufficient public funding. Providers of senior transit scramble to meet demands, and senior consumers feel frustrated by inadequate services.

An argument may be advanced to justify the greater use of public resources for senior transit: the current automobile-centered, market-driven transportation system does not meet the needs of normal aging people. Arguably their compromised mobility and elevated crash risk constitute a market failure and unintended consequences that warrant correction through public expenditure.

Justification for the use of public resources is one matter; availability of those resources is another. Table 1 shows the estimated costs of meeting the transportation needs of elderly people based on the following general assumptions accepted by the research community:

- 25% of people age 75 or older will need alternative transportation.
- Each ride will cost \$15 on average to deliver.
- People will require 4 to 16 trips a week.

Given these assumptions, alternative transportation for seniors will cost between \$572 billion and \$2.2 trillion by 2030.

### Private

In 1998 private expenditures for transportation were five times greater than government expenditures for all

roads, highways, and transit systems (3). Personal expenditures for transportation in 1998 accounted for \$675 billion. At the household level, 17.9% of the average household budget was for transportation, second only to housing at 19%. Automobiles received the most private transportation dollars: of the \$6,312 out-of-pocket annual transportation expense for the typical American household, people spent \$6,200 to purchase, fuel, insure, and maintain personal cars and trucks (3).

The automobile is not only the preferred mode but also an investment instrument. When older people no longer drive, they often give the vehicle away or sell it for a nominal amount to a grandchild or neighbor, sometimes in exchange for the promise of future rides. Either way, the mechanism for holding the economic resources necessary to fund private transportation is gone. This observation is important but generally ignored. Resources must reside somewhere, whether in a bank account, stock portfolio, art collection, or automobile. Furthermore, resources either appreciate—for example, when invested in a home—or depreciate—for example, when invested in an automobile.

If a transportation alternative replaces the automobile, both the mode and the investment instrument that hold the economic resources must be replaced. The resource implications are twofold: either the costs must be borne publicly, or individuals must accept the true costs of personal transportation. Publicly provided resources must be gathered and distributed, or private resources must be established through incentives and investment instruments. Sometimes businesses and corporations, such as retirement communities and assisted living facilities, provide private expenditures for senior transportation. In other instances, hospitals and other health care providers become involved in transportation so that senior consumers can access their services.

The most significant transportation resource for older people, other than the personal automobile, is actually another form of the automobile—the volunteer ride or transportation favor offered by friends and family represents the second most significant transportation resource for older people. Many seniors who restrict or stop driving rely on these favors (4). This form of trans-

TABLE 1 Projected Senior Transportation Costs Through 2030

Year	2002		2030	
75+ population	17,174,000		32,597,000	
Rides per Week	Weekly	Annual	Annual	30-Year Costs
4	257,610,000	13,295,720,000	25,425,660,000	572,119,080,000
8	515,220,000	26,791,440,000	50,851,320,000	1,144,238,160,000
16	1,030,440,000	53,582,880,000	101,702,640,000	2,288,476,320,000

NOTE: All costs are in US\$, based on a \$15 cost per ride, and not adjusted for inflation.

portation creates a complex relationship for seniors. The positive aspects of riding with family or friends are comfort, opportunity for personal assistance, familiarity, low cost (for the senior), and the opportunity to barter for favors or goods. The negative aspect is placing seniors in a dependent, socially inequitable position. Furthermore, senior volunteer drivers may not be safe operators. The favor-based system acts like a barrier to mobility by preventing able seniors from traveling independently and imposing the burden of asking favors. The system buries the resource issue, but the issue never goes away—it just changes form.

### *Consumer Expectations*

There is a direct relationship between customer satisfaction and the willingness to use and pay for services, including senior transportation. The more convenient and satisfying transportation alternatives are, the more likely an older person will use and pay for them. Confounding the market solution, the consumer expects that however expensive the operation and maintenance of an automobile may be, the alternative ought to be inexpensive or even free. This attitude may derive from a cultural expectation that developed from social security and Medicare entitlement programs. The attitude also may originate from policies that support subsidized fares on mass transit in general or may be the expectation of an older generation for whom money has a different value. Whatever its source, the underlying consumer expectation stands in the way of a sustainable solution. Of the 236 community-based transit providers interviewed in the Supplemental Transportation Programs for Seniors Study (5, p. 17), 69% said that they charged no fees, yet 85% of their problems were finding adequate volunteers (43%) and adequate financial support (42%).

### **Logistics**

Transportation is essentially a logistics problem, with the basic challenge of how to move people from one place to another efficiently and conveniently. Transportation consists of a complex, interdependent process, with endless opportunities for interruptions and mistakes. A problem in one element may affect other elements. For example, late plane arrivals cause missed connections. Too many cars on the road at the same time in the same area cause congestion and gridlock. Alternatively, solutions in one area may create problems in another. For example, widening roads may reduce congestion, but the resulting increased speeds may cause more accidents.

### *Relationship Between Resources and Logistics*

The relationship between logistics and resources is interdependent, as shown in Figure 1, and trade-offs frequently occur. Trade-offs may affect customers' willingness to pay, but as long as communication remains adequate and trade-offs reflect free choice, customer satisfaction stays intact. Airlines frequently take advantage of the relationship between resources and logistics by overbooking flights and then paying people a few hundred dollars to give up their seats voluntarily. As long as the customer's decision is voluntary and compensated, satisfaction results.

When public resources fund transit within political boundaries, logistical problems abound. If the vehicles and passengers cannot cross over jurisdictional boundaries, neither free choice nor compensating resources mitigate thwarted customer needs and market realities. For example, seniors in Berkeley, California—a transportation-rich community—use publicly funded senior transit to go to Kaiser Permanente Health Services in Oakland, but they cannot return on the same system because the ride originates in Oakland and Berkeley taxpayers fund the senior transit service.

### *Mass and Personal Transit Alternatives*

When using a vehicle to transport people, there are two logistical alternatives: bring the person to the vehicle or bring the vehicle to the person. Bringing the person to the vehicle creates an opportunity to lower the cost of a ride by moving many people at the same time in a high-occupancy vehicle (HOV). Train stations, airports, ferry terminals, and fixed-route bus stops represent waiting areas for this logistical solution. HOVs also help reduce vehicle and labor costs. However, when demand is low, large vehicles travel fixed routes with few passengers. An efficient solution during peak demand becomes inefficient when demand declines.

Further restrictions aimed at increasing logistical efficiency include limiting service to certain geographic areas and specific times. If four passengers want to travel from Massachusetts to California, the most efficient way to manage the trip would be to gather them in one place and send them in a single vehicle—the definition of traditional mass transit. This type of transit works best in high-density areas, where bringing together enough riders to fill a vehicle to maximum capacity is most efficient.

Solutions for bringing the vehicle to the person, such as automobiles and bicycles, deliver higher levels of consumer satisfaction and represent personal transportation. Individuals relate to automobiles or bicycles as they would to their home; but they relate to the pub-

lic transportation system as they would to a park or other common area. People may feel a sense of connection and ownership for both forms of transportation, but a sense of private ownership for an automobile does not compare with the feelings of public ownership for a train station.

Personal transportation creates a different set of logistical requirements. First, personal vehicles must be garaged or parked when not used. Second, personal vehicles must be operated or driven by someone physically capable. When a driver becomes functionally impaired—as many older drivers do—the previously hidden high cost of labor to operate the personal vehicle emerges, making transportation for seniors very expensive.

### *Unique Challenges for Senior Transportation*

Age and its frailties affect all traveling experiences. Senior transit requirements confound both the mass transit solution and the personal vehicle solution because the same frailties that cause difficulties in using mass transit also cause difficulties in driving personal vehicles. With mass transit, older people cannot easily wait at bus stops in extreme temperatures or inclement weather. Long walks to transit stops, icy sidewalks, snow mounds, and weedy embankments all impede the use of mass transit. When seniors are able to ride a train or bus, they often cannot carry packages, such as grocery bags. Seniors also cannot easily transfer from one mode to another, and they cannot tolerate long travel times as well as their younger counterparts can. Many seniors travel for medical purposes, and many cannot easily control that time. Scheduling return trips also presents a problem; uncertainty and extended wait times, worsened by weakness and ill health, frustrate seniors and transit providers alike.

The difficulties older people experience while driving personal automobiles are many and are well documented. Many seniors limit their driving to daylight hours, fair weather conditions, familiar roads, and off-peak traffic. They avoid merging traffic, busy intersections, and unprotected turns. Personal transit, like mass transit, may be difficult. When traveling in an airplane, bus, or automobile, older people often need assistance. The assistance must be provided as an integral part of the trip, instead of as a special favor, if the transportation system is to deliver the services an aging, traveling population requires.

### *Logistics of Sprawl*

No discussion of senior transportation logistics can be complete without including the impact of sprawl—the

post-World War II expansion of urban areas into the surrounding countryside. In rural and suburban communities that lack the density for traditional mass transit, paratransit provides a logistical solution. Often funded with public resources, paratransit vans and buses are a hybrid between traditional HOVs on fixed routes, like buses, and personal vehicles that take people from door to door. Using HOVs as a logistical solution, paratransit services travel various routes, picking up and dropping off passengers. Paratransit service exemplifies the resource-logistics trade-off. The cost of providing a personal vehicle and driver for every trip would be prohibitive. Yet the economic efficiency gained by transporting many passengers in one vehicle often comes at the price of longer trips and waiting times, which lower customer satisfaction.

## PRIMARY FORCES

### *Technology*

For centuries, technology has been a driving force for change. From the discovery of the wheel to the launch of the space shuttle, from the making of fire to the release of nuclear energy, and from the invention of the alphabet to the expansion of the Internet, technology in three forms—mechanical, energy, and information—has catalyzed civilization. Technology gives rise to the form and availability of transportation. Mechanical technology is the source of the mode, energy technology produces the fuel, and information system technology makes traveling from one point to another possible. Without communication, transportation cannot occur except by chance.

When the transcontinental railroad was built, the telegraph wires were strung simultaneously. The communication and transportation teams worked side by side, with the telegraph crew sometimes stringing wires across the tops of trees to keep up (6, p. 257).

Human interactions with technology are either active or passive. In active technology, the benefiting person needs to be an active participant. Steering an automobile is an active use of technology, while benefiting from an airbag is passive. As the functional changes of age progress, the benefits of active technology diminish for older drivers.

### *Mechanical*

The impact of mechanical technology on transportation resources and logistics has influenced history immensely. The invention of the railroad, for example, changed the way freight and passengers moved in this

country. A 6-month sailing trip from the Atlantic Ocean to the Pacific Ocean became a 7-day train ride (6, p. 369). However, no mechanical transportation technology has changed the face of America more than the automobile. In the half century since World War II, 86% of the population growth has occurred in rural and suburban areas. People who moved to the suburbs after the war and relied on the automobile for transportation have aged in place. Because driving represents an active technology, older people (and others) with functional impairments, such as visual loss, struggle for even minimal mobility.

Passive mechanical technology offers improvements in the roadway (wider pavement markings, larger letters on reflective road signs) and vehicles (airbags, padded interiors, crash-resistant doors), serving seniors as passengers and as drivers. Mechanical technology in mass transit offers benefits such as kneeling buses and Americans with Disabilities Act-accessible facilities.

### *Energy*

The reliance on the private automobile has brought U.S. drivers into an era of nonrenewable fossil-fuel dependence, with all of its unintended consequences, including air pollution and dependence on foreign oil. Of all the renewable energy sources that might affect transportation, people remain the most important. For seniors, walking is the most popular transportation mode after driving or riding in an automobile. Transit-oriented development builds communities around walking because the parameters of orientation are set for a human instead of a machine—which excludes the transportation needs of the nondriving young and old (7, p. 17).

### *Information*

Information technology and its impact on communications and data processing create a great opportunity for change in transportation. Intelligent transportation systems (ITS) consist of the communication and information system improvements in transportation made possible by computer technology. ITS technologies represent efficiency capabilities that need appropriate application. They have the potential to revolutionize transportation because they increase the kind, amount, and speed of information communication and available processing to support the required logistics of moving people and goods. Automated vehicle locating systems that rely on the Global Positioning System, fare-collection systems that run on computer chips imbedded in plastic cards (smart cards), and a geo-

graphic information system (GIS) that plots coordinates and maps routes all are examples of computerized information system applications.

The benefits of information technology advances are profound. The full impact will not be felt in the foreseeable future because information processing lies at the heart of logistics and logistics lies at the heart of transportation. Current modes already are logistical solutions. Each mode incorporates certain mechanical and energy technologies and relies on available information and communication systems. For example, airplane technology, which is approximately 100 years old, uses mechanical and energy improvements to add speed, comfort, and efficiency. Reservations once made by telephone or through the mail now may be scheduled over the Internet.

The full potential for change through information technology will occur only when the power of computerized information systems is applied to the basic elements of resources (public and private) and logistics directly, instead of to any previous logistical or technological solution. Moreover, the invented transportation modes or services must occur in the context of free consumer choice. For the greatest number of seniors to benefit from the modes, the modes must involve passive instead of active technologies.

### *Policy*

An analysis of consumer preferences and needs, available resources, logistical challenges, and promising technologies provides insight into the public policy needed to support the creation of sustainable transportation for seniors. In addition to any incremental improvement in personal automobiles that will allow for seniors to drive as safely as possible for as long as they are able, society will benefit from policies that support

- The emergence of many diverse transportation services;
- Continued funding from public resources with an increasing development of private resources, both personal and charitable;
- Routine planning for the cost of transportation, integrated with the practice of planning for other expenses of later life;
- Consumer comparison shopping for senior transit services in the same way consumers comparison shop for a personal automobile;
- Reliance on volunteers as an integral part of the transportation services;
- Sustainable transportation responsive to consumer preference (private consumers control the majority of transportation resources; if the service does not

meet their needs in a satisfactory manner, they will not pay for it);

- Use of marketing to capture the independence of modern lifestyles and incorporate that essential understanding into the service characteristics and payment choices designed to adjust for resource or logistical trade-offs; and
- Information system technology use to solve both resource and logistic problems.

The best marketing for both public and private senior transportation will avoid the simple approach in which service providers try to convince older consumers to ride. Instead, the providers will pay close attention to what older people want. Although independence is synonymous with driving and automobiles, older people who lose their comfort or confidence in driving or who need to stop driving for safety reasons will rest on the edge of consumer choice for acceptable alternatives. Successful transportation providers will learn to capitalize on this market potential. Just as the number of women who never learned to drive has declined with successive aging cohorts, so the number of older people who expect transportation to be inexpensive or free will also decline, as aging boomers accustomed to spending money for services replace Depression-era seniors.

As providers rely more on volunteers, database management will become more complex. It takes many volunteers to replace one full-time driver. The amount of managed information to provide high-quality service is directly related to the numbers of riders and of volunteers involved. Mass transit efficiency based on shared rides and advanced planning will be achieved more through information system management than through the use of HOVs. GISs that create shared rides and dispatched information to volunteers will provide consumer-friendly transportation. Fares will be gathered electronically, and programmed computer calculations, instead of service provider agreements, will resolve jurisdictional resource issues. The Internet will bring the benefits of information technology to small communities, which currently cannot afford the sophisticated software available to large transit providers in high-density areas.

## CONCLUSION

Decision makers are the architects of the future, and policy is the blueprint. By guiding resources, stimulating research and technology development, and educating people on the foreseen mobility problems, policy makers can build a solution for the future. What specific areas of policy will affect sustainable transportation for seniors?

The most important issue concerns resources at both the micro (personal) and macro (societal) levels. Given the vast amount of money Americans are willing to pay for transportation, incentive for people to plan for mobility expenses creates the best opportunity to find the money to pay for senior transportation. Investment instruments may be created for transportation, as they have been for retirement and education. Seniors who might give away their largest transportation asset—that is, the personal automobile—may be encouraged through incentives to sell the car and save the proceeds for purchasing rides.

Private resources also can be charitable. Policy makers can use incentives to guide the creation and allocation of private charitable donations for senior mobility. Through tax incentives, social prestige (e.g., a national register for senior mobility), or newly created instruments for donations at the national level (a national endowment), policy makers can help create funds to pay for solutions.

At the macro level, public funding is most strategically placed on information system technology research and development, with an emphasis on consumers' needs instead of providers'. Land use policy makers also must take into account and accommodate the needs of seniors. Finally, policies must be developed to recruit, train, encourage, and protect volunteers—the most important private transportation resource after the personal automobile.

Effective decisions are based on a thorough understanding of the options, but most people are unable to imagine an alternative beyond the private automobile. In addition to policies that guide and develop resources to pay for a solution and information technology to create logistical opportunities and efficiencies, there is a need for public policy to guide education and public information about the importance of mobility to older people's quality of life. With that clear message as a cultural context, senior mobility policies will stand a good chance to guide consumer behavior successfully.

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# Highway Design, Pedestrian Facilities, and Land Use

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# Highway Research to Enhance Safety and Mobility of Older Road Users

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The 1988 Transportation Research Board's *Special Report 218 (1)* represented a milestone in the history of transportation research. The report summarized the knowledge on the special needs of older people, considered how emerging needs might affect future mobility and safety, and served as a blueprint for a decade of research primarily sponsored by the Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration (NHTSA). The report emphasized research and development needs in the area of highway design and operations. One reason for this emphasis stemmed from the fact that in this area the lag is often very long between discovery and implementation. When needed, changes to concrete, signing, and lighting often require a generation to implement the changes cost-effectively. Thus, if changes to the highway infrastructure can be made to accommodate better the older drivers who will reach retirement age during the early decades of the new millennium, the need to know about them is now. Otherwise, the changes will not have sufficient implementation time to meet the appointment with the demographic destiny of a graying traveling population.

Several assumptions guided this literature review. First, the term "old" arbitrarily was defined to include people age 65 or older. Second, in many cases, a critical judgment was assumed about whether a particular highway design factor accommodated the needs of older travelers (usually drivers). The criterion used to make judgments was the 85th percentile level of performance of a designated older sample or group. For example, if 85% of the older drivers in a study could read a high-

way sign at a given letter height, the sign was judged to accommodate the needs of older drivers in general.

Third, older volunteers in most of the studies represented the 80% of older people living independently in a community and capable of successfully performing activities of daily living (2). No doubt, some volunteer bias was and will be present in most studies of older travelers. Given the assumption that better-educated and healthier people are more likely to volunteer as participants in research projects, logic dictates that the samples tend to be biased slightly toward the cream of the crop. Some investigators have attempted to implement a correction for volunteer bias by using either the 90th or 95th percentile performance levels as a criterion for judging the age appropriateness of various highway designs and experimental treatment levels. Yet no direct empirical rationale has supported the use of inflated criterion levels. Without rigorous empirical support, research conclusions and recommendations based on inflated values likely would be rejected as overly conservative and not cost-effective. Because the analyses of age-appropriate design in this paper were based on the adoption of the 85th percentile performance criterion, the conclusions sometimes conflict with those reached in *Special Report 218*.

A major development since the release of *Special Report 218* was the astronomical growth in intelligent transportation systems (ITS) research and development. Many anticipated mobility and safety problems resulting from a poor fit between the older roadway user and the highway infrastructure may be amenable to remediation through the strategic application of ITS technol-

ogy.<sup>1</sup> However, ITS technology offers not only the promise to assist older travelers but also the potential to increase their burden if the information-processing demands of in-vehicle interfaces are engineered without special regard for older people's emerging needs and changes in capacity. Special care needs to be taken to assure that older road drivers are included in the next generation of vehicle-highway systems.

## HIGHWAY GEOMETRIC DESIGN

Several major categories of research in the area of highway geometric design and operations received considerable attention during the decade following the release of *Special Report 218*. Perhaps the most critical work in this area dealt with the evaluation of whether commonly applied models of human driving performance accommodate the capabilities of older drivers. If the models did not accommodate the older driver capabilities, roadway elements and intersections designed on the basis of these models might not accommodate the needs of older road users either. This section covers work and other significant research on intersection design, freeway design and operations, work zones, and pedestrian crossings.

### American Association of State Highway and Transportation Officials Models

Written by the American Association of State Highway and Transportation Officials (AASHTO), *A Policy on Geometric Design of Highways and Streets* (3)—informally known as the Green Book—listed the most widely used guidelines for U.S. highway design. Many design formulas in the Green Book are based on assumptions about the perception–reaction time of the design driver. *Special Report 218* presented evidence suggesting that the perception–reaction-time assumptions of the driver behavior models in the Green Book may not allow sufficient time to accommodate the general behavioral slowing seen in older drivers (1). If this were the case, the mobility of older drivers and the safety of all drivers would be compromised. Recently, several studies investigated whether the AASHTO driver behavior models accommodate the needs of older drivers.

One of the most fundamental design concepts in the Green Book is stopping sight distance. The stopping sight-distance model specifies the minimum sight distance required by a driver to detect a target on the road-

way and then bring the vehicle to a safe stop. Stopping sight distance equals the sum of two distances: the distance traveled by the vehicle from the time the driver sights an object necessitating a stop until the time braking is initiated (brake-reaction time) plus the distance required to stop the vehicle from the time the brake is applied (braking distance). The stopping sight-distance model assumes a brake-reaction time of 2.5 s, which accommodates the performance of the 85th–90th percentile driver in Johansson and Rumar's (4) classic field study on unalerted braking behavior. The braking-distance component is based on a simple physical model, with the speed of the vehicle and the coefficient of friction between the tires and roadway as parameters. However, Fambro et al. (5) proposed a reformulation of the braking-distance equation on the basis of empirically determined deceleration behavior instead of the coefficient of friction. The minimum stopping sight-distance requirement specified by the AASHTO model is computed in Equation 1.

$$\text{Stopping sight distance (ft)} = 1.47PV + [V^2 / 30(f \pm G)] \quad (1)$$

where

$P$  = brake-reaction time (2.5 s),

$V$  = vehicle speed (mph),

$f$  = coefficient of friction between tires and roadway, and

$G$  = grade (%).

Lerner et al. (6) conducted a study to evaluate the validity of the 2.5-s brake-reaction-time assumption in the AASHTO stopping sight-distance model. A sample of 253 drivers, from age 20 to 70 or older, drove their cars along a predetermined route. The drivers were given a distraction task of rating the quality of the road surface along various segments of the course. The last segment required the participants to enter a closed section of the highway. Traveling at approximately 40 mph (64 km/h), the driver reached a predetermined point on the highway where an unexpected emergency event was triggered, requiring an avoidance response. A construction barrel, initially hidden from view, was rolled down the hill on the side of the road and apparently into the path of the participant's vehicle.<sup>2</sup> The barrel came into view approximately 200 ft (61 m) ahead of the vehicle, creating a 3.4-s time to collision. Because the critical element of surprise would be difficult to replicate on subsequent trials, each participant only experienced the emergency event once. Because of technical problems and difficulty in unambiguously scoring the behavioral

<sup>1</sup> Because space is limited, see the paper on ITS by Caird (pp. 236–255) in these proceedings.

<sup>2</sup> A safety chain was attached to the barrel to prevent actual contact.

responses, only 116 of the 253 participants yielded data that were judged useful for the analysis. Of the 116 participants, 30 were young (age 20–40), 43 young-old (age 65–69), and 43 old-old (age 70 or older). Almost half (56) of the participants made an avoidance response that involved braking; the other participants executed a steering-only or other avoidance response. Table 1 summarizes the brake-reaction-time data for the emergency event. Statistical analysis of the data revealed that age had no significance. All of the unalerted brake-reaction times, except for one, fell within the 2.5 s assumed by the AASHTO stopping sight-distance model. The one exception demonstrated a brake-reaction time of 2.54 s. In field studies, Knoblauch et al. (7) and Fambro et al. (5) recently have confirmed these results. Kloeppel et al. (8) also reported no age differences in the time needed to perform emergency maneuvers in an interactive driving simulator.

At first glance, the conclusion of Lerner et al. (6) appears surprising. Laboratory studies on decision-making time consistently have revealed a marked reduction in information-processing time with advancing age. The finding that drivers older than age 70 demonstrated the same median and 85th percentile brake-reaction times for an unexpected event as did drivers age 20–40 suggests that emergency braking for a roadway hazard is a highly overlearned or “automatized” behavior. Research has suggested that highly practiced behaviors involving consistent stimulus–response pairings tend to become automatic or proceduralized. According to Hasher and Zacks (9), overlearned or automatized operations not only are faster than controlled behavioral responses but also use up little of an operator’s attentional-resource capacity. Responses to

situations that are not overlearned require controlled or executive decision-making processes that take more effort insofar as they require more attentional resources and often more time to complete. It appears that driving behaviors that have become automatic across a lifetime of experiences may become protected from the harmful effects of normal adult aging. This dichotomy between automatic versus controlled processes ultimately may play a significant role in the understanding of age-related changes in driving capacity and the intervention to mitigate the deleterious effects of the changes (10). A related and important feature of highway geometric design is the concept of intersection sight distance. The AASHTO Case III intersection sight distance model is computed in Equation 2.

$$\text{Intersection sight distance (ft)} = 1.47V(J + t_a) \quad (2)$$

where

$J$  = perception–reaction time (usually 2.0 s) and  
 $t_a$  = acceleration time required to clear intersection or to reach 85% of design speed when turning onto cross road.

The Green Book specified a model for determining the minimum safe sight distance for several classes of intersections (see Table 2). All of these models have a perception–reaction-time component that represents the ability of the design driver. A 2.0-s perception–reaction time is assumed for all intersection sight-distance model scenarios except for Case II, which assumes 2.5 s on the basis of its similarity to the scenario used to model stopping sight distance, as described above.

TABLE 1 Brake-Reaction Times (Seconds) for Unexpected Driving Event (6)

Age (Years)	N	Mean	Median	85th Percentile
20–40	14	1.44	1.35	1.97
65–69	18	1.59	1.47	1.92
70+	24	1.49	1.52	1.72
All	56	1.51	1.46	1.85

TABLE 2 AASHTO Intersection Sight-Distance Model Classifications

Intersection Classification	Description
I	No controls
II	Yield control
III-A	Stop controlled; crossing major road
III-B	Stop controlled; turning left onto major road
III-C	Stop controlled; turning right onto major road
IV	Signal controlled
V	Turning left from major roadway



Hostetter et al. (11) quantified the perception–reaction time required to negotiate an intersection as the “time between the first head movement following a stop at an intersection and the first application of the accelerator.” Using this definition, field studies revealed a mean intersection perception–reaction time of 1.8 s for the AASHTO Case III-A scenario. However, the estimated value for the 85th percentile reaction time was 2.6 s, which suggests that the AASHTO model’s 2.0-s estimate does not allow sufficient time for many drivers to manage the information-processing demands of many intersections. The data from the Case III-B and III-C intersection scenarios demonstrated an even greater mismatch between the 2.0-s AASHTO assumption and the empirically determined 85th percentile perception–reaction-time requirement. Primarily on the basis of the results of this investigation, *Special Report 218* recommended that a systematic series of field studies be conducted to evaluate whether the perception–reaction-time assumptions of the AASHTO intersection sight-distance model were accommodating the needs of the older-driver population (1).

Several studies have attempted to evaluate systematically the age appropriateness of the perception–reaction-time estimates used by the AASHTO intersection sight-distance model. These studies focused on the AASHTO Case III and Case V scenarios because older drivers appear to be overrepresented in automobile crashes at stop-controlled intersections and when executing left turns (12).

Lerner et al. (6) developed a technique to open the visual-search loop of a driver stopped at an intersection, simplifying the measurement of the perception–reaction time to negotiate an AASHTO Case III maneuver. When drivers encountered a stop sign, they came to a full stop. Once stopped, they were required to look down at an indicator light (situated low on the instrument panel) until the light signaled them to proceed. When the signal light was activated, the drivers raised their heads, searched the intersection, and completed the maneuver through the intersection. Perception–reaction time was defined as the interval between the time the driver’s head was raised from the indicator-monitoring task until the time the vehicle began to accelerate through the intersection.

Daytime perception–reaction times to negotiate the AASHTO Case III-A, III-B, and III-C intersection maneuvers were collected from 25 young (age 20–45), 27 young-old (age 65–69), and 29 old-old (age 70 or older) volunteer drivers. As the most noteworthy finding, no age-related slowing in perception–reaction time emerged for Case III maneuvers, collapsed across 14 intersections. The median perception–reaction time for all participants was 1.3 s, but the 85th percentile interpolated from the cumulative response function was

approximately 2.0 s. On the basis of these findings, Lerner et al. (6) concluded that the AASHTO model for specifying minimum intersection sight distance successfully accommodates the information-processing time required by older and younger drivers.

### Gap-Acceptance Models

Several recent studies have concluded that the minimum safe sight distances specified by the AASHTO model appear overly conservative. That is, drivers (at least younger ones) may not need as much sight distance as specified by these models. For example, the AASHTO model for minimum safe sight distance for executing a Case III-B intersection maneuver yields values ranging from 290 to 1,340 ft (88 to 408 m) as highway design speed increases from 25 to 65 mph (40 to 104 km/h). When these intersection sight distances are expressed as times-to-arrival of approaching vehicles, to enter a highway with a speed limit of 65 mph (104 km/h) requires a critical gap in the traffic stream of at least 14.1 s (i.e., the time a car takes to travel 1,340 ft at 65 mph).

Yet observational field studies have revealed that the average gap-acceptance times of drivers at historically safe intersections typically are only a fraction of the equivalent temporal safety cushions specified by the AASHTO model. Drivers on average select 9.2-s gaps, regardless of the speed limit (13). On the basis of such findings, some investigators have argued that geometric design based on gap-acceptance models is more valid and cost-effective than the overly conservative AASHTO approach (14). The conservative tendency might help to explain the unexpected conclusion drawn by Lerner et al. (6) that the AASHTO stopping sight-distance and intersection sight-distance models, without modification, already accommodate the perception–reaction-time requirements of the 85th percentile older driver.

Harwood et al. (13) provided a rationale for using the gap-acceptance measurement as a criterion for the intersection sight distance:

If drivers will accept a specific critical gap, such as 7.5 sec, in the major road traffic stream when making a turning maneuver, and if such maneuvers are routinely completed safely, then sufficient intersection sight distance should be provided to enable drivers to identify that critical gap. (p. 39)

On the basis of this rationale, driver gap-acceptance times derived from observational studies of highway sites with good safety records can be used to develop intersection sight-distance criteria. This approach has the advantages of being easy to measure and avoiding the conceptual difficulties that plague the AASHTO models

(e.g., serial-sequential versus parallel-simultaneous processing stages). Harwood et al. (13) completed a series of analytic and field studies as part of a comprehensive National Cooperative Highway Research Program project that recommended the adoption of models for highway geometric design based on the gap-acceptance approach. Several U.S. states—including California and Oklahoma—and national governments—including France and Sweden—have already adopted highway geometric design guidelines based on gap-acceptance models. Only recently, however, have data become available to evaluate whether the models accommodate the needs of older drivers.

Lerner et al. (6) instructed 29 young (age 20–40), 23 young-old (age 65–69), and 22 old-old (age 70 or older) volunteer participants to sit in a static test vehicle parked perpendicular to a busy roadway. They then were asked to make yes versus no judgments about potential maneuvers during daytime lighting conditions. Approximately half of the participants in each age group made judgments for a 30-mph (48-km/h) road, and the other half made judgments for a 50-mph (81-km/h) road. They were asked to imagine that they were waiting for the opportunity to proceed straight through an intersection, turn left, or turn right. Participants signaled their judgments by pressing a button when they considered the situation safe to initiate the target maneuver and releasing the button when they considered the situation unsafe. The test vehicle was equipped with microwave sensors and a battery of videocameras that allowed for accurate offline calculations of the vehicle gap times that were accepted as safe or rejected as unsafe. The resulting data were quantified by constructing functions that expressed the cumulative probability of gap acceptance as a function of gap size in seconds. Table 3 summarizes the critical gap-acceptance parameters interpolated from these functions, collapsed across speed condition and type of maneuver.

The critical performance value for the gap-acceptance paradigm typically equals the time at which the driver accepts 50% of the traffic gaps. Gap intervals shorter than the critical gap are less likely to be accepted, and gaps longer than the interval are more likely to be accepted. Statistical analysis of the 50% gap-acceptance parameters revealed a significant age effect. The oldest drivers demonstrated a critical gap-acceptance time 1 s

**TABLE 3** Gap-Acceptance Times (Seconds) for Daytime Case III Maneuvers as Function of Age (6)

	Age Group		
	20–40	65–69	70+
50% acceptance	6.7	7.2	8.2
85% acceptance	9	11	11

**TABLE 4** Critical (50%) Gap-Acceptance Times (Seconds) for Left Turns (15) with Equivalent Gap-Time Recommendations from the AASHTO and Harwood et al. (13) Case V Scenarios

	Age Group		
	25–45	65–74	75+
Staplin et al. <sup>a</sup> (15)	5.9	5.9	6.6
Harwood et al. <sup>b</sup> (13)	6.0	6.0	6.0
AASHTO Case V			
Equivalent gap size <sup>a,b</sup>	8.0	8.0	8.0

<sup>a</sup> From p. 81:  $G = 6.0$  s; 2 lanes of traffic.

<sup>b</sup> From Table 64: speed = 35 mph; acceleration distance = 84 ft; acceleration time = 5.8 s.

greater than the time of their younger counterparts. This difference climbed to approximately 2 s in the 85% gap-acceptance interval. Lerner et al.'s (6) demonstration that gap-acceptance times must be longer to be judged as safe by older drivers suggests that proposed highway geometric design guidelines based on the 50% gap-acceptance models may not accommodate the needs of the older-driver population.

Staplin et al. (15) conducted a field study to investigate age differences in gap-acceptance times during the performance of an AASHTO Case V maneuver (a left turn from a major roadway). A total of 33 young (age 20–45), 37 young-old (age 65–74), and 30 old-old (age 75 or older) drivers made left turns during the permissive phase of a traffic signal when they were positioned within a left-turn lane of varying offset geometry.<sup>3</sup> Cumulative curves for the probability of executing a left turn as a function of the size of the gaps in the approaching traffic stream were then calculated. The critical (50%) gap-acceptance parameter was estimated for each age group using logistic regression.

Table 4 lists the gap-acceptance values for the Case V scenarios, along with the equivalent gap sizes recommended by the AASHTO and Harwood et al. (13) gap-acceptance models. Table 4 shows that the critical gap size observed for drivers age 75 or older is 0.7 s longer than the gap size observed for younger drivers. The 6.0-s equivalent highway sight distance recommended by the Harwood et al. (13) gap-acceptance model exceeds the needs of the younger drivers but fails to accommodate the needs of the oldest drivers. Unlike the newly proposed gap-acceptance model, the 8.0-s equivalent gap size generated by the AASHTO Case V intersection sight-distance scenario appears to accommodate all of the drivers in the left-turn study. Unfortunately, Staplin et al. (15) did not report the 85% gap-acceptance values for their three age groups.

<sup>3</sup> The effects of varying offset geometry are discussed in the section on intersections in this paper.

## Age-Appropriate Models

*Special Report 218* generated considerable research on the appropriateness of the AASHTO perception–reaction-time models for the older-driver population. The data from several studies suggest that the minimum information-processing time requirements of typical older drivers are accommodated by the perception–reaction-time assumptions (2.0–2.5 s) of the AASHTO sight-distance models. Recently, however, considerable activity in the research community has claimed that the AASHTO models are too conservative and result in highway geometric design standards that are unnecessarily costly. As an alternative, a new generation of models based on field surveys of driver gap-acceptance behavior has been proposed. But the critical time parameters of the proposed gap-acceptance models do not accommodate the processing-time requirements of drivers over age 70.

Additional research is required to establish the validity and age appropriateness of gap-acceptance models for highway geometric design. Should the critical gap be at the 50% level? For gap-acceptance models, this major issue remains unresolved. Is it logical to design an intersection on the basis of a value that is judged unsafe 50% of the time? If an 85% safe gap criterion were the critical gap size, then the differences between the sight distances recommended by the gap-acceptance models and the AASHTO models would be reduced considerably. Harwood et al.'s (13) data for the Case III-B (their Figure 25) and Case III-C (their Equation 41) scenarios appear to support this conclusion.

## TRAFFIC OPERATIONS

### Intersections

Knoblauch et al. (7) conducted a study to determine if drivers understand the various configurations of protected and permitted phases of left-turn traffic signals. Sixteen different scenarios from the *Manual on Uniform Traffic Control Devices* (MUTCD) and related state traffic-design manuals were tested. Results of the study revealed that the 126 older drivers (age 65 or older) did not comprehend the operational meaning of either the protected or permitted phases of left-turn traffic signals as well as the 121 younger drivers (younger than age 65) did. These results show a consistency with the findings of other recent studies demonstrating age-related declines in traffic-signal comprehension (16, 17). However, Knoblauch et al. concluded that neither age group demonstrated an “acceptable level of comprehension associated with left-turn signalization.” Furthermore, they recommended that future efforts focus on improving the comprehension level of all drivers instead of developing efforts only targeted to the older-

driver population. Knoblauch and other investigators repeatedly have suggested that more uniform and consistent applications of the MUTCD specifications would contribute to improvements in driver comprehension of traffic-control devices.

Many studies have reported that older drivers have a higher risk of being in a crash during a left-turn maneuver than in any other category of motor vehicle accident (e.g., 7, 18). The studies also have reported that the relative alignment of opposing left-turn lanes significantly contributed to the probability of a crash when the driver was turning left, especially during the permitted phase of the traffic signal. These studies have found that the relative alignment of opposing left-turn lanes influenced the intersection sight distance of drivers when both opposing turning lanes were occupied by vehicles. When the offset was negative or zero in the relative alignment of the opposing left-turn lanes, sight distance decreased and the number of crashes observed increased. However, intersections designed with opposing left-turn lanes and a positive offset in their relative alignment increased turning drivers' sight distance and, presumably as a result, decreased the incidence of left-turn crashes (see Figure 1 for turning-lane offset examples).

In a search for countermeasures to reduce the high proportion of left-turn crashes among older drivers, Staplin et al. (15) identified the optimization of left-turn-lane geometry as a likely source of remediation through improved highway design. Their primary arguments were that older drivers when turning are affected more likely by limited intersection sight distance and that the appropriate offset of opposing left-turn lanes minimizes exposure to these conditions. To evaluate this claim, Staplin et al. in a field study examined age differences in left-turn maneuvers as a function of intersection geometry. A total of 100 drivers participated in the study, with approximately equal numbers of participants in each age group: young (age 25–45), young-old (age 65–74), and old-old (age 75 or older). Each participant drove around a predetermined course and passed through each of the experimental intersections four times.

The intersections selected for study had traffic signals and one of four levels of opposing left-turn-lane geometry: full-negative offset, partial-negative offset, aligned or zero offset, and partial-positive offset. The sight distances afforded at the intersections during the performance of the left-turn maneuver criterion (i.e., turning during the permitted phase of the traffic signal when another vehicle occupied the opposing left-turn lane) increased as the lane offset moved from full negative to partial positive. Video equipment positioned at each intersection recorded each driver's behavior and the opposing traffic stream for offline analysis. The primary measure of driv-

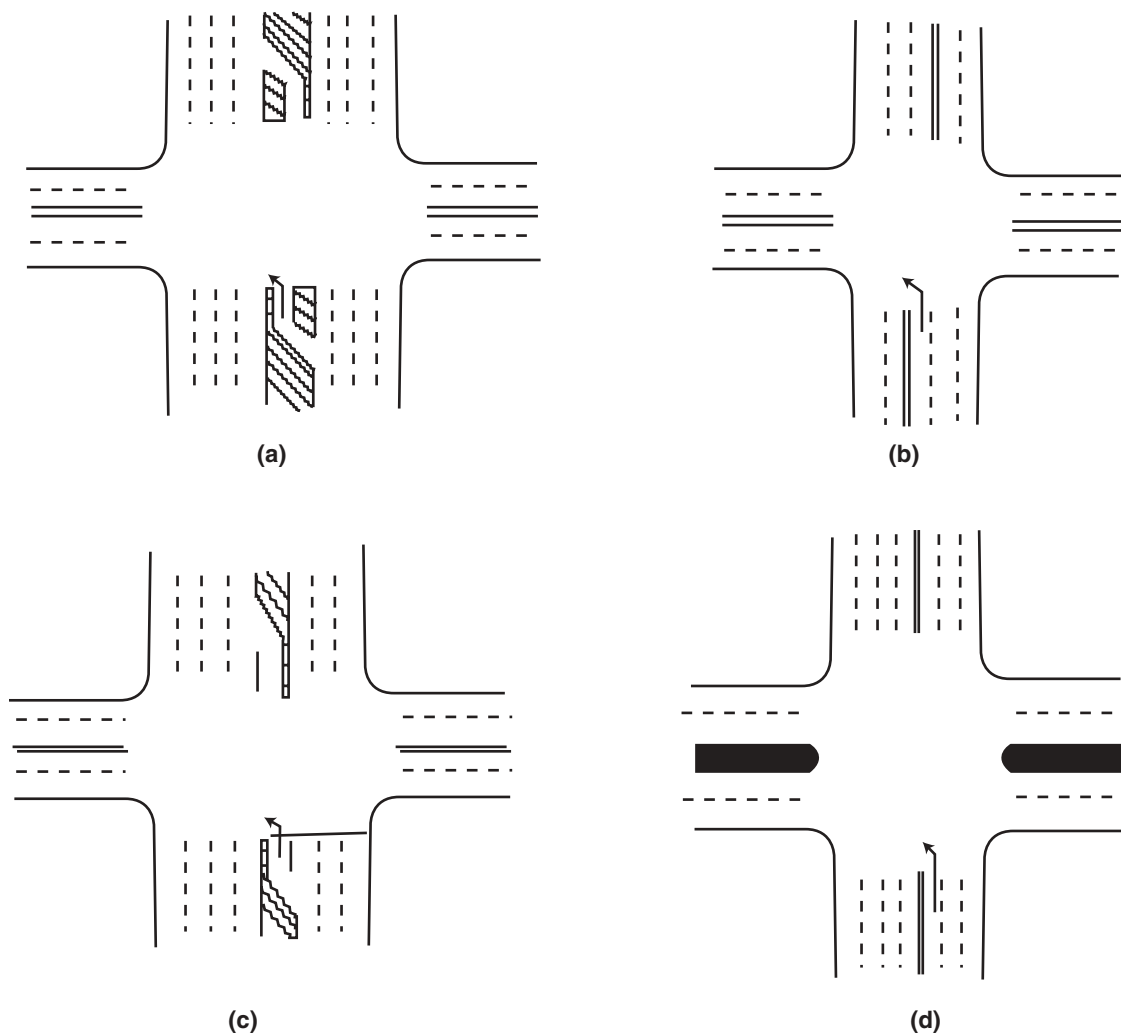


FIGURE 1 Left-turn lane offset geometries (15): (a) partial positive offset; (b) no offset (i.e., aligned); (c) partial negative offset; and (d) full negative offset.

ing performance focused on the size of the critical gap in the opposing traffic stream accepted by drivers during the performance of the left-turn maneuver. Figure 2 depicts the results of the study, which confirm the argument that the positive offset of opposing left-turn lanes results in improved driving performance, especially for older drivers.

Another aspect of driving performance measured in this study related to the positioning of the driver's vehicle before executing the left-turn maneuver. Most drivers tended to encroach slightly into the intersection (i.e., to self-position) before turning, presumably to compensate for the obstruction in the sight distance caused by the vehicles in the opposing left-turn lane. However, the proportion of drivers demonstrating the compensatory self-positioning before executing a left turn declined significantly with increasing age. Fully 92% of the

young drivers and 84% of the young-old drivers self-positioned their vehicles when waiting to turn left, but only 68% of the old-old drivers engaged in this behavior. Although this difference in behavior appears to be subtle, it could indicate an age-related passivity that is rooted in either decreased situation awareness or another systematic change in the nature of the driving task among older drivers. Regardless of the cause, the *Older Driver Highway Design Handbook* suggested that age-related differences in vehicle positioning before turning represent a critical consideration for intersection geometric design. If opposing left-turn lanes have a positive offset, there is no need to self-position, thus reducing the potential affect of the negative behavior observed among older drivers.

Staplin et al. (15) also examined the effects of intersection lane geometry on age differences in driving

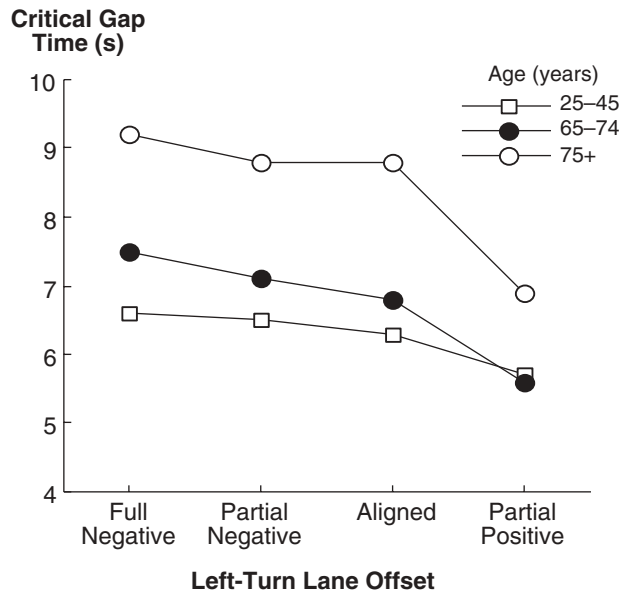


FIGURE 2 Driving performance as function of driver age and left-turn lane geometry (15).

behavior when the driver turns right. This study focused on the right-turn-on-red (RTOR) maneuver because previous investigations had demonstrated that older drivers have a high risk of being in a crash when executing a right turn (19). Research participants negotiated a predetermined test route that included four experimental intersections with one of two design dimensions: (a) the right-turn lane was either channelized or not channelized, and (b) the receiving road either had or did not have an acceleration lane. Approximately 100 drivers equally distributed across the age groups participated in the study: young (age 25–45), young-old (age 65–74), and old-old (age 75 or older).

The results of the study indicated that the implementation of an exclusive right-turn lane, established through lane channelization, significantly contributed to the mobility of the younger drivers. Participants from the young and young-old age groups executed right turns at speeds from 3 to 5 mph (4.8 to 8.0 km/h) faster at intersections with channelized right-turn lanes than at intersections without channelization. However, this mobility benefit of channelization was not observed among drivers in the old-old group. The young drivers used 83% of the opportunities to execute a RTOR maneuver. Young-old drivers used only 45% of the opportunities, but the old-old drivers used only 16% of the opportunities. Also of interest, channelization significantly increased the probability of a driver completing a RTOR maneuver without first coming to a complete stop. This phenomenon was robust for both the young and the young-old groups but was almost absent among the old-old drivers, who came to a com-

plete stop for 19 of the 20 observed RTOR maneuvers. Finally, the results indicated that the presence of an acceleration lane on the receiving road had little effect on right-turn driver behavior, regardless of age.

## Freeways

Reilly et al. (20) conducted an observational field study of 35 freeway sites to investigate the relationship between driver gap-acceptance and acceleration-deceleration behavior when entering and exiting the freeway. Having developed a model of driver freeway entry and egress behavior, they concluded that the Green Book guidelines for freeway speed-change lanes did not provide sufficient distance for merge or diverge maneuvers. This conclusion suggests that freeway entry and egress lanes may fall short in meeting the needs of many older drivers. Survey results from licensed drivers older than age 65 supported this conjecture (21).

Knoblauch et al. (22) conducted a major analytic study of older-driver freeway operations with the following objectives:

- Identify the characteristics of older drivers that affect their ability to drive on freeways,
- Identify the characteristics of freeway driving that cause the greatest difficulties for older drivers,
- Conduct problem identification research to define the difficulties experienced by older drivers on freeways, and
- Recommend topics for further research to develop guidelines for countermeasures designed to accommodate the needs and capabilities of older drivers.

These objectives were achieved through the application of human factors task analysis techniques, focus groups, a large-scale survey, and a detailed analysis of freeway crash records. The focus group studies included 44 men and 44 women, ranging in age from 65 to 88 (median age = 70), recruited from four major metropolitan areas (Phoenix, Ariz.; San Diego, Calif.; Tampa, Fla.; and Washington, D.C.). Results from the focus groups suggested that older drivers were very concerned about traffic congestion, inconsistent signing and sign placement, entrance ramps that did not allow enough time to merge onto the freeway, work zones, and inadequate rest areas. Problems with freeway signing included inadequate advance warning for right-turn and exit-only lanes and difficulty reading shoulder-mounted signs. Well-lit overhead signs were preferred to shoulder-mounted signs. Design issues raised by the focus groups also included the need for longer acceleration (i.e., merging) lanes, increased use of high-concrete median barriers to promote safety and reduce



glare, more shoulder rumble strips to help maintain driver alertness, and less use of combination exit and entrance ramps. Perhaps the most interesting finding from the focus groups was that no direct evidence showed that older drivers avoided using freeways.

In a survey of 1,400 members of the American Association of Retired Persons, ranging in age from 50 to 97 (mean age = 72.2), however, approximately one-quarter of the respondents deliberately avoided freeway driving. Lane-changing difficulties were common; a large number of drivers reported that they would rather slow down than pass a slow-moving vehicle. Nearly half commented on problems with fatigue when driving. Many drivers mentioned difficulties entering or exiting freeways: 25% reported coming to a stop before merging into the traffic stream, and 52% slowed down before reaching the exit lane. Approximately half of the older drivers said that they had problems staying in the lanes because of faded lane markings, and fully 75% reported that more light was needed at various freeway locations, such as exit ramps and interchanges. The drivers expressed appreciation for the benefits provided by various sources of roadway delineation, including painted lane markings, raised pavement markings (RPMs), and post-mounted reflectors. Finally, the survey respondents concurred with the preference of Knoblauch et al.'s focus groups for overhead, instead of shoulder-mounted, freeway signs.

The accident analyses conducted by Knoblauch et al. revealed that older drivers were overinvolved in single-vehicle, run-off-the-road crashes, possibly because of the effects of fatigue.<sup>4</sup> Older drivers had a lower risk of involvement in a multivehicle crash. But when older drivers were involved, it was more likely that they were merging or changing lanes. Older drivers also were more likely to be struck by vehicles that were traveling faster than they were (although not necessarily speeding). Table 5 represents a modified version of Knoblauch et al.'s (22) summary of results, along with suggestions for future research in the areas of freeway operation and geometric design.

## Work Zones

During recent years, the number of traffic-related fatalities has increased significantly in and around roadway maintenance and construction areas. Much of this increase is due to an increase in the amount of maintenance required as the U.S. highway infrastructure itself begins to show the effects of aging. As a result of these trends, work zone safety has become a

high priority for FHWA, which recently established the National Work Zone Safety Information Clearinghouse ([wzsafety.tamu.edu](http://wzsafety.tamu.edu)) at the Texas Transportation Institute (23). Because work zones create many visual, attentional, and cognitive challenges, it is expected that crash frequency among older drivers will be elevated near roadway construction and maintenance projects. However, little work has been conducted to investigate this potential problem for older drivers.

Chiu et al. (24) conducted a study to investigate the interacting influences of driver age and roadway illumination on driving performance in work zones. Young (age 35 or younger) and older (age 58 or older) participants operated an interactive driving simulator under six conditions, defined by two types of work zones (all lanes shift versus one lane closure) and three illumination conditions (day, dusk, and night). All drivers made more steering errors (lane departures) during the dusk and nighttime conditions than during the daytime condition. In addition, all drivers reduced their driving speed in the nighttime condition, although young drivers drove slightly faster than older drivers did, regardless of the illumination level. Older drivers made lane changes in response to work zone shifts in lane geometry at a much later time than their younger counterparts, especially in the simulated nighttime condition. When asked about the helpfulness of simulated traffic-control devices, older drivers found lane markings with reflectors beneficial, while some young drivers were distracted by the same lane markings because of excessive brightness.

Given the increased workload and safety hazards created by roadway work zones, it is surprising that little is known about age differences in driving behavior and crash history in these situations. Although preliminary, the simulation-based work of Chiu et al. (24) strongly suggested that older drivers have increased difficulty negotiating roadway work zones, despite the fact that they more likely slow down and obey signs posted before and in the work zone area. The complexity of work zone environments and their tendency to violate driver expectations may overload the functional capacities of many older drivers. Additional studies based on detailed crash analysis and observational field studies appear warranted.

## Pedestrian Crossings

*Special Report 218* identified the high incidence of older pedestrian injuries and fatalities at intersections as a high priority area for research. Subsequent epidemiological studies have verified these findings (25, 26). The report specifically recommended a need to evaluate the walking speed parameters for the design of signal lights

<sup>4</sup> Almost 25% reported to be fatigued or asleep.



TABLE 5 Older People's Problems During Freeway Driving and Future Research Needs (22)

<i>Research Area</i>	<i>Problems</i>	<i>Future Research</i>
Navigation/ wayfinding	Difficulties navigation. Over involvement in crashes in unfamiliar areas.	Further explore problem. Develop and test alternative traffic control device designs.
Freeway ramp merging	Merging onto mainline from ramps.	Identify ramp geometry and mainline characteristics that contribute to the problem. Develop and test new designs.
Illumination requirements	Reduced visibility while driving at night.	Identify critical factors associated with highway lighting; e.g., lamp placement, intensity.
Speed/lane selection	Inappropriate lane selection. Inappropriate speed selection.	Identify relevant design parameters: horizontal vs. vertical curvature; lane and shoulder width; median type and proximity; guard rail type and proximity.
Work zones	A major concern and reason for avoiding freeways.	Identify characteristics of construction and maintenance areas that are troublesome especially for older drivers. Develop and test treatments to improve older driver performance in work zones.
Fatigue/ medication	Fatigue was identified as a major contributory factor in single-vehicle freeway crashes. Self-reports of fatigue problems also are common.	Identify interventions that could offset effects of fatigue in older freeway users.
Lane-changing/ passing behavior	Many crashes are related to lane-change maneuvers. Self-reported problems with lane changing and passing.	Conduct detailed behavioral analysis of lane-changing and passing behavior. Determine adequacy of exit and advanced exit signing relative to the time needed to complete these maneuvers.
Roadway delineation	Heavy reliance on delineation, RPMs and post mounted delineators at night and during challenging visibility conditions. Run-off-road and lane-changing crashes may be related to a need for improved delineation.	Determine minimum and optimal size or width and retroreflectivity of lane markings, RPMs and post-mounted delineators for older drivers.
Roadway signing	Strong preference for overhead signing.	This preference is unexpected and may not generalize to unilluminated signs at night. Additional investigation is needed.

and related traffic-control devices at intersections. In the MUTCD (27), the U.S. Department of Transportation assumed the walking speed for pedestrians crossing a street to be 4 ft/s (1.2 m/s). *Special Report 218* urged that the age appropriateness of this walking speed parameter be evaluated and, if necessary, updated for future reference in the MUTCD and related highway design guidelines.

Knoblauch et al. (26) conducted a comprehensive study on the characteristics of older pedestrians' street crossing behavior. Using the conventional tools of a literature review, task analysis of pedestrian crossing behavior, focus groups, and functional analysis of pedestrian crash records, they categorized the problems faced by many older pedestrians attempting to negotiate busy urban intersections. To translate these findings into design guidelines, the authors conducted field studies to

establish the parameters for the street crossing behavior of older people, such as walking speed, stride length, and latency between signal change and initiation of a crossing response. Data from 3,458 young (younger than age 65) and 3,665 old (age 65 or older) pedestrians were collected from urban intersections in four U.S. East Coast cities. Mean walking speeds for the young and old pedestrians were 4.79 ft/s (1.43 m/s) and 3.97 ft/s (1.18 m/s), respectively. This age difference in average walking speed of nearly 1 ft/s showed statistical significance.

The 15th percentile values for each age group also were calculated to establish a design value for walking speed that would accommodate 85% of the pedestrian population. The resulting values were 3.97 ft/s (1.18 m/s) and 3.08 ft/s (0.92 m/s) for the young and old pedestrians, respectively. The slower walking speed of older pedestrians appeared to be because of a signifi-

cantly shorter average stride. The authors concluded that the traditional design speed of 4 ft/s could result in traffic-signal timing and related pedestrian crossing implementations that failed to accommodate the emerging needs of a significant proportion of the older population. On the basis of these results, Knoblauch et al. (26) recommended that the MUTCD and the Green Book be modified to reflect a pedestrian walking speed that accommodates 85% of older people—namely, change the speed to 3 ft/s (0.9 m/s). Similar conclusions have also been reached by other investigations (28, 29). As a result of this work, appropriate changes to both the MUTCD and Green Book have been proposed.

Knoblauch et al. (26) observed significant age differences in the latency of initiating a walking response after the onset of the appropriate traffic-control device signal. Mean start-up time latencies of 1.93 and 2.48 s were computed for young and old pedestrians, respectively. The respective 85th percentile start-up times for the young and old groups were 3.06 and 3.76 s. Hence, the design pedestrian, accommodating the older group, would require approximately 3.75 s to begin crossing the street once the light turns green or the walk signal is initiated, or both. This start-up time suggests that much remains to be learned about pedestrian behavior at signalized intersections (30). Treatments aimed at improving pedestrian situation awareness during the “Don’t Walk” phase of the pedestrian crossing signal appear to hold promise for improving the safety and efficiency of urban intersections. However, decrements in basic visual capacities, such as acuity and contrast sensitivity, also may confound older pedestrians’ reading of traffic-control devices or detecting and judging approaching vehicles. For example, at a busy urban area, approximately 25% of older pedestrians reported experiencing difficulty seeing the pedestrian crossing traffic signal from the other side of the street (31).

In an effort designed to improve pedestrian situation awareness in a targeted and cost-effective manner, Blomberg and Cleven (32) developed and verified the efficacy of the zoning technique for reducing pedestrian crossing fatalities in the older population. Accident analyses in Phoenix revealed that seven hot zones (six circular zones with a 1-mi radius, one zone of a 2-mi linear stretch of roadway) accounted for 54% of the pedestrian accidents but only 5% of the metropolitan area landmass. An intensive educational and informational campaign only focused on the seven identified zones emphasized behavioral phenomena, such as daytime conspicuity and waiting for the next green before crossing. The campaign resulted in significant reductions in pedestrian accidents. The authors suggested that the zoning technique for focusing traffic-safety countermeasures also might be effective in other domains of traffic and safety engineering.

## Traffic Calming and Roundabouts

Traffic-calming devices date back to the introduction of the speed bump in the Netherlands. Since 1970 the development and deployment of traffic-calming systems has increased throughout Western Europe. The use of these devices has focused on the maintenance of quality of life for neighborhood residents and drivers (33). Traffic-calming devices are beginning to be planned and implemented with increasing frequency in the United States (34). On initial inspection, traffic calming appears to support the needs of older road users. For example, slower traffic flows with smaller speed variances may result from decreased time pressures on drivers and pedestrians. However, traffic-calming engineering devices, such as narrowed lanes and roundabouts, also may be associated with unanticipated increases in workload demands on drivers, especially older ones. The increased complexity of decision making to negotiate a busy roundabout may be problematic. In addition, recent guidelines and specifications for traffic-calming devices, such as roundabouts, appear to have ignored the needs of older drivers (35).

## FHWA’s *Older Driver Highway Design Handbook*

In January 1998, FHWA released a comprehensive set of guidelines that attempted to translate the knowledge about human aging into principles of highway geometric design and operations. Collectively known as the *Older Driver Highway Design Handbook* (36), these guidelines are a must-read for anyone interested in highway design and older drivers. On the basis of an exhaustive review of the literature, this volume makes specific recommendations about roadway and traffic-control device design. The handbook covers the topics listed in Table 6, which are discussed in the paper on highway enhancements by Staplin. The comprehensive nature of this work merits follow-up by FHWA. Perhaps a standing committee could be formed to monitor and validate the guidelines continuously. Given this level of commitment, many of the guidelines eventually will evolve to the point of formal acceptance into the MUTCD.

## TRAFFIC-CONTROL DEVICES

### Roadway Delineation

Safe and efficient driving depends on adequate roadway delineation. Boundaries of the roadway and nearby off-road appurtenances need to be clearly visible to drivers; otherwise, drivers who unintentionally deviate from their lane risk a collision with another vehicle or stationary

TABLE 6 Contents of the *Older Driver Highway Design Handbook (36)*

I. INTERSECTIONS	
A. Intersection Angle (Skew)	I. Traffic Control for Right-Turns
B. Receiving Lane Width for Turning	J. Street-Name Signage
C. Lane Channelization	K. One-Way/Wrong-Way Signage
D. Intersection Sight Distance	L. Stop/Yield Signage
E. Left-Turn Lane Geometry	M. Lane Assignment Devices
F. Edge Treatments/Hazard Delineation	N. Traffic Signal Parameters
G. Right-Turn Curb Radius	O. Fixed Lighting Installations
H. Traffic Control for Left-Turns	P. Pedestrian Control Devices
II. FREEWAY INTERCHANGES	
A. Exit Signing and Delineation	C. Fixed Lighting Installations
B. Acceleration/Deceleration Lane Design	D. Traffic Control Devices for Prohibited Movements on Freeways
III. ROADWAY CURVATURE AND PASSING ZONES	
A. Delineation of Horizontal Curves	C. Advanced Signing for Sight Restrictions
B. Pavement Width on Horizontal Curves	D. Passing Zone Length and Sight Distance
IV. CONSTRUCTION/WORK ZONES	
A. Advance Signing for Lane Closure	D. Delineation of Crossovers
B. Changeable Message Signs	E. Temporary Pavement Markings
C. Channelization Practices	

hazards, such as unprotected bridge-supporting columns or drainage culverts. Naturally occurring changes in brightness and contrast provide much of the visual requirements for drivers during daylight conditions. But most of the visual information at night comes from engineered roadway and hazard delineation treatments with specially engineered retroreflective materials. Without the widespread use of such retroreflective materials, light from vehicle headlights would reflect away from the driver. Retroreflective materials significantly enhance the revealing power of headlamps by selectively steering the light output back to the eye of the driver.

Many studies have revealed that adequate roadway delineation must support two classes of driver visual needs. First, roadway delineation must support the driver's immediate need of continuous lane tracking or the so-called short-range visual requirements of steering. Drivers require approximately 2 to 3 s of delineation lead time to maintain smooth and efficient lane tracking (37). Second, roadway delineation treatments must provide for the long-range visual needs of the driver. Rumar and Marsh (37) showed that drivers need approximately a 5-s warning to prepare adequately for significant changes in roadway curvature and the appearance of intersections or nearby off-road hazards.

*Special Report 218* acknowledged that improvements in roadway delineation treatments might be needed to accommodate the changing visual and attentional capacities of older adults. But Deacon concluded that available data were insufficient to guide the formulation of specific

recommendations (38). Since then, several studies have quantified the magnitude of age differences in visibility distance afforded by delineation treatments and identified improvements in delineation that could compensate for the differences. Because of the special problems older drivers experience under low-illumination conditions, most of this work has focused on retroreflective delineation treatments designed to improve the nighttime visibility of the roadway and nearby hazards.

### *Lane Markings*

Given the significant reductions in retinal illuminance and contrast that accompanies normal adult aging, it is expected that older drivers would experience difficulty seeing pavement markings when driving at night. Zwahlen and Schnell (39) reported that the average nighttime visibility distance of retroreflective pavement markings for older drivers (mean age = 68.3) was only about half the distance achieved by younger drivers (mean age = 23.2) under identical conditions. Simulator-based studies have demonstrated similar results (40, 41). Such age differences may be exacerbated in wet weather.

Current guidelines and recommendations for the brightness of retroreflective road markings do not address specifically the emerging requirements of older drivers; the markings range from 90 mcd/m<sup>2</sup>/lux (42) to 400 mcd/m<sup>2</sup>/lux (43). The recently proposed European

standard (44) specifies a replacement retroreflectivity level of 300 mcd/m<sup>2</sup>/lux but does not recommend an optimal value for new applications. Zwahlen and Schnell (45) used the well-validated computer-aided road-marking visibility evaluator computer model to determine the minimum pavement-marking retroreflectivity levels for the accommodation of short-range steering performance at night. Their calculations were based on a constant preview time of 3.65 s and the visual needs of the average 62-year-old driver (i.e., the 85th percentile). Figure 3 shows the recommended minimum values for white edge-line pavement markings.

An examination of Zwahlen and Schnell's recommendations reveals that the proposed European replacement level of 300 mcd/m<sup>2</sup>/lux would accommodate the short-range visual guidance needs of the average 62-year-old driver for speeds below 65 mph (105 km/h). However, the European minimum would need to be approximately doubled to meet the minimum retroreflectivity demands of driving at 75 mph (120 km/h).

Table 7 summarizes the expected retroreflectivity levels of newly installed roadway markings. When newly applied, the state-of-the-art materials from Table 7 appear capable of meeting the minimum visibility requirements specified by Zwahlen and Schnell's model at 65 mph (105 km/h). However, engineering estimates of the half-life durability—that is, the time required for retroreflectivity to degrade to half of its initial value—for the materials suggest that they would have to be replaced every 1 or 2 years to remain in compliance with the recommended minimum levels. The peak retroreflective performance of modern roadway marking systems

**TABLE 7** Retroreflectivity Levels for Newly Applied Road-Marking Materials and Half-Life Durability Estimates

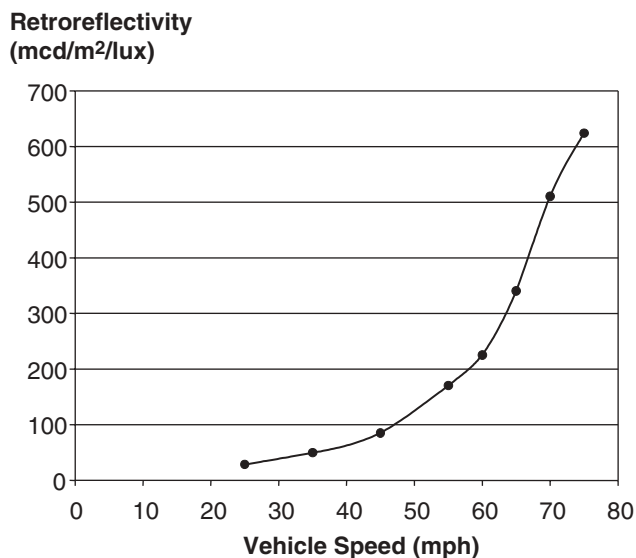
<i>Pavement Marking Material</i>	<i>Initial Value (mcd/m<sup>2</sup>/lx)</i>	<i>Estimated Half-Life Durability</i>
Paint/Glass Beads	300–500	<1 year
Thermoplastic	350–400	<2 years
Durable Traffic Tape	700–800	2 years
Ceramic	1,200	Unknown

has improved dramatically over the last decade. However, additional research is needed to improve the operational durability significantly, with the ultimate goal of meeting and maintaining the visibility needs of older drivers in a cost-effective manner.

Pietrucha et al. (46) conducted a series of engineering studies to evaluate the efficacy of available retroreflective treatments for improving the nighttime lane visibility distance of older drivers. On the basis of a review of the literature and a preliminary simulation-based study, they identified 11 treatment combinations that showed potential for improving the nighttime visibility of older drivers without negatively affecting the performance of young drivers. Despite previous indications that older drivers would benefit from this type of manipulation (38), none of the candidate treatment combinations involving an extrawide edge line [8 in. (20 cm)] survived the preliminary evaluation phase of the study. The experimental treatments included variations in the width and brightness of center and edge lines, RPMs, and a variety of post-mounted delineators and chevrons, with both standard and wide spacing. Table 8 summarizes the retroreflective delineation treatments.

The controlled field study was conducted on a closed course that could be configured for the 12 conditions in Table 8. Experimental participants consisted of 33 younger (mean age = 34.7; mean visual acuity = 20/20) and 33 older (mean age = 70.2; mean visual acuity = 20/25) drivers. The treatment efficacies were assessed using two measures: a static curve-recognition distance measure and a dynamic visual-occlusion technique. Because the visual-occlusion technique resulted in large within-age-group variations and no systematic age differences, only the results of the static curve-recognition distance study are presented (Figure 4).

Two criteria were used to evaluate the pattern of results: (a) the magnitude of the age difference observed for a given treatment and (b) whether the observed recognition distance met the 5-s visibility requirement of long-range steering performance (with a top nighttime driving speed of 65 mph, 5 s of visibility distance corresponds to 477 ft). With the exception of the control condition



**FIGURE 3** Minimum pavement-marking retroreflectivity requirements as function of speed.

TABLE 8 Delineation Treatments in Field Study on Age Differences in Nighttime Visibility Distance (46)

No.	Treatment Description	Grade	Relative Cost
1	4-in. yellow centerline (baseline control)	F	—
2	4-in. yellow centerline and a 4-in. high-brightness white “profiled” edge line	F	—
3	4-in. yellow centerline with widely spaced yellow RPMs	F	—
4	4-in. yellow centerline with widely spaced yellow RPMs and widely spaced white edge line RPMs	F	—
5	4-in. yellow centerline with high-intensity chevrons at standard height and spacing	B	1.15
6	4-in. yellow centerline, 4-in. white edge line, and high-intensity chevrons at standard height and spacing	A	1.52
7	4-in. yellow centerline and standard flat post delineators at standard spacing	C	1.63
8	4-in. yellow centerline, white edge line, and standard post delineators	C	2.00
9	4-in. yellow centerline and fully retroreflectorized flat post delineators at standard spacing	A	1.05
10	4-in. yellow centerline and high-intensity T-post delineators at standard spacing	A	1.00
11	4-in. yellow centerline with yellow RPMs at standard spacing and high-intensity T-post delineators at standard spacing	A	2.72
12	4-in. yellow centerline, 4-in. white edge line and engineering-grade T-post delineators at standard spacing	A	2.03

— = cost was not calculated for treatments receiving a failing grade. 4 in. = 10.16 cm.

(Treatment 1), all age differences of curve-recognition distance showed statistical significance.

Six treatments resulted in the greatest curve-recognition distances and statistically were indistinguishable from one another—namely, Delineation Treatments 5, 6, 9, 10, 11, and 12. All six treatments afforded a visibility distance that exceeded the 5-s criterion (i.e., 477

ft at 65 mph) and merited the highest relative grade (A). With a relatively large age difference, Treatment 5 was assigned the grade of B. Treatments 7 and 8 were different statistically from the other treatments but not from each another. These two treatments were assigned a passing grade of C because the visibility distances afforded by both exceeded the 5-s sight-distance criterion established by Rumar and Marsh (37). Treatment Conditions 1, 2, 3, and 4 were assigned the failing grade of F because they yielded visibility distances below the criterion level. These treatments only provided a 5-s visibility distance for drivers traveling at speeds of 30 mph or slower.

Pietrucha et al. (46) also performed a cost-effectiveness analysis for the top-performing delineation treatments.<sup>5</sup> On the basis of the performance results and the application costs of the manipulations, they recommended that Delineation Treatments 10 and 12 be selected as the best treatments to improve the performance of older drivers. However, there was an important difference between Treatments 10 and 12: although much less expensive, Treatment 10 contained no edge line and might have failed to provide adequate support for the short-range lane-tracking requirements of steering. Of the top-performing treatments in this

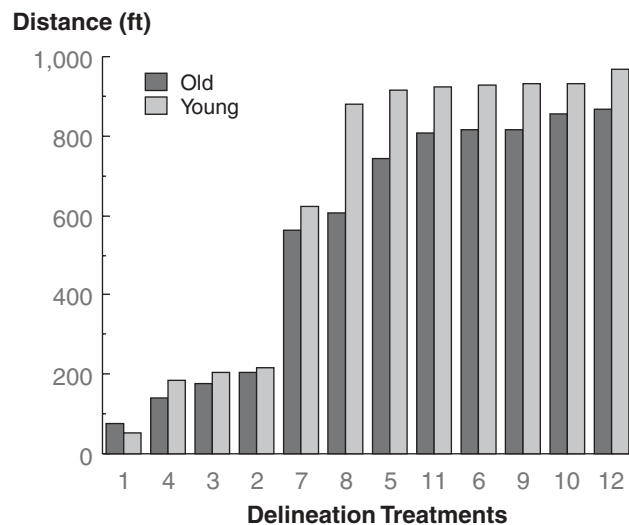


FIGURE 4 Visibility distance of nighttime delineation treatments as function of age.

<sup>5</sup> See Table 8 for a summary of the relative costs of applying each treatment.



study, several contained no edge lines. Given the nested experimental design, the relative contribution of the edge line to any given treatment combination could not be determined.

### *Hazard Delineation*

Lerner et al. (47) performed a series of laboratory and field studies to evaluate the conspicuity of MUTCD object markers for delineating near off-road hazards, such as ditches and bridge supports. Age differences in the comprehension and visibility of prescribed hazard delineation treatments were assessed, and potential conspicuity enhancements for a series of ad hoc manipulations in marker size, color, shape, and symbology were evaluated. The studies were conducted under both daytime and nighttime viewing conditions across a range of roadway geometry. Although the authors observed reliable age differences in the viewing distances afforded by the hazard delineators, they found that few of the engineering manipulations explored with increased visibility yielded operationally meaningful improvements in performance.

### *Ultraviolet-Activated Delineation Treatments*

Recently, FHWA sponsored a series of studies to evaluate the potential effectiveness of using ultraviolet (UV)-activated materials to improve the effectiveness of nighttime roadway delineation treatments. Experimental high-beam headlamps that emit UV light present little or no glare hazard because the UV light virtually is invisible to the human eye. Yet when this UV energy strikes materials treated with special pigments, the UV energy is transformed into visible light by a process known as fluorescence. Roadway delineation treatments that fluoresce when illuminated by UV headlamps appear to glow and are visible from a much greater distance than would be possible under normal low-beam-only operation conditions.

Mahach et al. (48) in a preliminary field study evaluated the potential effectiveness of UV headlamp-fluorescent roadway delineation treatments with 36 observers, age 25 to 65 or older. Three 90-m sections of roadway were treated with edge lines constructed from (a) worn and faded retroreflective white paint, (b) new white thermoplastic material, or (c) new white thermoplastic treated with fluorescent photopigments. All observers rated the fluorescent delineation treatment as significantly more visible than either of the two other treatments when the UV headlamps of the test vehicle were activated. Static performance measurements revealed that the UV headlamp-fluorescent

delineation combination increased visibility distance by an average of 40 m.

Turner et al. (49) conducted a more extensive follow-up study on the visibility of fluorescent delineation treatments. They measured the visibility distance benefits of UV headlamp-fluorescent delineation treatments under static and dynamic conditions on a closed test track. Static visibility distances afforded by various lane, post-mounted, and off-road hazard delineation treatments were measured in 8 young (age 16–25), 14 middle age (age 26–59), and 6 older (age 60 or older) observers. The authors saw statistically significant increases in both detection and recognition distance when they activated fluorescent delineation treatments with UV headlamps. For example, recognition distances for fluorescent-activated thermoplastic lane markings to delineate right curves, no passing zones, and crosswalks improved by 27%, 57%, and 55%, respectively. The authors also saw similar gains for the recognition of dynamic targets, such as walking or jogging pedestrians, with fluorescent-activated retroreflective delineators.

Unfortunately, neither of these two studies of fluorescent-activated delineators reported analyses based on age. However, there is no a priori reason to believe that fluorescent delineation treatments would not improve visibility performance for older adults, thus suggesting an important new approach for providing improved guidance during nighttime driving. But the infrastructure investment required to implement this approach may be too high to preclude implementation in the near future.

### **Highway Signage**

Highway signs represent one of the most important elements of the surface transportation infrastructure. These critical signs provide route guidance, regulatory information, and operational and safety warnings and advisories. Traditionally, the perception of highway signs has been considered within a serial or sequential information-processing model, consisting of four distinct stages: detection, recognition, comprehension, and response. The detection process relates to the conspicuity of a sign, and the recognition process usually is measured in terms of legibility. Research involving these aspects of highway effectiveness is reviewed below.

### *Conspicuity*

Because a sign first must be detected before it can be read and understood, it is not surprising that much research has been conducted to optimize highway sign conspicuity. Cole and Hughes (50) defined two classes



of sign conspicuity. Attention conspicuity refers to the capacity of a sign to attract a driver's attention when the driver is not searching actively for a sign. Search conspicuity, on the other hand, refers to the capacity of a sign to be located quickly and reliably during a search. Clearly, conspicuity is not the property of a sign but an emergent property of the interaction among the sign's characteristics, its background, and the observer's state. The major factors influencing highway sign conspicuity include size, brightness, color contrast, background scene complexity, location, and design speed of the highway—the relative importance of these factors varies across daytime and nighttime viewing conditions (51).

Mace et al. (52) examined age differences in the conspicuity distance afforded by incremental changes in sign brightness. A total of 15 young (age 40 or younger) and 15 older (age 65 or older) participants looked for signs along the roadside as the front passenger in an automobile traveling at the posted speed limit of 35 mph (56 km/h). Conspicuity was defined as the distance at which the color of a sign was identified correctly. Target signs varied in brightness, size [24–36 in. (61–91 cm)], and background color (orange, white, and green). Brightness varied by the manipulation of sign retroreflectivity: Type I, II, IV, and VII corresponded to engineering-grade, medium-intensity, high-intensity, and super-high-intensity sheeting materials, respectively. Although nighttime conspicuity increased with size, neither observer age nor sign brightness had a systematic effect on visibility. This outcome is not entirely surprising because gains in sign conspicuity as a function of luminance have been shown to reach asymptote at relatively low luminance levels, suggesting that the luminance levels achieved by the Type I sheeting material already had exceeded the conspicuity asymptote of both the young and older observers in the study. Unfortunately, photometric values for the stimuli were not in the report. The authors obtained similar results in a parallel study, in which they examined the daytime conspicuity of the same stimuli.

The findings above suggest that the additional luminance from high-intensity (Type IV) and super-high-intensity (Type VII) retroreflective materials may have little affect on highway-sign conspicuity. Some evidence has shown that the optimal brightness level for sign conspicuity may be elevated markedly under conditions of high-background-scene complexity (53). This complexity especially might be the case for older drivers who appear to be affected disproportionately by background visual clutter (54).

To examine this possibility, Schieber and Goodspeed (55) used a nighttime scene simulator to assess age differences in a driver's glance conspicuity of highway signs as a function of sign brightness and background

visual complexity. The authors manipulated sign luminance to simulate the levels afforded by engineering-grade versus super-high-intensity retroreflective sheeting materials. Young (mean age = 31.8; age range = 22–44 years) and older (mean age = 71.5; age range = 61–80 years) observers reported the location of a highway sign embedded in a background road scene presented for 250 ms. At low levels of background scene complexity, no age differences in the time needed to detect and localize the target sign emerged, regardless of brightness. However, when the sign was embedded in a complex background, the authors observed significant increases in the time needed to detect the target in the driving scene, especially by older observers.

With the introduction of the complex background, a change in sign conspicuity was reduced significantly when target sign luminance increased to a level approximating the brightness achieved by super-high-intensity sheeting material. It appears that the strategic application of highway signs constructed from super-high-intensity retroreflective sheeting material might offset partially the age-related increases in the deleterious effects of background visual clutter usually found in densely populated urban areas.

Recent experimental work has suggested that state-of-the-art developments in sheeting material also might contribute to an increase in the daytime conspicuity of highway signs. Durable fluorescent sheeting material was introduced for the high levels of retroreflectivity needed for nighttime visibility and for improved daytime brightness and color contrast. Durable fluorescent pigments, unlike the UV-headlamp-activated pigments above, achieve a unique color appearance by converting a short but visible wavelength light from the sun, which usually is absorbed and converted to heat, producing a longer wavelength light. This recruitment of short wavelength light fosters the brighter-than-bright appearance of fluorescent materials (56).

Preliminary reports [(e.g., Hummer and Scheffler (57)] have suggested that the use of fluorescent orange signs at a North Carolina construction site resulted in significant improvements in driver behavior (e.g., merging ahead of a lane drop) in comparison with conventional nonfluorescent orange signs. Jenssen et al. (58) conducted a study to determine the distance at which volunteer observers could detect and recognize the shape, color, and contents of fluorescent versus nonfluorescent signs. Young and older participants searched for signs while seated on an open-platform railway car traveling 15 km/h along a 4-km straight track. The colors of the sign targets were yellow, yellow-green, and orange (both fluorescent and nonfluorescent). The detection distance afforded by the fluorescent signs showed greater significance than the distance demonstrated by the nonfluorescent counterparts. Older

observers demonstrated a 79-m increment in detection distance for fluorescent signs, and younger observers demonstrated a 92-m advantage. The age difference in the size of the fluorescent-sign conspicuity benefit also had statistical significance. Clearly, the strategic deployment of fluorescent highway signs may be helpful particularly for older drivers. However, the mechanism by which fluorescent materials improve the behavioral salience of highway signs remains undiscovered. That is, do fluorescent signs improve driving behavior because they increase attentional conspicuity or search conspicuity, or both?

### Legibility

Survey studies on driver visual capacities and complaints consistently have revealed that older adults experience considerable difficulties reading traffic and street-name signs (59). This is not surprising given the characteristic declines in acuity and contrast sensitivity that accompany normal adult aging (60). Recent studies have examined several design factors that can be manipulated to mitigate age differences in highway-sign legibility distance, including letter size, font characteristics, and brightness.

**Letter Size** In *Special Report 218*, Mace (61) demonstrated through a detailed review of the literature that the specification of letter size for use on U.S. highway signs clearly fails to meet the legibility requirements of a large percentage of older drivers. As the de facto standard for the specification of highway signs, the legibility index traces its history back to the classic work by Forbes and his colleagues (62, 63). The 50:1 legibility index specifies that for every 50 ft of legibility distance required of a sign, 1 in. needs to be added to the letter's height. For a sign to be readable at 400 ft, the legibility index computes an 8-in. required letter height. Even under ideal observation conditions, a driver must have a visual acuity of 20/23 or better to read letter heights specified by the 50-ft/in. (6-m/cm) legibility index. Epidemiological data indicated that approximately half of the people age 65–75 would not have this level of acuity, even when they were wearing glasses (60).

Mace (61) suggested that the traditional 50-ft/in. specification be changed to 40 ft/in. (4.8 m/cm), which presumes a visual acuity of approximately 20/30. This modification falls short of accommodating all drivers because the typical minimum acuity level for U.S. licensed drivers is 20/40 (64). But the 40-ft/in. specification would accommodate the visual-acuity levels of 85% of the people age 65–75 (62). Empirical data reviewed by Mace also supported this recommendation. For example, Olson and Bernstein (65) found that older

drivers in their sample would be accommodated by the 40-ft/in. specification if signs had an internal contrast of at least 5:1 and a luminance of 10 cd/m<sup>2</sup> or higher. In support of this suggestion, federal rule making has been initiated to modify the legibility index from the 50-ft/in. specification to a more accommodating 40 ft/in. In addition, FHWA (66) adopted a change to the MUTCD that would increase the required height of letters used in street-name signs from the current 4 in. (10 cm) to a more appropriate 6 in. (15 cm).

Recent work appears consistent with the recommended adoption of the 40-ft/in. legibility index specification. Chrysler et al. (67) measured legibility distances for 8-in. (20-cm) Landolt ring stimuli mounted on 24-in. (61-cm) signs. Young (mean age = 20.5 years) and older (mean age = 65.6 years) adults seated in the passenger seat of an automobile traveling on a closed course demonstrated mean legibility distances of 467 ft (142 m) and 320 ft (97.5 m), respectively. The equivalent legibility index to accommodate the average older driver was 40 ft/in. (i.e., 320 ft / 8 in. = 40 ft/in.). Another recent field study on legibility distance for highway signs also obtained results supporting the adoption of a less-demanding legibility index specification. Hawkins et al. (68) reported 85th percentile daytime legibility distances of 55 ft/in. (6.6 m/cm) for young drivers (younger than age 40), 40 ft/in. (4.0 m/cm) for middle-age drivers (age 55–64), and 32 ft/in. (3.84 m/cm) for older drivers (age 65 or older) when the drivers viewed white-on-green signs with 16-in.-tall Series E letters.

Mace et al. (52), however, challenged the simple linear relationship between letter size and the legibility distance afforded by a highway sign, as implied by the legibility index. Daytime legibility distance thresholds were collected from 15 young (age 16–40) and 15 older (age 65 or older) drivers for Series C and Series D letters in a black-on-white format and for Series E letters in a white-on-green format. The authors determined the legibility distances for five different letter heights: 6, 8, 10, 12, and 16 in. (15, 20, 25, 30, and 41 cm). Legibility distance increased as a function of letter height. However, the nature of the relationship was not the simple linear function implied by design specifications such as the legibility index. Figure 5 depicts Mace et al.'s data for the white-on-green Series E letters. The linear relationship implied by the legibility index appeared to break down at 600 ft (183 m), which corresponded to a letter height of between 8 and 10 in. for the young observers and a letter height of approximately 12 in. for the older observers. Increases in letter height beyond these critical values resulted in legibility gains significantly below the values predicted by the legibility index formula.

These findings are anomalous but have potentially critical importance for highway-design interventions aimed at accommodating the changing visual needs of

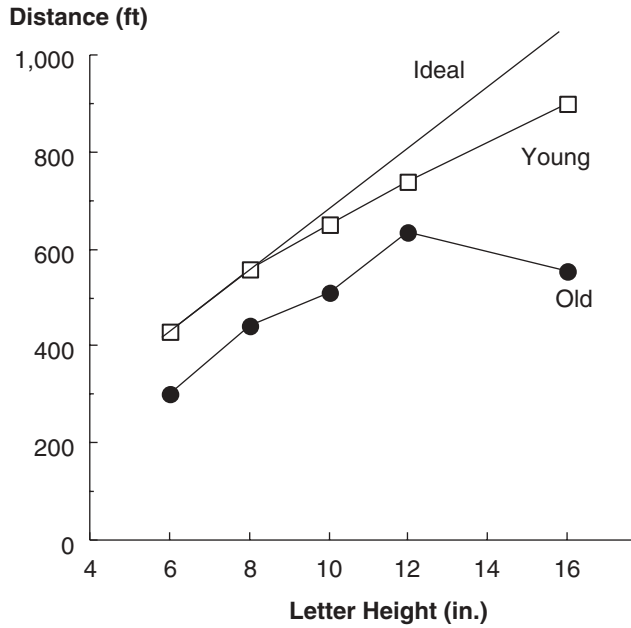


FIGURE 5 Sign legibility distance as function of age and letter height. Note divergence from ideal linear function (52).

aging drivers. The suboptimal performance of highway signs with very large letters in this particular case could have been due to the insufficient spacing between the letters of the target stimuli.

**Font Characteristics** As discussed above, highway signs constructed from state-of-the-art high-brightness

material sometimes can experience a visibility-reducing condition called irradiation or halation. This problem often occurs in white-on-green guides with the traditional Series E bold character font. In particular viewing geometry, the width portions of large, wide stroke letters can appear to glow and blur into one another. Spaces within and between the letters appear to fill in because of this halation effect, and legibility subsequently is reduced. Susceptibility to the effects of irradiation glare is believed to increase with advancing age (10). Mace et al. (52) modified the traditional highway sign text font so that the interstices within critical letters had an increased area. By increasing the size or area of the critical gaps within certain letters, they hoped to develop a text font that would be less susceptible to irradiation effects. Their initial work yielded signs that showed no irradiation effects during nighttime viewing conditions but created reduced legibility distance during daytime viewing conditions.

Given this promising starting point, Garvey et al. (69, 70) conducted a more extensive follow-up investigation by using reiterative design procedures (i.e., the recursive blur technique, which is discussed later) to develop a complete text font that was optimized for both nighttime and daytime viewing conditions. They developed the Clearview font as the new-generation highway sign alphabet (see Figure 6). Garvey et al. then conducted a field study to determine the effectiveness of their new font. Legibility distance data were collected from 48 (age 65–83) observers of signs with either the Clearview font or the traditional Series E font. Results



(a)



(b)

FIGURE 6 (a) Series E (modified) font versus (b) Clearview font for large freeway signs. Interstices in Clearview font characters are much larger, minimizing negative effects of overglow or halation when viewed under nighttime driving conditions (68).

of the study indicated that the nighttime legibility distances achieved by older drivers increased by an average of 17 m when Clearview letters were used instead of Series E letters (118 m versus 101 m). Unlike in the initial work of Mace et al. (52), no decline in daytime legibility distance emerged for the Clearview font. This font was designed specifically to improve the legibility of high-brightness highway signs at night. Under these conditions, the Clearview font resulted in a 16% increase in the recognition distance of older drivers.

Hawkins et al. (68) examined the relative legibility of white-on-green guide signs with 16-in. (40-cm) Series E, British Transport Medium, and Clearview text fonts. In a field study, young (younger than age 40), middle-age (age 55–64), and older (age 65 or older) observers reported that the Clearview font was readable from farther away than the Series E font under both daytime and nighttime viewing conditions. However, this advantage was limited to overhead guide signs. The extent of this improved visibility for overhead signs ranged from 2% to 8%—an increase in legibility distance of up to 15 m (50 ft). The authors also noted that the worst-case drivers, who presumably were the very old or had the worst visual acuity, demonstrated the largest gains in legibility distance.

Although the advantages of the Clearview font demonstrated by Hawkins et al. (68) were small and limited to specific situations, real gains in legibility distance were achieved for older drivers with restricted visual capabilities. In other words, drivers who needed the most help benefited the most from the font manipulation. However, some unexpected outcomes of the study—such as greater effect sizes for overhead as opposed to shoulder-mounted signs—were puzzling and will require additional study before the benefits of the Clearview font can be established firmly.

**Brightness** Although letter size and contrast set the limits for daytime legibility of a highway sign, brightness emerges as a critical factor under nighttime viewing conditions. Because the brightness of a sign at night typically is mediated by the return of headlamp illumination, the retroreflectivity of a sign becomes synonymous with its nighttime luminance.

Mace et al. (52) conducted a complex study of age differences in highway-sign legibility as a function of brightness (retroreflectivity), letter size, and letter style. Only the aspects of the investigation relevant to highway-sign brightness are discussed here. Legibility distances were assessed under field conditions for both partially and fully reflectorized highway signs. Retroreflectivity (brightness) varied with four different grades of sheeting material: Types I, II, IV, and VII corresponding to engineering grade, super-engineering grade, high-performance cube corner, and super-high-intensity prismatic sheeting, respectively.

Mace et al. concluded that the nighttime legibility performance of older observers was very low, ranging from 5 to 20 ft/in. worse than the performance of young observers. The relative performance of the older observers was even worse during the parallel daytime legibility study—that is, 20–30 ft/in. worse than the performance of their young counterparts). The researchers attributed this conclusion to the fact that the restricted range of headlights instead of the restricted visual acuity set the upper limit of legibility performance under nighttime viewing conditions for the young but not for the older observers. The authors estimated that the maximum improvement in legibility distance for older drivers viewing highly reflectorized signs was between 50 and 100 ft (15.2 and 30.5 m)—the equivalent of increasing letter height by a mere 1–2 in. (2.5–5.0 cm). So enhancements in nighttime legibility distance can be achieved more efficiently through increases in letter size or, where appropriate, through the more widespread application of bold symbol signs, which are readable from much farther away than their text counterparts (see below).

A more recent study investigated a straightforward but deceptively challenging question for the research of modern highway human factors: What is the minimum nighttime brightness required to read a traffic sign safely and efficiently? Graham et al. (71) conducted a field study to estimate the minimum brightness needed to read a reflectorized sign at night. Nineteen young (mean age = 24.2 years) and 42 older (mean age = 69.3 years) observers seated in the passenger seat of a stationary test vehicle attempted to read the two digit numerals constructed of 6-in. Series E letters mounted on a 76- × 76-cm background of yellow retroreflective sheeting material. The brightness of the signs ranged from high to low (in 10 steps) using transmissive filter overlays of varying optical density. The observers viewed the signs from different distances, including 30, 60, and 90 m, so that the perceptual load represented by the 6-in. target letters varied. At these distances, the target letters subtended 17.5, 8.7, and 5.8 min of arc, respectively.

Criterion performance was established as the level of sign brightness to achieve 85% correct identification of the target numerals at the three viewing distances. At the 30-m viewing distance, both the young and the older observers needed very little luminance to recognize the contents of the test signs reliably, which is not surprising given the large angular size of the stimuli at this distance. At the 90-m viewing distance—when the target letters afforded the equivalent legibility index of 50 ft/in.—the luminance requirements were quite high. In fact, the maximum brightness available (40.2 cd/m<sup>2</sup>) failed to provide enough light to meet the 85% correct identification level for the older group. The data col-



lected at the 60-m viewing distance proved to be the most interesting. At this distance, the target letters had an angular extent, which was within the range of the legibility index recommended to meet the visual needs of older drivers (30–40 ft/in.). The authors estimated that the older observers needed an average brightness of 6.5 cd/m<sup>2</sup> to read the signs 85% of the time. This estimate was based on static viewing conditions and may be less than the luminance requirements to read highway signs in dynamic, real-world conditions.

In support of necessary revisions of the MUTCD to include standards for the minimum retroreflectivity levels of traffic signs, FHWA sponsored the development of an analytical model called the computer analysis of retroreflectance of traffic signs (CARTS). CARTS first finds the minimum required visibility distance (MRVD) established for a given class of sign under specified design and operating conditions, then calculates the minimum sign luminance needed by an observer of a particular age and acuity, and finally outputs a retroreflectivity requirement with viewing geometry and type of sign sheeting material taken into account.

Paniati and Mace (51) used the CARTS model to establish FHWA guidelines specifying the minimum retroreflectivity requirements for traffic signs. Instead of specifying one value for all signs, the CARTS model generated a family of minimum values, depending on a sign's MUTCD classification (i.e., the minimum required recognition distance), size, type of retroreflective sheeting, and mounting position (surface versus overhead). Table 9 summarizes a subset of these suggestions for yellow-on-black warning signs.

Paniati and Mace noted that the equivalent minimum luminance outputs of the CARTS model (ranging from 7 to 15 cd/m<sup>2</sup>) were consistent with the results of previous studies that attempted to establish minimum values for the legibility of highway signs (53, 72, 73). In developing the minimum sign brightness recommendations, FHWA used the 66th percentile driver. This design driver has the following characteristics: age 47,

20/20 visual acuity, and 1.807 contrast sensitivity. Given the nature of the design driver's age and excellent visual sensitivities, the ability of the proposed minimum brightness standards to accommodate the needs of older drivers must be questioned.

In an internal FHWA study, Simmons and Paniati investigated the reasonableness of the variance in minimum required retroreflectivity values by sign type and the extent to which the proposed standards would accommodate older drivers (74). The authors assessed the minimum luminance requirement to recognize 25 representative highway signs for 100 observers ranging in age from 20 to 85. The signs were observed from their (simulated) respective MRVD in a laboratory setting. Typical results are presented in Figures 7 and 8. The solid boxes in Figure 7 depict the minimum luminance requirement to recognize a right-curve symbol sign as a function of observer age. The diamonds represent the CARTS model's prediction of the minimum luminance requirement as a function of age. The dashed line horizontally bisecting the figure represents the proposed FHWA minimum retroreflectivity requirements for the right-curve symbol sign (expressed in the equivalent luminance of 8 cd/m<sup>2</sup>). Although there is a slight elevation in the minimum luminance requirement to read this sign for people older than age 60, all of the data fall below the 8 cd/m<sup>2</sup> recommended minimum luminance level by a factor of 10. Given this cushion, the needs of the older observers probably were accommodated by the recommended minimum sign luminance in this particular case.

However, the data in Figure 8 tell a somewhat different story. A "Right Lane Ends" text sign affords a much lower legibility index than the right-curve symbol sign, so the text sign is more visually challenging. The increased spatial resolving power requirement to recognize the text sign is apparent in the elevated luminance requirements of the observers, especially people age 60 or older. The minimum luminance requirements of older observers appear to be consistent with the 6.2 cd/m<sup>2</sup> estimate reported by Graham et al. (71) for text signs requiring similar levels of spatial resolution. Although the luminance required by most of the people age 70–80 to recognize this sign approached—and in a few cases exceeded—the proposed minimum brightness value, the CARTS model accommodated the specifications for the visual needs of approximately 85% of the sample.

The Simmons and Paniati (74) report summarized above deals with threshold luminance recognition levels. Yet threshold measures are phenomena of the laboratory, not the real world of the road user. Obviously, effective road signs will need to sustain luminance levels above the requirements of laboratory thresholds, which are measured under ideal static conditions. The

TABLE 9 Minimum Retroreflectivity Requirements (cd/lux/m<sup>2</sup>) for Yellow-on-Black Warning Signs as Function of Sign Type, Size, and Sheeting Classification (51)

Legend	Material Type	Size		
		30 in. (76 cm)	36 in. (91 cm)	48 in. (122 cm)
Bold symbol	All	25	20	15
Fine symbol and text	I	35	30	20
	II	45	35	25
	III	55	45	30
	IV & V	70	60	40

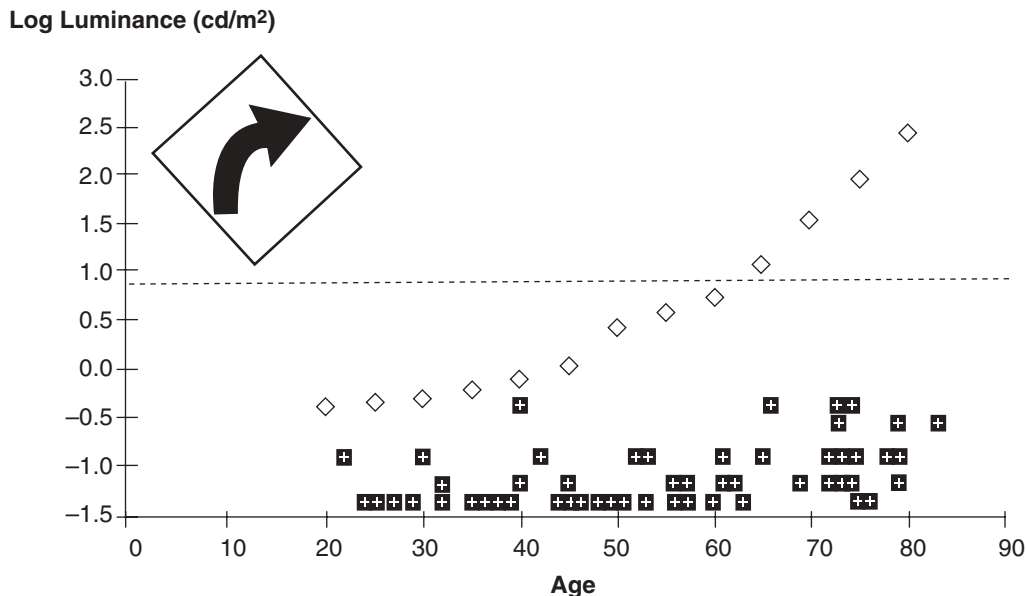


FIGURE 7 Minimum luminance requirement to recognize a bold symbol warning sign as function of age. Diamonds represent predicted output of the CARTS model; dashed line indicates proposed minimum brightness level (74).

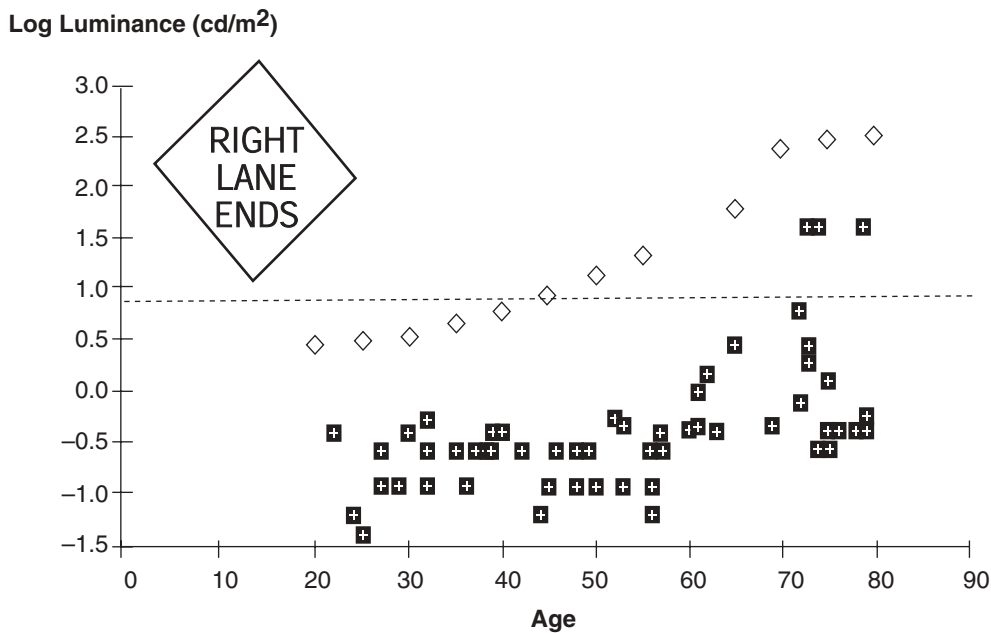


FIGURE 8 Minimum luminance requirement to recognize a warning sign as function of age. Diamonds represent predicted output of the CARTS model; dashed line indicates proposed minimum brightness level (74).

age function, predicted by the CARTS model (the open diamonds in Figure 8), closely followed the shape of the age distribution in the empirical data. This following suggests that the model addresses many of the critical changes in visual-perceptual function that accompany adult aging.

The CARTS model appears to be robust, to be sensitive to critical aging effects, and to possess a rudimentary type of validity. Clearly, however, additional work must be conducted in the field to improve and validate the CARTS model. But first the transportation community needs to have access to the model. Next, a forum



should be developed for debate and evaluation of the model's subcomponents and assumptions (75). Finally, comprehensive field studies must be conducted to validate the model for both surface-mounted and overhead highway-sign configurations. The specification of a meaningful standard for highway-sign minimum nighttime brightness (retroreflectivity) levels is an important yet challenging activity that cannot be undertaken in one study or contract. Instead, a long-term commitment needs to be built on the important analytic work completed so far. Special care must be exercised to assure that the needs of older drivers are considered during each phase of the development and validation process.

### *Symbol Signs*

Symbol or pictorial highway signs rely on large graphical icons instead of alphanumeric text to convey their message to road users. Symbol signs typically are recognized from twice as far away as their text sign equivalents (76). However, the visual superiority of symbol signs is neither uniform nor universal. Some symbol signs are legible from three times as far away; other more poorly designed signs are recognized at only half the distance of their textual equivalents. Because well-designed symbol signs can be recognized from very far distances, *Special Report 218* recommended that studies be conducted to determine if age-related visual deficits could be compensated for, at least in part, by an increased reliance on the symbol sign format.

Kline et al. (77) demonstrated that the legibility advantages afforded by symbol highway signs relative to text signs were as good for older drivers (mean age = 66.5 years) as for younger drivers (mean age = 24.2 years). Using a traveling speed of 96.6 km/h, the authors estimated that the improved legibility distance provided by symbol signs resulted in an added response time cushion of approximately 2 s for the older drivers in the sample.

Dewar et al. (78) determined legibility distance and driver comprehension for 85 graphical symbol signs in the MUTCD. They identified many signs judged deficient because of poor legibility or poor comprehension, or both. However, when the authors developed new graphical symbols for highway signs, few guidelines were available for optimizing the process. Unlike text-based highway signs that consist of a finite set of alphanumeric elements (i.e., 26 letters and 10 numerals), symbol signs can change into countless shapes and permutations. As a result, specific rules for design and optimization remain elusive. Schieber (79) proposed that much of the variability in the legibility of symbol highway signs could be accounted for by the degree to which these signs depend on high spatial frequency con-

tours to convey critical information. That is, the greater the dependency on high spatial frequencies, the worse the legibility distance.

Two corollaries of the hypothesis above have been confirmed. Schieber et al. (80) demonstrated that a symbol sign's legibility distance was related directly to its blur recognition threshold. Kline and Fuchs (81) demonstrated that a symbol sign's legibility distance could be improved by increasing the resistance to blur using a recursive design procedure. On the basis of these findings, Dewar et al. (78) developed the recursive blur technique—a successive approximation procedure for improving the legibility of graphic symbols (see Figure 9 for a schematic representation). The application of the recursive blur technique requires a set of computerized graphic tools and image-processing procedures that enable the graphic designer to modify and test continuously a graphic symbol to increase systematically its resistance to blur degradation and increase the legibility distance afforded by the revised symbol design (82). Comparisons of the legibility distance before and after optimization through the recursive blur technique have demonstrated significant gains in legibility distance for optimized signs (see Figure 10).

### *Traffic Signal Lights*

No comprehensive performance regulations or standards for traffic signal light visibility are available currently in the United States. Instead, traffic engineers responsible for purchase specifications or traffic signal deployment heavily rely on the Institute for Transportation Engineers (ITE) 1985 standard (83) or the Commission Internationale de l'Éclairage (CIE) 1988 guidelines and recommendations (84). Unfortunately, the ITE standard is not firmly based on the human-performance research literature, and there is a considerable amount of disagreement between the two competing documents. Table 10 summarizes the major elements of traffic signal design from the ITE and CIE guidelines.

Only about one-third of the light reaching the retina of a typical 20-year-old driver will reach the retina of a typical 75-year-old driver. Under such circumstances as dim illumination of green-blue-colored targets, this age-related reduction in retinal illumination may be as low as a factor of 10 (85). Clearly, the situation suggests that the emerging visual requirements of older drivers need to be considered in any effort to generate standards or guidelines for traffic signal lights. Neither the ITE nor the CIE specifications thoroughly consider the potential difficulties that older drivers may encounter with traffic signal visibility. Recent research also has suggested that some aspects of these guidelines may fall short of accommodating the needs of older drivers.

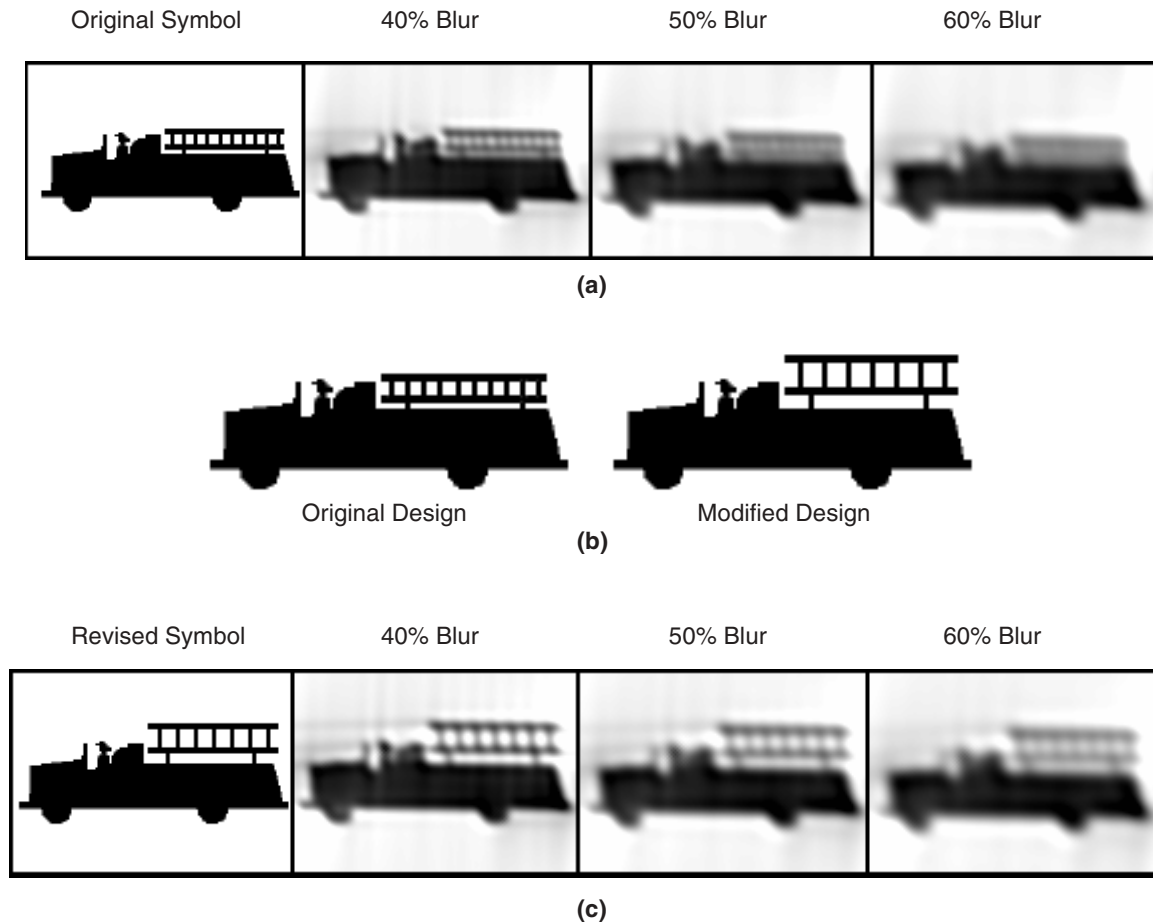


FIGURE 9 Recursive blur technique for optimizing symbol sign legibility. (a) Step 1: Level of blur was increased progressively until details in original symbol became unrecognizable. The ladder—a detail necessary for identification of symbol as fire truck—became unrecognizable at both 50% and 60% blur levels. (b) Step 2: Using graphic tools, the designer modified the symbol under optimization to make the symbol more resistant to blur degradation effects. Overall size of the ladder element was increased, but some rungs of the ladder were eliminated. (c) Step 3: The symbol's modified or revised version was blurred progressively to determine if a new design was more recognizable under higher levels of blur than the original version. Comparisons of the progressive blur series demonstrated that the modified version of the symbol became more resistant to the blur degradation—the revised version of the symbol remained recognizable at the blur levels, but the original symbol design degraded significantly. Step 4: The blur modify–blur inspect cycle was repeated to render the symbol recognizable under higher levels of blur. FHWA-sponsored research has demonstrated a significant improvement in legibility distances afforded by highway sign symbols that have been optimized using the recursive blur technique.

In an extensive analytic review, Freedman et al. (86) concluded that the minimum daytime brightness levels for red traffic signals specified by ITE—as well as for green and yellow signals specified by CIE—may be too low to accommodate the needs of older drivers. An examination of Table 10 reveals that ITE's recommended intensity for red signals and the CIE's recommended intensities for green and yellow signals fall short of Freedman et al.'s determination of 200, 265, and 600 cd, respectively, for red, green, and yellow traffic signal lights. Although the ITE standard does not address the issue of nighttime intensity levels, the CIE guidelines recommend a minimum nighttime intensity of 25 cd and a maximum nighttime intensity of 200 cd.

The CIE guidelines specify that a range of nighttime intensities between 50 and 100 cd should be maintained when possible.

Performance data collected from a sample including representative older drivers suggest that even the more conservative nighttime minimum intensity of 50 cd may be too low. Freedman et al. (87) recommended that the minimum nighttime intensity levels required to accommodate the needs of older drivers were 50, 95, and 220 cd for red, green, and yellow traffic signal lights, respectively. Little experimental work has been conducted to determine maximum nighttime intensity levels, although some indirect evidence has shown that the 200-cd CIE recommendation may be associated with

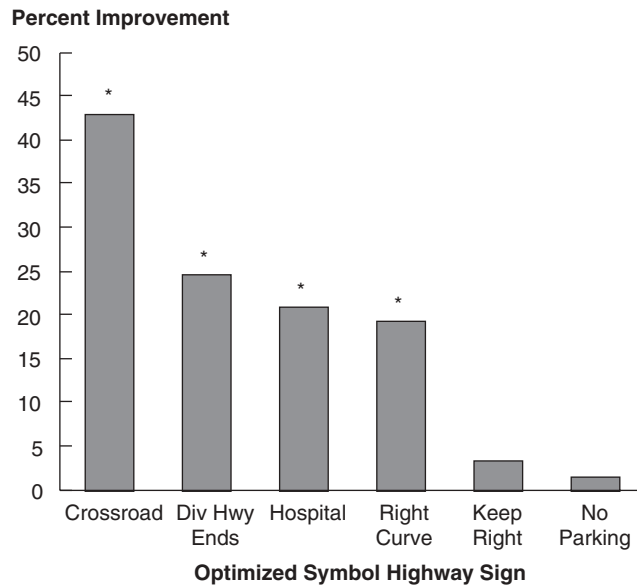


FIGURE 10 Relative increase in symbol sign legibility distance following application of recursive blur optimization technique. Asterisk denotes statistically significant before-and-after comparisons.

excessive levels of glare for older drivers, for example, who are stopped at an intersection with a traffic signal. Despite the summarized observations, all of the survey studies on driver visual complaints above failed to reveal self-reported difficulties with traffic signal lights.

The National Cooperative Highway Research Program sponsored a comprehensive study *Traffic Signal Brightness: An Investigation of Nighttime Dimming* (87). This

research included a series of laboratory and field studies to determine performance-based requirements for traffic signal intensity, intensity distribution, and related photometric parameters for a subject population that was oversampled with representative older drivers. The results of this study will be translated into a model standard, which hopefully will be adopted in future releases of the ITE and CIE specifications—both of which currently are being revised.

### HIGHWAY LIGHTING

Although the number of vehicle miles driven at night is much lower than the number driven during the day, over half of all traffic fatalities occur at night. On a per mile basis, the nighttime fatality rate is approximately three times higher than the daytime rate (88). Many studies have shown that well-designed fixed-lighting installations on roadways can reduce nighttime driving accidents significantly, especially accidents not directly related to alcohol intoxication (89). Given that normal adult aging is associated with large declines in nighttime visual functioning, it appears that older drivers would benefit specifically from improvements in highway illumination (10). Despite the fact that many studies have identified nighttime illumination as a critical area for research and development (90), little progress has been made in this area since the release of *Special Report 218*.

One of the reasons that little work has been conducted on nighttime illumination requirements for older drivers has been that they rarely drive at night.

TABLE 10 Summary of ITE and CIE Traffic Signal Design Standards for 200-mm (8-in.) Round Signal Lights

	ITE (83)	CIE (84)
Red light intensity (cd)		
Daytime	> 157	> 200
Nighttime	—	25 < I < 200 50 < I < 100 (advised)
Green light intensity (cd)		
Daytime	> 314	> 200
Nighttime	—	25 < I < 200 50 < I < 100 (advised)
Yellow light intensity (cd)		
Daytime	> 726	> 200
Nighttime	—	25 < I < 200 50 < I < 100 (advised)
Intensity distribution		
50% peak intensity	11° horizontal, 10° vertical	10° horizontal, 5° vertical
12.5% peak intensity	20° horizontal, 10° vertical	20° horizontal, 10° vertical
Arrow luminance	—	> 3000 cd/m <sup>2</sup>

— = no recommendation from source.

Data from the 1990 Nationwide Personal Transportation Survey, as depicted in Figure 11, reveal that the percentage of vehicle trips completed between dusk and dawn (7 p.m.–6 a.m.) declines from 24.9% at age 20–24 to approximately 2% for people age 85 or older. Mortimer and Fell (91) reported that drivers age 65 and older accounted for only 1% of all driver fatalities between midnight and 6 a.m. Several survey studies also have reported that older drivers intentionally reduce their amount of nighttime driving (59). The voluntary reduction in nighttime driving exposure often is interpreted as an adaptive behavior that compensates for marked age-related reductions in the older driver's ability to see at night.

FHWA recently initiated a contracted research project titled Night Driving and Highway Lighting Requirements for Older Drivers. The objectives of this project included an analytic study based on a small-target visibility model and related techniques aimed at finding the lighting practices that optimize old driver safety and mobility. Special emphasis is being placed on illumination engineering designs that improve the contrast of objects and potential hazards on the roadway and minimize the opportunity for glare. The project included a controlled field study to validate the principles from the analytic study. Results from the study should be available in Fall 2002.

Projects such as the FHWA initiative may be premature because researchers still know very little about how

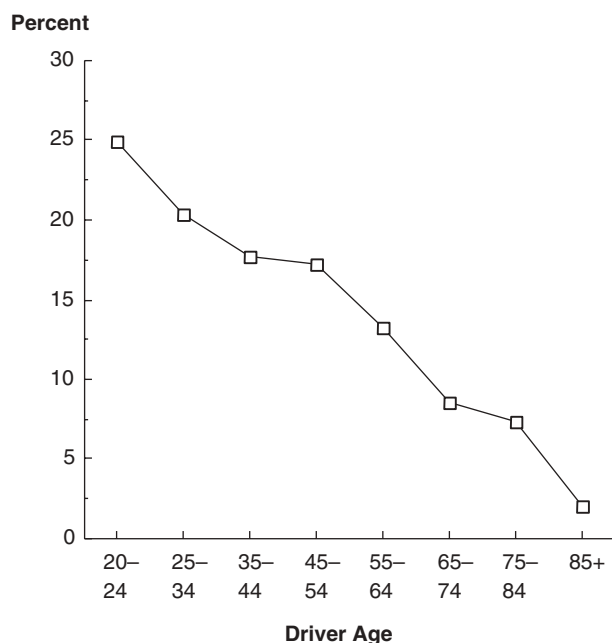


FIGURE 11 Percentage of vehicle trips taken at night as function of age, based on the 1990 Nationwide Personal Transportation Survey (19).

the effects of age-related visual changes affect nighttime driving performance. It may be difficult to fix the nighttime visual problems of older drivers before identifying the specific nature of the problems. Instead, several preliminary lines of research are needed in the area of aging and the nighttime illumination of highways. First, an analytic study could predict the future mobility needs of older drivers during nighttime hours. It appears likely that the next generation of drivers to grow old may want or need to drive more frequently at night. If this hypothesis is true, considerable efforts will be needed to improve the U.S. highway lighting infrastructure. Next, a comprehensive set of observational field studies could examine whether the nighttime mobility of older drivers changes as a function of the quantitative and qualitative levels of highway lighting installations. These studies also could provide the basis for determining the extent to which improved lighting might contribute to the mobility of older drivers. Finally, the effects of low levels of roadway illumination could be determined for basic driving behaviors, such as speed, lane tracking, and turning efficiency, and the subjective experience of workload and personal safety.

## SUMMARY

Two lists of suggestions for implementation and research needs are compiled below and are presented in descending order of priority. Appearance on either one of the lists is justified by supporting evidence from the review of the research literature above. However, the prioritization is biased highly toward personal experience, with limited domains of expertise.

## Implementation and Practice

1. The 85th percentile 75-year-old design driver should be adopted for all highway research, design, and decision-making purposes.

2. A 3-ft/s pedestrian walking speed should replace the 4-ft/s design speed in the MUTCD. The increase in the minimum walk interval required at a pedestrian crossing from 4 to 7 s in the millennium edition of the MUTCD is consistent with this recommendation.

3. The 40:1 legibility index for letter height on highway signs should be incorporated into federal, state, and local design guidelines. The MUTCD 2000 edition reflected this accommodation of the needs of older drivers by changing the legibility index from 50 ft (in the 1988 edition) to 40 ft of legibility distance per inch of letter height.

4. A standing review panel should be set up and funded to evaluate continuously the theoretical and

practical merits of the recommendations in the *Older Driver Highway Design Handbook*. This panel could maintain the handbook as a living document and could be highly instrumental in identifying areas where new research efforts can support the mobility and safety of older road users.

5. There should be continued support and application of the AASHTO intersection sight-distance and stopping sight-distance models for highway geometric design because these guidelines appear to accommodate the needs of the 85th percentile, 75-year-old design driver.

6. State-of-the-art high-brightness retroreflective materials are suggested especially for highway signs in unlit or highly cluttered urban areas.

7. The U.S. Department of Transportation should provide direct support for implementing the changeover from 4- to 6-in. letter heights for street-name signs, as specified in the MUTCD.

8. Increased use of durable fluorescent signs should be encouraged. Fluorescent orange signs should be considered for universal deployment in highway work zones. Fluorescent yellow-green signs should be deployed widely for pedestrian and school zone warning signs, as recommended in the MUTCD. Finally, the use of fluorescent yellow warning signs should be encouraged for deployment in high-density and high-speed traffic situations.

9. The greater use of symbol versions of highway warning signs should be encouraged. These signs have been shown to yield both high comprehension levels and superior legibility distances relative to their text sign counterparts.

10. The voluntary application of the Clearview font for new and replacement street-name signing applications should be encouraged by providing downloadable versions of the font that are compatible with most computer graphic application programs.

## Research

1. Develop performance-based requirements for highway sign legibility, and use these parameters to establish and validate minimum retroreflectivity requirements for the devices. Document cost-benefit analyses and trade-off studies to justify any specifications that fail to meet the performance-based requirements of the design older driver.

2. Develop performance-based requirements for roadway delineation, and use these parameters to establish and validate minimum retroreflectivity requirements for roadway markings. Document cost-benefit analyses to justify any specifications that fail to meet the performance-based requirements of the design older driver, particularly the increased visual requirements.

3. Carefully evaluate the conceptual and methodological basis of gap-acceptance models for highway geometric design relative to the characteristics of the 85th percentile, 75-year-old design driver.

4. Conduct studies to ascertain and model how older and young drivers scan the visual environment using state-of-the-art eye-tracking techniques. Determine what visual information drivers use and when they need it. This invaluable input will assist with the development of a system-level approach for providing information to drivers through traffic-control devices and ITS in-vehicle technologies.

5. Ascertain how geometric design, traffic-control devices, and ITS can be modified to accommodate the problems that older drivers experience when merging into high-speed and high-density highway traffic.

6. Evaluate the affects of small-target visibility models of highway lighting design on the performance, comfort, and fatigue of older drivers.

7. Investigate the magnitude and extent to which driver fatigue disproportionately may influence performance of older drivers.

8. Evaluate the performance and workload demands of traffic-calming techniques, such as lane narrowing and roundabouts, on the oldest drivers before the development of new traffic-calming regulations and guidelines.

9. Develop a system-level approach to the design, placement, and maintenance of highway signs. Bigger and brighter may not be the optimal solution; instead, learn how to use the principles of information redundancy and consistency.

10. Model and evaluate the dramatic reluctance of older drivers to execute RTOR operations in urban areas with varied traffic capacity.

11. Evaluate the affects of various levels of street lighting on the mobility of older drivers. Conduct cost-benefit analyses to determine if increased investments in highway lighting infrastructure will be needed to accommodate the rapidly increasing proportion of older drivers experiencing nighttime visibility problems.

12. Further study and quantify the role of durable fluorescent colors in the improvement of conspicuity and legibility of highway signs for older drivers. The safety and mobility affect of the signs should be robust, especially in work zone areas and high-density urban traffic situations.

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# Highway Enhancements to Improve Safety and Mobility of Older Road Users

## Practical Applications

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The increasing number and proportion of older road users in the United States presents a special urgency for highway designers and traffic engineers. Maintenance of health, personal dignity, and overall quality of life for seniors depends on remaining independent to an extraordinary degree, and independence requires mobility. Without diminishing the need for desirable, affordable transportation alternatives, it is safe to assume that virtually all who can continue to drive will continue to drive.

It has been well documented that many functional capabilities contributing to safe driving decline as a consequence of normal adult aging. However, ample evidence has shown that the impact may be mitigated by engineering improvements, which also benefit younger, more functional drivers. With the projection that age-related diminished capabilities will surpass alcohol as a causal factor of traffic fatalities in the early decades of the 21st century (1),<sup>1</sup> system safety places a high priority not only on identifying highway enhancements but also on implementing them as soon as feasible.

This paper directs attention to the highway modifications that can make an immediate difference. The cost of modifications exceeds only modestly, if at all, the cost of current practices that fail to meet the needs of many seniors. Some promising practices that rely

on expensive or unproven new technology are ignored. Wholesale changes to the infrastructure are cost prohibitive. Replacement of all signs, signals, markings, and so forth is simply not an option. The priorities for application of the recommendations in this paper are

- New construction,
- Reconstruction of current facilities,
- Regularly scheduled maintenance activities and spot treatments where crashes have occurred, and
- Other demonstrated safety problem-solving or locally desired proactive approaches.

This paper complements the paper on highway research to enhance the safety and mobility of older road users by Schieber, which discusses underlying theoretical issues and future research needs, by focusing on near-term implementation opportunities. The opinions of practitioners proved essential to this paper's development. The release of the Federal Highway Administration's (FHWA's) *Highway Design Handbook for Older Drivers and Pedestrians* (2) opened a constructive dialogue with more than 500 state and local highway designers and engineers. Obtained during a series of workshops throughout the United States in 1999 and 2000, their feedback was used to prioritize a subset of the handbook's contents for presentation here. The resulting recommendations focus on common situations where enhancements will have the broadest range of benefits and can be implemented in the shortest possible time frame.

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<sup>1</sup> Citations are limited; where references are included to support countermeasure recommendations, consultation of primary sources is encouraged for study methodology.



## PROBLEM-SITUATION SOLUTION TOOLS

Crash statistics, research, focus groups, and surveys have defined several situations in which older drivers and pedestrians experience the greatest difficulty. The degree of difficulty to meet the driving task demands of the situations can be influenced strongly by the range of tools available to practitioners with highway design and operations responsibility. The following text presents a rationale for the selection of five problem situations and a discussion of the tools available to practitioners to ameliorate the difficulties.

### Nighttime Driving

The link between reduced visibility and either crashes or mobility costs for older road users may be difficult to quantify but is straightforward conceptually. Low light levels contribute to a reduction in visual capabilities, such as acuity, contrast sensitivity, distance judgment, sight speed, color discrimination, and glare tolerance. These conditions already are diminished in older drivers (3, 4). Later processing stages, such as target recognition, perception, and comprehension, depend on visual information to an overwhelming extent. A delay or inability to detect key elements in the driving scene compounds age-related difficulties in attention switching, gap judgment, complex reaction time, decision making, and initiation of control movements—which inevitably compromise timely and appropriate vehicle control responses. When asked to rank driving activities that have become more difficult in the past 10 years, 62.2% of 644 Illinois seniors ranked driving at night as the highest (5). Many surveys have reported that older drivers intentionally reduce their nighttime driving exposure (e.g., 6). Self-regulation is commendable, but some are concerned about an effort directed toward increasing the amount seniors drive at night. An increase in nighttime visibility of the roadway and immediate environment would permit all drivers to maneuver more safely and efficiently, especially older drivers.

### Intersections

The greatest concern for accommodation of older road users, both drivers and pedestrians, involves the ability to maneuver safely through intersections. About half of the fatal crashes involving drivers age 80 and older occur at intersections, compared with 23% or less for drivers age 50 years or younger (7). Within the large body of evidence showing dramatic increases in intersection crash involvement as driver age increases, analyses have revealed detailed patterns of data that associate

specific crash types and vehicle movements with particular age groups. Some cases have linked these patterns to the driving task demands in a given maneuver situation (8–10). Crash analyses and observational studies are complemented by focus-group reports, surveys, and other subjective data from older road users; a large percentage of seniors confirmed experiencing difficulty as drivers and as pedestrians with the diverse aspects of intersection negotiation (5, 11).

### Freeways

Between 1977 and 1988, older-driver freeway travel has increased dramatically (12), and this trend is expected to continue, because tomorrow's seniors will have decades of familiarity with freeway driving. Although freeways have the highest safety level (lowest fatality rate) when compared with other types of highways in rural and urban areas (13), analyses of crashes in the vicinity of freeway interchanges have shown that drivers age 75 or older are overrepresented as the driver at fault in merging and weaving incidents (10). In a Michigan data set, older drivers also were cited most frequently for failing to yield and for improper lane use. Lunenfeld (14) described interchanges as locations where a driver must process a large amount of directional information in a short period of time and at high speeds, while maintaining or modifying a position within the traffic stream. Unfamiliar locations exacerbate this condition. Erratic maneuvers resulting from driver indecisiveness in these situations include encroaching on the gore area and even backing up on the ramp or the through lane. In Lerner and Ratté's research (12), focus groups cited merging onto the freeway as the most difficult maneuver.

### Pedestrian Crossings

Overinvolvement of older pedestrians in injury and fatal crashes at intersections provides a strong basis for concern. Knoblauch et al. (15) analyzed data from the Fatal Accident Reporting System for the 1980s. They found that 32.2% and 35.3% of the deaths of pedestrians ages 65–74 and 75 or older, respectively, occurred at intersections, in comparison with 22% or less for two younger groups (ages 10–44 and 45–64). Hauer (16) reported earlier that when the proportion of people 65 and older in the population was 12%, this group accounted for 39% of all pedestrian fatalities.

In a survey of older pedestrians in the area of Orlando, Florida, 25% of the participants reported difficulty seeing the crosswalk signal from the opposite side of the street (17). Besides reduced visual acuity, other diminished capabilities that complicate older pedestri-

ans' negotiation of intersections include decreased contrast sensitivity, reduced peripheral vision and useful field of view, decreased ability to judge safe gaps, slowed walking speed, and physical restrictions from arthritis and other health problems. Documented behaviors indicating the problems seniors experience when crossing intersections include spending more time at the curb, taking longer to cross the road, and making more head movements before and during a crossing (18).

## Highway Work Zones

In a crash analysis of 20 work zones, two of the most frequently listed contributing factors were driver attention errors and failure to yield the right-of-way (19). Older drivers most likely demonstrate these deficits. Special attention to older-driver needs in highway construction and maintenance zones deserves consideration because decisions of multiple or unfamiliar alternatives, or both, have unexpected path-following cues—that is, the decisions present a strong potential to violate driver expectancy. Work zone traffic control must provide an adequate notice to motorists that describes the condition ahead, the location, and the required driver response. Once drivers reach a work zone, pavement markings, signing, and channelization must be conspicuous and provide particular guidance. The National Transportation Safety Board indicated that the *Manual on Uniform Traffic Control Devices* (MUTCD) guidelines may be inadequate for an inattentive or otherwise impaired driver (20). Within this context, functional deficits associated with normal adult aging place many older drivers at greater risk when negotiating work zones.

## General Solutions and Tools

Professionals who design highway facilities and control operations use an extensive array of materials and practices that dictate the significant features of the roadway environment and, to a large degree, people's interaction with the roadway. Key elements of highway design and operations for discussion include

- The physical dimensions of paved surfaces on the traveled way, geometry of the junctions, and changes in vertical and horizontal alignment;
- The rules determining how fast traffic moves, which lanes traffic moves in, which maneuvers are permitted or prohibited, who has right-of-way to proceed under specified conditions, which types of vehicles are permitted on what classes of roadways, and how vehicles and pedestrians share the space where the two come into potential conflict;

- Fixed or static traffic signs that convey regulatory (black characters on white background), warning (black characters on yellow or orange background), and navigational (white characters on green background) information to drivers;

- Changeable message signs (CMS) that typically have three lines of internally illuminated characters, which are placed on portable signs at the roadside or on larger displays mounted over the highway, to present urgent information about changes in the traffic, road, or environment;

- Traffic signal lights displaying the common round ball and arrow indicators, mounted overhead and on the corners or medians at intersections;

- Pavement markings of painted lines and arrows that show lane boundaries and the road's edge and that may be used to indicate a maneuver (e.g., a turn is either permitted or prohibited) and to convey information on what lane to use to complete or avoid the maneuver; and

- Raised retroreflectorized surfaces and objects placed in the road or on the side of the road to delineate the path of travel and the presence of barriers or obstacles (including, but not necessarily limited to, small reflectors embedded in the pavement; painted curbs and medians; and reflectorized posts, tubes, cones, barricades, and drums).

Designers and engineers configure the elements above to move anticipated volumes of vehicles, pedestrians, and cyclists as safely and smoothly as possible. Standards of practice—notably the American Association of State Highway and Transportation Officials' (AASHTO's) *A Policy on Geometric Design of Highways and Streets* (21) and FHWA's MUTCD (22)—establish design values for features of highway geometry, rules of operation for different types and classes of roadways, and specific devices that must be used in particular circumstances to convey regulatory, warning, and guidance information to drivers. Additional sets of guidelines that practitioners commonly rely on to ensure system safety and operational efficiency include the *Highway Capacity Manual* (23) and the *Roadway Lighting Handbook* (24).

Each of the principal standard documents undergoes periodic revision. As part of the review and revision process, new research findings on driver performance that specifically focus on age-related limitations redefine the design driver. The responsible government agencies and expert advisory committees adjust the standards of practice as appropriate. But within the manuals above, significant latitude is allowed for engineering judgment. For example, decisions about when to use particular devices on highways—as well as adjustments in size, brightness, placement, and other attributes—frequently



are permitted if justified by engineering studies. These studies may be driven by capacity considerations—that is, how to accommodate the volume of traffic seeking to use a road. The studies also may reflect a user needs assessment, when better accommodation of the capabilities or restrictions of drivers or pedestrians represents the deciding factor. The decision to prohibit right turns on red at an intersection often reflects a problem (e.g., bushes, buildings) that obstructs the driver's view of approaching (cross) traffic. In this case, neither a young nor an old driver's abilities are adequate to stop a turning movement in time to avoid a crash if the driver has only 1 or 2 s to detect an approaching vehicle before the vehicle enters the intersection.

The central question then becomes, Using the tools available, what highway enhancements have the highest safety impact? Table 1 presents an overview of where the most practical fixes can be implemented to help preserve and extend safe mobility for the largest number of normally aging individuals. Specific recommendations follow.

## RECOMMENDATIONS FOR HIGHWAY ENHANCEMENTS

The recommendations follow the same problem areas and situations as above. Some recommendations are crosscutting by providing benefits across multiple driving situations but appear only once (based on where the countermeasure has the greatest safety impact for older road users). Technical terminology for certain highway features and traffic control elements has been preserved intentionally. This approach allows for sufficient precision so that the recommendations are meaningful to both practitioners and lay audiences.

### Nighttime Driving

For nighttime driving, a large benefit would be expected from treatments that give motorists a better indication of lane and road boundaries and of the proper use of travel

lanes. This indication may be accomplished in most cases through a more effective use of painted markings on the road surface and raised delineation treatments. The selective use of larger and brighter signs also is recommended. Although the most expensive to implement, a fixed lighting installation may represent the only viable solution for certain high-crash or -conflict locations.

The diminished visual capabilities of older drivers dictate increases in the contrast levels of painted edge-line markings against the background of the surrounding pavement. Problems occur where edge lines have not been applied or, more commonly, not maintained. This condition usually is found at locations other than intersections under low-beam headlight illumination at night.

- Install and maintain white edge lines of normal width (22) on horizontal curves at an effective luminance ( $L$ ) contrast level of at least 5.0 on all highways, including arterials, without median separation of opposing directions of traffic. Luminance contrast equals the brightness of the target (stripe or marking), minus the brightness of the background (surrounding pavement surface), and divided by the brightness of the background.

$$\text{Luminance contrast} = \frac{L_{\text{strips}} - L_{\text{pavement}}}{L_{\text{pavement}}}$$

- Maintain a minimum in-service contrast value of 3.75 for pavement edge lines on horizontal curves when median barriers effectively block a driver's view of oncoming headlights or the median width exceeds 15 m (49 ft).
- Maintain a minimum in-service contrast level of 2.0 between pavement edge lines and the adjacent road surface for intersections with overhead lighting and a minimum in-service contrast level of 3.0 for intersections without overhead lighting.

Highway construction and maintenance authorities typically do not measure and calculate contrast values for treatments. New thinking is needed. Practitioners could measure the retroreflectance values ( $R_L$ ) for treat-

TABLE 1 Practical Solutions for Older Road Users in Selected Problem Situations

Problem Situation	Practical Countermeasure Elements						
	Static Signs	Changeable Signing	Traffic Signals	Pavement Markings	Other/Raised Delineation	Geometric Design	Traffic Operations
Nighttime driving	✓			✓	✓		
Urban-suburban intersections	✓		✓	✓	✓	✓	✓
Freeways	✓	✓		✓	✓	✓	
Pedestrian crossings	✓					✓	✓
Work zones	✓	✓		✓	✓		✓

ments and pavements and then consult tables or databases that give headlight (low-beam) illumination distributions to determine the available contrast for a driver at a given distance and angular orientation from the pavement marking. Using a simpler approach, they could incorporate direct luminance readings of the treatments and pavements, from inexpensive handheld meters, into regularly scheduled maintenance activities and then perform the straightforward calculation above.

Next, various delineation treatments raised above the pavement surface provide extra information to help drivers steer safely. These treatments are useful particularly during wet weather and at night. Raised delineation treatments are recommended for conventional and limited-access highways.

- Install centerline raised-pavement markers at standard spacing beginning at a 5-s driving time (at operating speed) before and continuing through the length of all horizontal curves with a radius smaller than 1,000 m (3,281 ft).
- Install roadside delineation devices at a maximum spacing (*S*) of 12 m (40 ft) on all horizontal curves with a radius smaller than 185 m (600 ft).

- Apply post-mounted delineators or chevrons, or both, to delineate the controlling curvature on exit-ramp deceleration lanes.
- Install exit gore delineation for nonilluminated and partially illuminated interchanges (Figure 1).

Other raised surfaces that help meet drivers' needs for visual guidance include curb lines, raised median barriers, and islands for channelizing traffic into lanes with different movements (e.g., to separate through traffic from turning traffic). Channelization provides well-documented traffic safety benefits (25–27) and can provide a refuge for pedestrians. At the same time, the potential for negative impacts is higher for aging drivers. They more likely will lose control of the vehicle and will be injured if they strike a raised object (28). To make the most of safety benefits of these treatments, the treatments should have high visibility.

- Delineate all curbs at intersections (including median islands and other raised channelization) with retroreflectorized markings on the vertical face and at least a portion of the top surface in addition to a retroreflectorized edge line on the road surface.

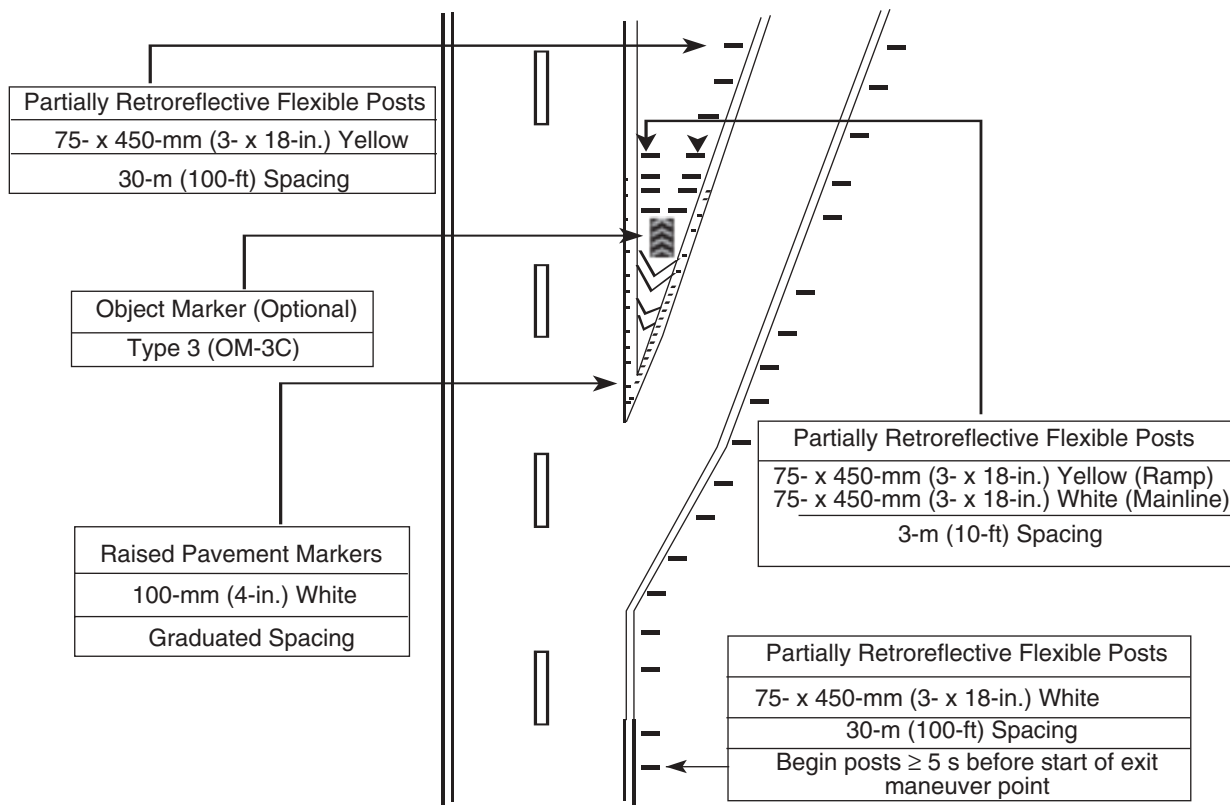


FIGURE 1 Exit gore delineations.

- Delineate median noses using retroreflectorized markings to increase visibility and improve driver understanding of the intersection design and function.

- Raise current channelization (using sloping, “mountable” curbs) with pavement markings for right-turn lane treatments at intersections and for left-turn treatments on roads with operating speeds of less than 40 mph. Treat island curb sides and curb surfaces with retroreflectorized markings, and maintain a minimum luminance contrast level of 3.0 or higher under low-beam (passenger vehicle) headlight illumination.

Many desirable enhancements in highway signing have been identified, but the following recommendations are expected to have the most significant payoff during nighttime operations:

- The minimum sign background (red area) retroreflectivity level for “Stop” (R1-1) and “Yield” (R1-2) signs should be 12 cd/lux/m<sup>2</sup>; below that, signs on roads with operating speeds slower than 64 km/h (40 mph) should be replaced. “Stop” signs and “Yield” signs on roads with operating speeds of 64 km/h (40 mph) or faster should have a minimum retroreflectivity level of 24 cd/lux/m<sup>2</sup>.

- For “Do Not Enter” (R5-1) and “Wrong Way” (R5-1a) signs, in accordance with sections 2A.24 and 2E.50 of the MUTCD, the minimum size of R5-1 should be 900 × 900 mm (36 × 36 in.) and the minimum size of R5-1a should be 1,200 × 800 mm (48 × 32 in.), with corresponding increases in letter sizes. Use high-brightness white (e.g., ASTM Type IX) and fluorescent red sheeting and a 900-mm (36-in.) mounting height (from the pavement to the bottom of the sign) or as close to this value as practical if snow or other obstructions are considerations.

- To accommodate age-related declines in visual acuity, use a minimum letter height of 150 mm (6 in.) for post-mounted street-name signs.

- On high-speed limited-access highways for new or reconstructed installations and at the time of sign replacement, calculate letter size requirements for signing on the basis of no more than 10 m (33 ft) of legibility distance for each 25 mm (1 in.) of letter height.

Finally, the benefits of roadway lighting must be acknowledged. However, the expense of installation and maintenance of roadway lighting necessarily limits the use to situations when the need is greatest. When feasible, fixed lighting installations are recommended where the potential for wrong-way movements is indicated, either through crash experience or engineering judgment; where pedestrian volumes are high; and where shifting lane alignment, turn-only lane assignment, or a pavement-width transition forces a path-following adjustment at or near an intersection.

## Urban–Suburban Intersections

As the locations for the largest percentage of older-driver fatalities, intersections are an obvious focus for countermeasures to accommodate seniors. Specific recommendations follow with two caveats. First, enhancements directed to the safer use of intersections by older pedestrians are addressed later in this paper. Second, the section above includes several recommendations for intersection improvements from the *Highway Design Handbook for Older Drivers and Pedestrians* because of special significance for nighttime operations. The enhancements to pavement markings, channelizing treatments, and signs in the vicinity of intersections noted above, other than enhancements directed to the maintenance of specified contrast levels or retroreflectivity values, also play a key role for safer daytime driving in complex and demanding situations.

The countermeasures below focus on elements of intersection geometry, traffic control and operations, signing, and delineation. Priorities for the following recommendations include geometric enhancements that can accommodate age-related physical limitations and can aid in the perception of traffic movements and judgment of gaps for the initiation of various movements at intersections:

- In the design of new facilities where right-of-way is not restricted, ensure that all intersecting roadways meet at a 90° angle.

- In the design of new facilities or redesign of current facilities where right-of-way is restricted, ensure that intersecting roadways meet at an angle no less than 75°.

- A receiving lane with a minimum width (for turns) of 3.6 m (12 ft), should add, where practical, a shoulder with a minimum width of 1.2 m (4 ft).

- Do not reduce the perception–reaction time (PRT) value in formulas for intersection sight distance to less than 2.5 s to accommodate older drivers who exhibit slower decision times and who prefer larger gaps.

- Provide a margin of safety for older drivers, who as a group do not position themselves within the intersection before initiating a left turn, by adding a positive offset to opposite left-turn lanes to achieve unrestricted sight distance.

- At intersections where engineering judgment indicates a high probability of heavy trucks during normal operations, implement the left-turn-lane (positive) offsets required to provide unrestricted sight distance for opposing left-turning trucks.

- To reduce the potential for wrong-way movements by turning drivers,

- At intersections with divided highways, add “Divided Highway Crossing,” “Wrong Way,” “Do

Not Enter,” and “One Way” signs, as per section 2B.30 and 2B.33 of the MUTCD, but use sign sizes larger than the MUTCD standard for conventional roadways and high-brightness, wide-angle retroreflective sheeting (e.g., ASTM Type IX) for the sign panels.

- Add retroreflective lane-use arrows (pavement markings) for channelized left-turn lanes and “Wrong Way” arrows in through lanes.

- Add retroreflective pavement markings that extend from the centerline and indicate the path through left turns, especially for dual and multiple turning lanes, except when extensions for traffic moving in opposite directions would cross.

- Except where precluded by high volumes of heavy vehicles, extend the corner curb radius to 7.5–9.0 m (25–30 ft) as a trade-off to facilitate vehicle-turning movements, to moderate the speed of turning vehicles, and to avoid unnecessary lengthening of pedestrian-crossing distances.

According to available evidence in the area of traffic control and intersection operations, countermeasures deemed most effective to accommodate older drivers’ diminished capabilities promote consistency, facilitate correct expectations about permitted and prohibited movements, reduce attentional demands or other information-processing requirements during intersection approach and negotiation, and aid comprehension and decision making. The following recommendations address the types of devices, special features, placements, and rules for use:

- Use protected-only signal operations for left turns—unless engineering judgment indicates that an unacceptable reduction in capacity will result. However, median width impacts on sight distance must be carefully considered.

- To reduce confusion at an intersection approach, use a separate signal to control turning phase movements for all signal operation modes.

- Implement a leading, protected left-turn phase with protected left-turn signal operations.

- Use common signing throughout the United States advising drivers of the correct response to a steady circular green signal indication during protected-permitted operations (e.g., R10-12, “Left Turn Yield on Green”), preferably placed overhead at the intersection.

- If a mounting location in the median or on an overhead structure is practical, use redundant upstream signing (R10-12, with a supplemental plaque ending with “At Signal”) to advise left-turning drivers of a permitted signal operation before they reach the intersection, thus improving driver expectancy by providing at least a 3-s preview of the rule for a permitted

operation before the driver has reached the decision point for initiation of the turn.

- To reduce confusion about the meaning of the red arrow indication, implement a steady green arrow for protected-only left-turn operations, which time out to a yellow arrow and then to a steady circular red signal.

- Where a minimum required sight distance—as calculated using a gap model or a modified AASHTO model with a 2.5-s PRT—cannot be achieved practically, eliminate permitted left turns and implement protected-only left-turn operations.

- At the intersection of a one-way street with a two-way street, place “One Way” signs at the near right or far left locations, regardless of left-to-right or right-to-left traffic.

- On divided roadways where the median width is 9 m (30 ft) or wider, use “Do Not Enter” and “Wrong Way” signs; consider using these signs also for median widths narrower than 9 m.

- Prohibit right turns on red at skewed intersections (where the angle is less than 75° or more than 105°).

- Add signing of prohibited right-turn-on-red movements, using the improved design (Figure 2, but in a standard highway font), on the overhead mast arm and at a location on either the near or opposite side of the intersection where the sign will be most conspicuous.

- To reduce confusion with the meaning of the (right-turn) red arrow, use a steady circular red signal at intersections where a right turn is prohibited, supplemented by the improved “No Turn on Red” sign.

- Implement advance (midblock) street-name signing at major intersections and mount overhead, where practical.

- At a minimum, use the standard size of 750 mm (30 in.) for a “Stop” sign (R1-1) and of 900 mm (36 in.) for a “Yield” (R1-2) sign (below-standard size R1-1 and R1-2 signs are not acceptable under any circumstances).

- Add a “Stop Ahead” sign (W3-1a) when the distance at which the stop sign is visible equals less than the AASHTO stopping sight distance (SSD) at operating speed plus an added preview distance of at least 2.5 s.

- Add a supplemental warning sign panel (W4-4p), mounted below the stop (R1-1) sign (Figure 3,

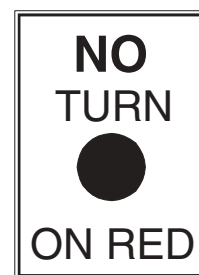


FIGURE 2 “No Turn on Red” sign.



FIGURE 3 “Cross Traffic Does Not Stop” sign.

but in a standard highway font), for two-way stop-controlled intersection sites selected on the basis of crash experience, where sight distance for the intersecting (major) highway is restricted and where a conversion from a four-way to a two-way stop operation is implemented.

- Maintain consistent postings of lane-use control signs and apply lane-use arrow pavement markings at a preview distance of at least 5 s (at operating speed) before a signalized intersection, regardless of the specific lighting, channelization, or delineation treatments at the intersection. Mount signs overhead when practical or on shoulder or median.

- At signalized intersections, consistently implement an all-red clearance interval, with the length determined according to the Institute of Transportation Engineers (29) to accommodate age differences in PRT.

- Consistently use a backplate with traffic signals on roads with operating speeds of 65 km/h (40 mph) or faster, and use a backplate with signals on roads with operating speeds slower than 65 km/h (40 mph), prioritized according to the potential for sun glare problems, site history, and other variables identified by engineering judgment.

As noted above, the largest reduction in older-driver fatalities likely will occur with intersection improvements because intersections constitute the greatest safety problem by a wide margin. The previous recommendations were developed through FHWA sponsorship (2) to supplement the current guidance provided to practitioners through standard design manuals. In some cases, the indicated countermeasures reflect innovative practices that research studies have suggested will have particular benefit for seniors. In other cases, an indicated countermeasure already reflects a practice described in a standard design manual but is only one of an acceptable range of alternatives. These countermeasures are included to emphasize adherence to a particular value in the range, as a minimum, to accommodate older road users.

## Freeways

The high speeds at which drivers enter, travel, and exit freeway facilities require a rapid and efficient search for guidance cues, recognition, and comprehension of traffic-control elements, as well as effective decision making under a high information load and divided attention conditions, to accomplish maneuvers safely and without disruption to other traffic. The following countermeasure recommendations were developed with these needs in mind. Additional enhancements to facilitate senior freeway driving are included in the section on nighttime driving.

- To speed the comprehension of lane assignment for maneuvers downstream, modify the diagrammatic guide signing displayed in the MUTCD so that the number of arrow shafts appearing on the sign matches the number of lanes on the roadway at the sign’s location (Figure 4).

- When local roads are near an entry ramp terminus—which may cause confusion—consistently use 1200- × 750-mm (48- × 30-in.) “Freeway Entrance” signs for positive guidance—which is cited as an option in the MUTCD—with a minimum letter height of 200 mm (8 in.) in a Series D or wider font.

- Where adjacent entrance and exit ramps intersect with a crossroad, place a median separator with the nose of the separator delineated with a yellow retroreflectorized marking and extending as close to the crossroad as practical without obstructing the turning path of vehicles. Also place a “Keep Right” (R4-7a) sign on the median separator nose. If the median nose is set back, the distance from the nose to the intersection should be treated with a 300-mm (12-in.) yellow stripe or wider, bordered by yellow ceramic buttons that touch all along the stripe’s length.

- Apply 7.1-m (23.5-ft) “Wrong-Way” arrow pavement markings near the terminus on all exit ramps.<sup>2</sup>

- For motorists traveling at freeway speeds, present messages using portable CMS that preferably are limited to a single phase but do not exceed two phases. If a message cannot be conveyed in two phases, use multiple CMS or a supplemental highway advisory radio message, or both.

The following recommendations are a priority for improved geometric design of freeway facilities:

- Determine acceleration lane lengths using the higher of AASHTO (21) Table X-4 speed-change lane criteria or National Cooperative Highway Research

<sup>2</sup> See MUTCD (22), Section 3B.19, Figure 3B-22.



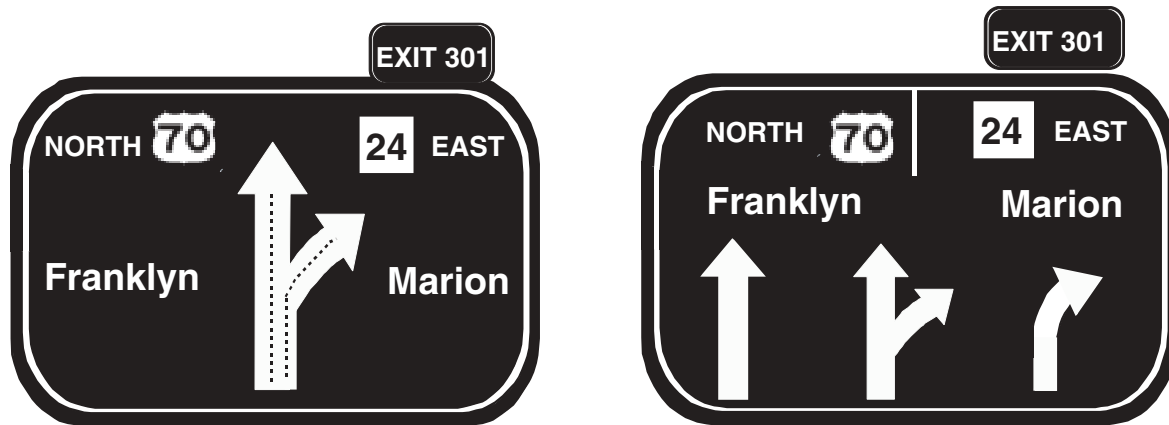


FIGURE 4 Examples of arrow shafts that match number of roadway lanes.

Program 3-35 (30) values for a given set of operational and geometric conditions and assuming a 65-km/h (40-mph) ramp speed at the beginning of the gap-search and -acceptance process.

- To better accommodate drivers who rely on mirrors because of a difficulty in turning the head to look over the shoulder during merging operations, implement a parallel, as opposed to a taper, design for entrance ramp geometry.

- To accommodate longer PRTs for seniors, apply AASHTO decision sight-distance values consistently when locating ramp exits downstream from sight-restricting vertical or horizontal curvature on the mainline of the freeway (instead of locating ramps based on SSD or modified SSD formulas).

### Pedestrian Crossings

With the development of recommendations to make the driving task safer and easier, especially at intersections, some trade-offs will penalize pedestrians. Because age-related declines in physical strength and agility and sensory (vision and hearing) losses make seniors less likely to detect approaching vehicles, they have an increased risk of being struck as pedestrians, both by through and turning drivers. If a senior is struck, the increased vulnerability results in more serious injuries and a higher chance of fatality than for a younger pedestrian. The selected enhancements recommended for pedestrian crossings fall within the domain of improved traffic- and pedestrian-control devices and operations.

- When a pedestrian crosswalk is delineated and engineering judgment indicates a clear potential for right-turning vehicles to encounter pedestrians using the crosswalk for permitted crossings, post a “Turning

Traffic Must Yield to Pedestrians” sign in a location visible to drivers before making the turn.

- To accommodate the shorter stride and slower gait of less capable (15th percentile) older pedestrians and an exaggerated start-up time before leaving the curb, base pedestrian-control signal timing on an assumed walking speed of 0.85 m/s (2.8 ft/s). At intersections with high pedestrian volumes and a “No Turn on Red” control for traffic moving parallel to a marked crosswalk, set a leading pedestrian interval between the onset of the “Walk” signal and the green light for traffic to reduce encounters between pedestrians and turning traffic. Time the interval to allow slower walkers to cross at least one moving lane (i.e., not parking lane) of traffic.

- Add a placard explaining the pedestrian-control signal operations (Figure 5), and include a warning to watch for turning vehicles at the near corner of all intersections with a pedestrian crosswalk.

- At intersections where pedestrians cross in two stages using a median refuge island, put the left placard of Figure 5 on the median refuge island and the right placard of Figure 5 on the near corner of the crosswalk.

### Highway Work Zones

The proliferation of unfamiliar and often conflicting cues for changes in the number, heading, and boundaries of travel lanes presents challenges to all drivers, but the functional deficits associated with normal aging place older drivers at a greatest risk. The following recommendations are designed to reduce the information-processing demands placed on drivers approaching a work zone, to improve the drivers’ expectancies of the proper path to follow through the work zone, and to render the cues where these expectancies are confirmed more visible, conspicuous, and comprehensible to older drivers.

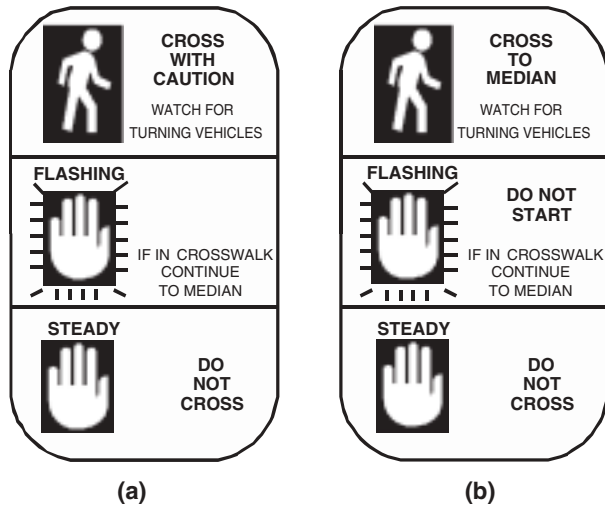


FIGURE 5 Pedestrian-control signal placards for (a) roads without median refuge island and (a and b) roads with median refuge island.

- On high-speed and divided highways, consistently use a flashing arrow panel at the taper for each lane closure.

- Reinforce the earlier recommendation that no more than two message phases be displayed on portable CMS, with no more than one idea or unit of information displayed on one CMS line and no more than three units displayed during any one phase. A unit of information consists of one or more words that answer a specific question—for example, What happened? Where? What is the effect on traffic? What should the driver do?

- For advance signing of lane closures—as per Part 6 of the MUTCD—place 800–1600 m (2,625–5,250 ft) upstream of the lane closure taper, or redundant static signing, supplemental portable CMS displaying the one-phase message “Left Lane Closed” (or right or center lane equivalent), with fluorescent orange sheeting and a minimum letter height of 200 mm (8 in.). Equip both the first (e.g., W20-1) and the second upstream sign (e.g., W20-5) with flashing warning lights throughout the time of the lane closure.

- For CMS messages split into two phases, use no more than four unique ideas or units of information.

- Display each phase of a CMS message for a minimum of 3 s.

- Where abbreviations are necessary in CMS operations, carefully adhere to the “acceptable,” “not acceptable,” and “acceptable with prompt” categories in the MUTCD 2000.

- Add channelizing devices to a work zone without a highway crossover, and space (in feet) throughout taper and transition sections at no more than the speed limit (in miles per hour). Space channelizing devices (in feet) throughout the taper for a lane closure no more than half the speed limit (in miles per hour).

- Add positive barriers in transition zones and positive separation (channelization) between opposing two-lane traffic throughout a crossover for all roadway classes except residential.

- For a highway crossover, use a minimum spacing (in feet) of half the construction zone speed limit (in miles per hour) for channelizing devices other than concrete barriers in transition areas and through the length of the crossover and in the termination area downstream—that is, where operations resume as they were before the crossover.

- Use the following minimum dimensions for channelizing devices in highway work zones to accommodate the needs of older drivers:

- Traffic cones—900 mm (36 in.) in height with two bands of retroreflective material of which the total width equals at least 300 mm (12 in.) for nighttime operations;

- Traffic tubes—1,050 mm (42 in.) in height with a single band of retroreflective material at least 300 mm (12 in.) wide for nighttime operations;

- Barricades—300 × 900 mm (12 × 36 in.);

- Drums—450 × 900 mm (18 × 36 in.) with orange and white retroreflective stripes of high-brightness sheeting.

- On high-volume roadways, mount plastic glare-control louvers (paddles) on top of concrete channelizing barriers in transition and crossover areas and space the barriers no more than 600 mm (24 in.) apart.

- For temporary pavement markings shorter than the standard length of 3 m (10 ft), place a raised pavement marker at the center of the gap between successive markings.

## CONCLUSION

As a normal consequence of aging, an older person can expect to not see as well, react as quickly, or attend to the driving task as efficiently. For a large segment of the older-driver population, these changes in the ability to drive safely can be accommodated, at socially acceptable costs, through more human-centered highway design and engineering practices.

The highway improvements in this paper represent a subset of the practices recommended in FHWA’s *Highway Design Handbook for Older Drivers and Pedestrians* (2). The handbook includes additions to the recommendations for highway features and operating conditions covered in this paper and recommendations for design elements not covered in this paper, such as roundabouts and highway–rail grade crossings.<sup>3</sup>

<sup>3</sup> The extensive practitioner review process contributing to the handbook’s development is also highlighted, plus a full accounting of the research findings and rationale for the recommendations.

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# Safety of Older Pedestrians

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Pedestrian travel is a major mode of transportation, even in highly motorized countries, and all road users are pedestrians at least some of the time that they use the road system. In Europe, for example, predominantly pedestrian trips account for 34% of the total number of trips in Britain, 17% in the Netherlands, and 23% in Sweden (1). Older adults make more pedestrian journeys than younger adults do because older adults are less likely drivers, less able to drive, and less able to afford to drive (2). For older adults, the proportion of pedestrian journeys has been estimated at between 30% and 50% of all journeys (3). Although the importance of walking has been underestimated in the past, walking is vital to the mobility of older road users for not only essential daily tasks but also social contacts and exercise. It follows that safe pedestrian travel also is an important factor in maintaining mobility for older road users. There is an urgent need to provide pedestrian-friendly road environments that are safe, convenient, and comfortable.

Elderly people are a rapidly expanding segment of the population who are especially vulnerable to injuries. Older road users currently do not represent a major road safety problem in terms of numbers in most western societies; nonetheless, compared with younger road users, older road users are involved in significantly more serious injury and fatal crashes per person. Older pedestrians in particular represent one of the most vulnerable road user groups. In most countries, older pedestrians have a significantly increased risk of death in a pedestrian crash when the rates are compared with those for younger pedestrians. Figure 1 shows that

pedestrians age 65 and older are overrepresented in fatal pedestrian crashes, compared with younger age groups, in most nations of the Organisation for Economic Co-operation and Development (OECD; e.g., Australia, Italy, Japan, Spain).

However, when all severity crashes are taken into account, this dominance is reduced. For example, in Britain in 1998 (4), for people age 60 and older, pedestrians comprised 21% of the total casualties, compared with car drivers (38%), car passengers (25%), bus passengers (10%), and other road user groups (6%). This issue has not been resolved completely, mainly because of the difficulties in the construction of consistent and comprehensive data. But it is clear that older road users' overrepresentation in population-based fatality rates greatly diminishes after casualty levels are introduced into the analysis and that the disproportionate rates of fatal pedestrian crashes mainly are due to an increasing fragility of people as they age.

This paper addresses the many issues associated with the safety of older pedestrians in five major sections. The first section provides an overview of the recent trends in pedestrian crashes, the causal factors related to pedestrian crashes, the types of crashes in which older pedestrians are involved, and the injury outcomes. The second section reviews pedestrian travel and crashes, the use of motorized wheelchairs, the involvement of alcohol, and seasonal effects on pedestrian travel and crash experience. Third, an examination of the associations among behavioral risk factors, crashes, and aging is provided. This section reviews the known risk factors for older pedestrians, with a focus



**Rate of Fatalities  
per 100,000 People**

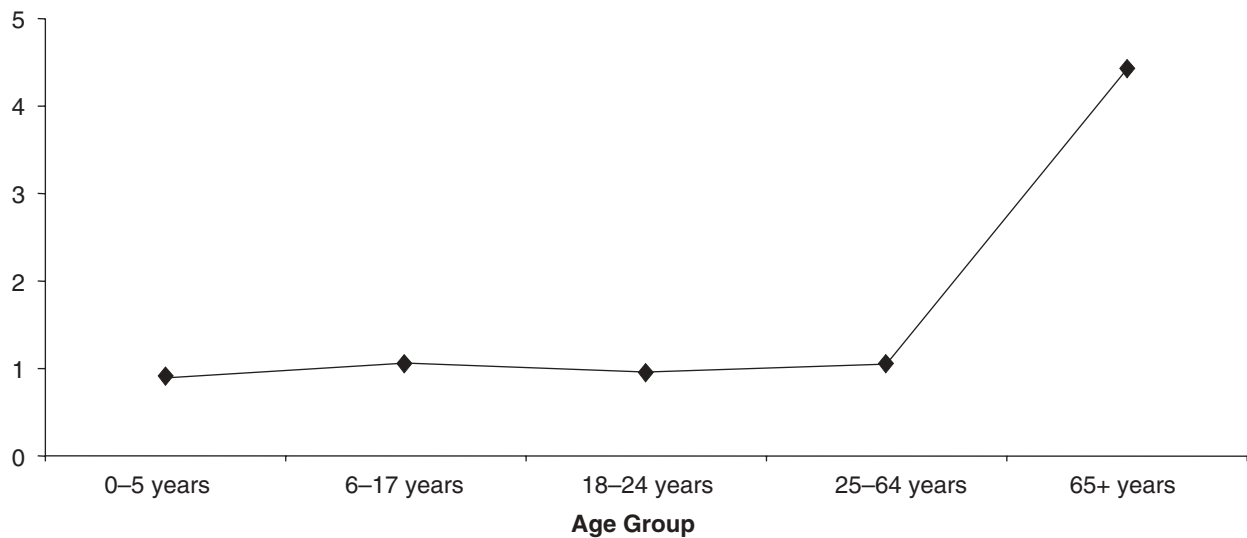


FIGURE 1 Pedestrian fatalities in OECD nations by age group, 1997 (114).

on age-related changes in functional abilities that may increase the risk of collision. The fourth section identifies several factors that affect pedestrian crashes, including land use and road design, vehicle design, intelligent transportation systems (ITS), education, and enforcement. The section also provides suggestions for countermeasure development. The fifth section draws some conclusions on how to improve older-pedestrian safety through research and implementation.

## PEDESTRIAN CRASHES

Crossing roads and driveways and negotiating parking lots are difficult yet everyday tasks that involve detection of traffic, judgment, decision making, and route planning. On all journeys, pedestrians encounter obstacles, make decisions on the basis of risk perception, and initiate numerous actions. Such decisions are complicated by the fact that for the most part, the traffic environment in which a pedestrian acts is dynamic. Complex perceptual, cognitive, and motor tasks need to be performed routinely to walk safely in ever-changing traffic situations, which may prove difficult for many older people.

### Recent Trends

Most OECD nations have seen a substantial reduction in the annual rate of pedestrians killed since 1990 (Figure 2). Pedestrian safety still remains a serious com-

munity concern. In the United States, pedestrians accounted for about 13% to 17% of traffic deaths between 1975 and 1998. But the absolute number of pedestrian deaths has decreased significantly (by more than 30%) during that period. The distribution of fatalities among road users age 65 and older also has changed; the percentage of total traffic deaths was about one-third pedestrians in 1975 and about one-sixth (16.1%) in 1998. The reason the number of pedestrian deaths, particularly the number of older-pedestrian deaths, has dropped in recent decades in the United States could be due to an increased availability of the personal automobile as a means of transportation, a lack of facilities for walking, or an environment that does not encourage walking—which all lead to less walking. Improved roadway design and traffic control at intersections also may have played a role.

### Causation

Although the majority of older pedestrians use roads without injurious consequences, crash statistics clearly identify older people as an at-risk group of road users (5, 6). But it is difficult to determine the causal factors of pedestrian crashes from crash statistics alone. Moreover, research has not been designed to determine how and to what extent risk factors contribute to crash risk for older pedestrians. Several explanations are offered to account for these numbers.

First, older pedestrians are more exposed to crashes than younger pedestrians are. Older people tend to

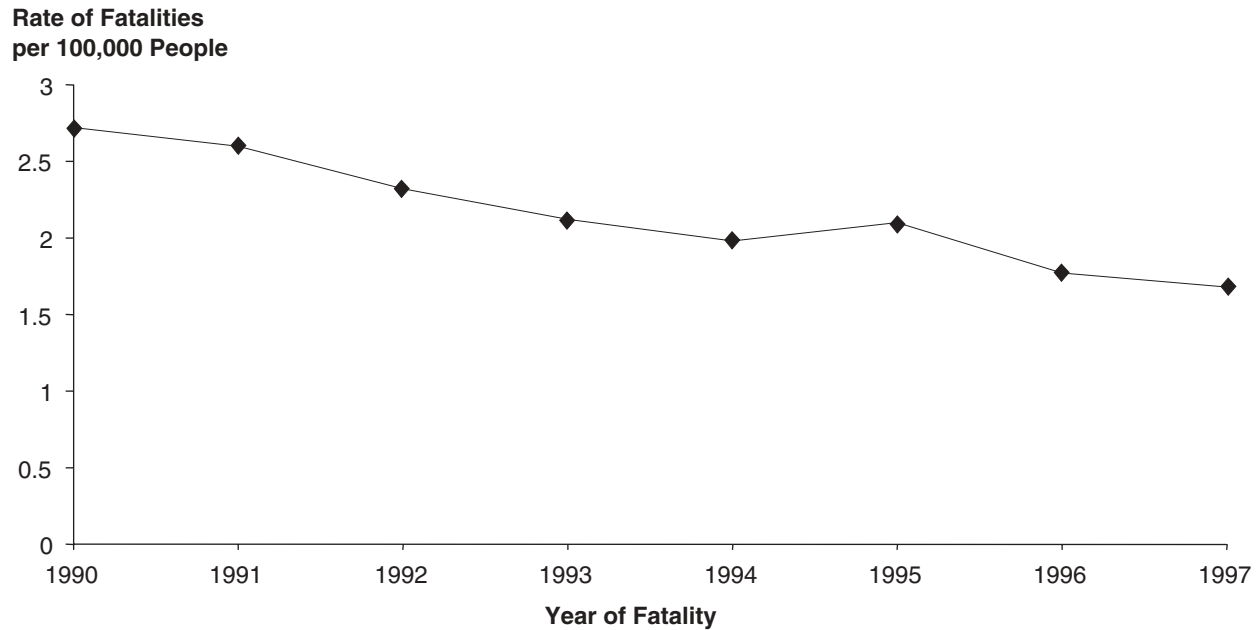


FIGURE 2 Annual pedestrian fatalities in OECD nations, 1990–1997 (114).

reduce or stop driving and thus more likely are pedestrians. They may use public transportation more frequently and may need to walk farther to get to transportation and shops. Furthermore, because of slower walking speeds and the need for more frequent stops, older people often spend a longer time walking the same distances than do younger pedestrians. Second, injury risk is related to the frailty of older people and the reduced ability to withstand crash forces or recover from injury. As a result of general physical weakening, older adults lose agility and endurance and experience musculoskeletal wasting and neuromuscular weakening. These changes may predispose older pedestrians to fatal or serious injury outcomes when in a crash.

It is possible that the road environment contributes to collision risk for all pedestrians, but particularly for older pedestrians who might have more difficulty coping in fast and heavy traffic, walking across wide roads, using poorly placed pedestrian-crossing facilities, and reading road signs. The issue of road design is discussed in more detail in the section on factors affecting pedestrian crashes.

Drivers share a proportion of the responsibility for pedestrian crashes, and many requests have been made to moderate vehicle speeds in high-activity pedestrian precincts (7, 8). As far back as the 1970s, studies have shown that many drivers were at fault or probably were negligent in pedestrian crashes (9, 10). Thompson et al. (11) also found that drivers check for pedestrians rarely, proceed through intersections without slowing, appear to overestimate a pedestrian's ability to cope with traffic, and only reduce speed in the presence of large

groups of pedestrians. More recently, Stutts et al. (12) categorized pedestrian–motor vehicle crashes according to the specific sequence of events leading up to individual crashes. In 55% of the crashes in six U.S. states, they found that one or more contributing factors were identified as driver factors. The most frequently cited driver factors included hit and run (16%), failure to yield to a pedestrian (15%), speed limit or safe speed exceeded (6%), improper backing (6%), safe movement violation (5%), inattention or distraction (4%), reckless driving (3%), and alcohol impairment (3%).

It also is possible that some drivers possess negative attitudes toward pedestrians, particularly older pedestrians, believing that it is the pedestrian's responsibility to cross the road safely, which in turn may result in these drivers acting in a manner not conducive to pedestrian safety. Job et al. (7) found that many drivers believed that elderly people rely on cars stopping for them, often cross dangerously, are a traffic hazard, and should do more to avoid holding up traffic. A small but substantial proportion of drivers in this study also supported the view that elderly people should stay off the road.

Others have argued that the overinvolvement of older adults in crashes is largely a consequence of behavior in traffic (8, 13, 14). Because changes in perceptual, cognitive, and motor abilities occur with age, it is reasonable to predict that older people's judgments and performance may be impaired when crossing roads, resulting in a higher risk of crash involvement. Some research has pointed to a causal link between age-related health and performance factors and crash risk (13–16). But the evidence supporting this view is

contradictory. The view that diminished perceptual, cognitive, and motor skills contribute to a reduction in the ability to perceive or recognize danger and to take measures to avoid the danger may heighten (perhaps unfairly) negative attitudes toward older pedestrians. Considerable research has suggested that older pedestrians are more cautious and more observant of rules than younger pedestrians are (17–20). Other research has pointed to older people's reduced ability to cross the road safely (14, 15, 21). Age differences in road-crossing behavior are discussed in more detail in the section on age, behavior, and crash risk.

### Need for Exposure Data

Crash data are used mostly to investigate road safety and usually are extracted from police reports, but these data often fail to provide insight into the causes of crashes. Ideally, high-risk groups should be identified, incorporating valid exposure measures such as time spent on the road, number of roads crossed, and distance traveled. However, because this information is largely unavailable, it is difficult to apply these kinds of exposure measures to crash data. Therefore, it is difficult to determine with a disproportionate reduction in the amount of pedestrian travel, for example, whether any downward trend is due to safer pedestrian travel or walking has become more dangerous.

The degree to which older pedestrians are exposed to crash risk is unknown, and very little is known about the amount and type of walking and their relationship to the number of pedestrian crashes. Providing an accurate estimation of the older-pedestrian problem is a difficult task because it is impossible to be definitive about the relative risk of pedestrian travel. Conducting a comprehensive measurement of pedestrian exposure to risk in the United Kingdom, Ward et al. found that people older than age 65 walked the least amount and crossed the least amount of roads compared with other age groups (22). Even when the data were adjusted using these findings, crash and injury rates were still higher for older pedestrians than any other age group. Keall (23) reported similar trends in New Zealand.

### Types of Crashes

It appears that older pedestrians are involved in different types of crashes than younger pedestrians, and several crash patterns for older adults have been identified (24, 25). The main predisposing factor in younger adult pedestrian crashes appears to be alcohol consumption (26, 27); these crashes generally occur close to drinking venues, mostly at night and on

weekends. Older-pedestrian crashes, conversely, tend to occur on a regular trip, often close to home or at shopping centers or recreational venues, where older people tend to spend much of their time away from home. Furthermore, the majority of crashes occur in daylight hours and at intersections, particularly intersections without traffic signals, suggesting that older pedestrians have difficulty with complex road designs (24, 28).

Older-pedestrian crashes also have been linked to reduced agility—that is, less ability to move out of the way of an oncoming vehicle—and age-related cognitive restrictions that may interfere with the sound judgment of when to cross the road safely (24). Unlike child and younger adult pedestrians, older pedestrians usually observe the law and do not behave irrationally. However, some older road users may lack the knowledge and understanding of current road rules, particularly in situations of right-of-way (2).

### Types of Injuries

The most common type of pedestrian crash occurs when a pedestrian is struck side on by the front of a vehicle (29, 30). Essentially, the pedestrian is run “under,” instead of “over,” when struck and scooped toward the hood and windshield. Jarrett and Saul (31) found that the most common injury contacts for newer vehicles were the front bumper, the A-pillar (where the front door hinges attach to the body of the car), and the windshield. The initial impact is with the bumper edge, which strikes the lower leg and typically results in fractured bones of the lower leg and dislocation or ligament damage to the knee. Depending on the height of the pedestrian and the overall shape of the front of the vehicle, the next impact is with the leading edge of the hood, which can result in the fracture of the pelvis or femur, or both. The pedestrian then rotates about the leading-edge impact until the head, shoulders, and chest hit the hood, windshield frame, or A pillar. The severity of these injuries largely depends on which part of the vehicle struck the head and the speed of the vehicle. Further injuries occur as the pedestrian moves over the roof or falls to the ground.

Isenberg et al. (32) highlighted that the majority of pedestrians in their sample who were struck sustained more than one injury and that lower extremity contacts accounted for 67% of the first injuries received. Overall, the lower extremities were the body region most frequently injured, accounting for 34% of the injuries, followed by the upper extremities, which received 19% of the total injuries. The head and face were the body region injured next most frequently, receiving 17% of the injuries. When minor severity

injuries were excluded from the total injury distribution, Isenberg et al. found that injuries to the lower extremities still were prevalent (31%), but head injuries also represented a large proportion of injuries (32%).

Isenberg et al. also found that contact with the ground was the most frequent source of injury; however, 93% of the injuries from this contact occurred at minor severity levels. Serious injuries more likely were caused by contact with the front bumper, hood edge, cowl area, or A-pillar. The authors concluded that if contact was made with one of these areas, there was a greater likelihood that a serious or life-threatening injury would result.

Although few studies have investigated age differences in type and severity of injuries sustained in pedestrian crashes, it is held widely that both children and older adults are at an increased risk of injury compared with young adults because of body kinematics. Physical changes that reduce tolerance to injury predict that older pedestrians would sustain more serious injury than a younger pedestrian would with the same physical insult. As a result of general physical weakening, older adults often experience musculoskeletal wasting and neuromuscular weakening and have decreased bone mass and increased bone brittleness. In addition, recovery time after injury is much longer for older adults than for younger adults. Evans (6) argued that with the same crash and physical insult, at age 70 the risk of death following a crash is about three times the risk at age 20. Isenberg et al. (32) support this contention; they examined fatal age distribution within their sample of pedestrian crashes and found that elderly people (age 60 or older) were overrepresented by about 10%, compared with younger adults.

### Costs

In the United States, the total cost of vehicle crashes was \$150.5 billion in 1994 (33). The Federal Highway Administration estimated that pedestrian injuries and fatalities alone result in \$20 billion in societal costs (34). In Australia pedestrian crashes cost the community nearly AUS\$1 billion per year (35), one-quarter of which is attributable to crashes involving older pedestrians (36).

The long-term costs to society of the temporary or permanent functional disabilities experienced by older pedestrians are not known, and very few studies have investigated the ongoing costs of pedestrian trauma. One Australian study, however, provided a detailed breakdown of the average claim cost filed by injured pedestrians for insurance compensation in the state of Victoria between 1987 and 1992 (28). The number of claims for older pedestrians was about two-thirds the number of claims for younger pedestrians, mostly

because of a lack of compensation for lost wages and earning capacity. This analysis also showed that the average total claim cost for older pedestrians was roughly 30% to 40% less than the cost for younger pedestrians. This reduction is a reflection of lower average claim costs for medical purposes, rehabilitation, loss of earnings, and earning capacity by older pedestrians. Further, the probability of claiming a death payment decreases sharply with age, with no claims made at all for people age 75 or older (28).

### PEDESTRIAN DEATHS AND USAGE WORLDWIDE

The rate of pedestrian fatalities differed markedly among OECD nations for pedestrians age 65 and older in 1997 (Figure 3). The median rate of older-pedestrian deaths for all OECD nations in 1997 was 4.53 deaths per 100,000 population. Although the majority of nations experienced similar rates of older-pedestrian fatalities, some nations experienced notably higher rates of older-pedestrian deaths. Korea, in particular, recorded almost 50 pedestrian fatalities per 100,000 population in 1997. Portugal also recorded a higher rate of older-pedestrian fatalities (14.7 per 100,000 population), compared with the median for the OECD nations.

Countries with low rates of pedestrian deaths in 1997 included Sweden (2.2 deaths), Norway (2.6 deaths), and the Netherlands (2.6 deaths). These and other European countries are known for innovative and enlightened approaches to pedestrian safety and amenity. For instance, in response to the rapid motorization of Western Europe, the Dutch Pedestrian Association was formed in the Netherlands about 45 years ago. The association's goals were to help pedestrians move safely in the street and to make cities and villages livable for residents and residential activities. By regulating traffic volumes to sustainable levels, instead of meeting the prevailing traffic demand, these countries have made it feasible for roads to be both safe for vulnerable road users (pedestrians and bicyclists) and efficient for other traffic. These approaches have resulted in low rates of pedestrian injury. Other countries—such as Korea, Portugal, the Czechoslovakian Republic, Hungary, and Japan—have not accompanied motorization with initiatives to assist in the safety of pedestrians.

Other sources have reported a higher overrepresentation of older pedestrians among fatalities. The U.S. Department of Transportation (37) reported that older pedestrians accounted for 23% of all pedestrian fatalities, even though older pedestrians make up about 13% of the population. The annual pedestrian fatality rate in Seattle, Washington, for example, increased from one fatality per 100,000 population for the age 22–34

### Rate of Pedestrian Fatalities per 100,000 People

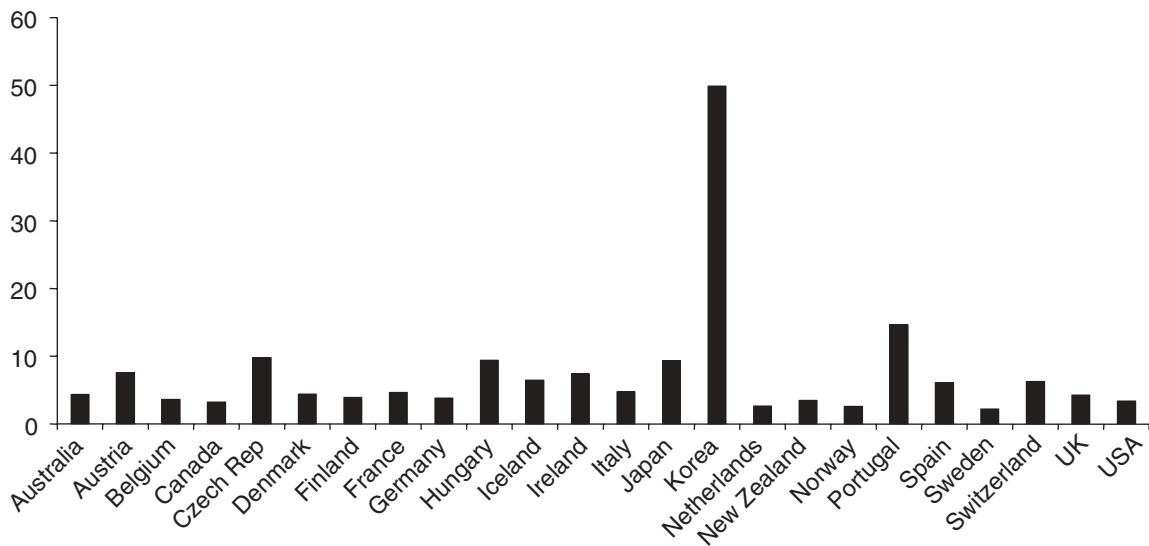


FIGURE 3 Fatalities of pedestrians age 65 or older by OECD nation, 1997 (114).

group to seven fatalities per 100,000 population for the group age 70 or older (38). It also has been shown that adult male pedestrian deaths and death rates (per 100,000 population) are about double the deaths and death rates for females and triple after age 85 (39). In Europe reports have shown that older people even more are overrepresented in pedestrian crashes, compared with the United States, as a result of a greater use of roads as pedestrians (14). Pedestrians in Western Europe older than age 64 account for 45% of the fatalities but make up only 15% of the population. This rate goes even higher in densely populated areas, particularly in Great Britain and Norway, where pedestrian deaths account for almost half of all crash fatalities for people age 65 or older (37).

### Cultural and Generational Differences

Any discussion of cultural differences must address two issues. First is the issue of ethnicity and the problems that people experience when they live outside their native country. Second is the issue of cultural change over time. For ethnicity, cultural minorities as a road user group have received very little attention in the road safety literature, and only a handful of studies have attempted to address the issue of road safety needs of cultural minorities. Many studies in the United States have examined the involvement of cultural minority groups as drivers in crashes. For example, Popkin and Council (40) compared alcohol-related driving behavior of white and nonwhite drivers in North Carolina

and found that the alcohol-related crash rates per licensed nonwhite males and females were at least twice the rates of white males and females. Grossman et al. (41) also found that rates of driver alcohol impairment were much higher among American Indian drivers than non-American Indian drivers.

For older-pedestrian crashes, however, little is known worldwide about the role of ethnicity in crashes. Alexander et al. (26) investigated factors of older-pedestrian crashes in Victoria and claimed that older pedestrians appeared to be socially vulnerable, frequently living alone or dependent on others, or both. The authors found that half of the group involved in a pedestrian crash were born outside of Australia compared with only one-quarter of all pedestrians using the same facilities. The majority also lived in inner suburbs of the city. Conceivably, ethnic minorities may have particular problems using the road because, for example, these groups tend to be poorer and usually live in areas that have poor facilities for walking, including a lack of sidewalks and poor road maintenance.

### Types of Trips

Pedestrian travel varies greatly worldwide. In the United States, Canada, Australia, and New Zealand, the dominant mode of transportation is the car and roads are designed to facilitate good traffic flow. The majority of pedestrian travel in these countries occurs around shopping precincts, town centers, and residential streets. Consequently, for many years, vehicles have



been the center of town and traffic planning, and little thought has been directed to the needs of pedestrians. However, during the last decade, there has been a growing awareness of the need for better and safer pedestrian environments in town centers and on residential streets. Attention has focused on the provision of a more pedestrian-friendly environment. In contrast, the needs and safety of pedestrians and bicyclists have long been recognized in many European countries. Other forms of transportation are used as frequently as the car, including public transportation, bicycle, and pedestrian travel. Many shopping precincts are designed with an emphasis on the safety of vulnerable road users.

Despite this gradual shift in attention toward the safety of all road users, little is known of the types of trips undertaken by older pedestrians. In the United Kingdom, Ward et al. (22) addressed this issue in a household survey on average walking patterns. They found that compared with younger pedestrians, older pedestrians walked less overall, tended to do most walking in the morning, crossed fewer local distributor roads—although older pedestrians walked more alongside this type of road—and made fewer crossings at pedestrian facilities. Others have demonstrated that older people tend to stop driving and thus more likely are pedestrians and that most of their destinations are shopping centers, medical facilities, and social venues (28). Older people may use public transportation more frequently but usually need to walk to get to a destination.

### Motorized Wheelchairs

Powered wheelchairs and motorized scooters are becoming a popular transportation alternative because they provide many mobility advantages for older road users. From early indications, users of wheelchairs and scooters enjoy a low crash involvement rate, which most likely is due to these vehicles' relative stability, low travel speed, and use of sidewalks. But crashes involving this form of transportation have not yet been categorized separately. However, their presence on roads introduces a new hazard as they mix with heavier, faster traffic.

Furthermore, the physical infrastructure often is not suitable for the widespread use of motorized wheelchairs. There may be no sidewalks, especially in rural areas. When there are sidewalks, they are often narrow, maintenance is often poor, and surfaces often do not allow comfortable or safe travel. Ramps are required for wheelchairs to change levels and move from the roadway over the curb to the sidewalk. Sidewalks need to be constructed so that the lateral edges do not cause wheelchairs to tip or do not prevent timely movement to the sidewalk. The introduction of disability legislation in many Western countries has resulted in

increased accommodation for people with disabilities, from which older-pedestrian travel also has benefited.

### Pedestrians with Disabilities

People with disabilities are much more mobile now than a few decades ago, so there is a greater need to take into account their restrictions in the design of a transportation system. Although the typical image of an individual with a disability is a person in a wheelchair, there are a variety of other deficits—physical, sensory, and cognitive. Vision and hearing deficits contribute to safety problems in the detection of traffic hazards and the perception of traffic-control devices.

For vision-impaired pedestrians to cross the road safely, they need to know the location of the intersection, to know the direction and speed of traffic flow, and to receive a traffic signal indicating that it is safe to cross. Takamiya and Hamada (42) outlined the information used by vision-impaired pedestrians in Japan. Many of these pedestrians seek information in advance of the trip or ask another person to explain the route. When en route, they tend to rely on familiar sounds and smells from shops, which are absent when the shops are closed, and, if possible, on sidewalk structure outlines, such as a mailbox and light pole. The features of the sidewalk, such as changes in texture and gentle curves, and the movement of other pedestrians and vehicles are used also. Vision-impaired pedestrians tend to confirm the distance walked by counting steps and the number of side streets along the route, but they report that counting steps often makes them less aware of the surroundings. Vision-impaired pedestrians rely on the sense of hearing to obtain information about the speed, direction of travel, and location of vehicles and the senses of touch and sound to tell when they have reached an intersection. Various textures of sidewalk surfaces and the provision of Braille maps and signs now assist with needs accommodation for pedestrians with disabilities. Auditory signals that emit a sound, such as beeping, chirping, or buzzing, are useful for telling vision-impaired pedestrians that it is safe to cross, as long as the signal is understood and clearly audible above the ambient noise levels.

Many ambulatory older pedestrians have conditions such as arthritis and restricted range of movement. Perry (43) showed considerably lower speeds for physically impaired pedestrians. None of the speeds reached the average 1.3-m/s (4-ft/s) speed for walking—the assumed speed used for the design of pedestrian crosswalk signal timing. Table 1 lists the mean walking speeds for people with various disabilities or assisting devices.

The following factors should be taken into account when pedestrian facilities are planned for people with disabilities:

**TABLE 1 Mean Walking Speeds of Pedestrians with Disabilities or Various Assisting Devices**

<i>Disability/Assistive Device</i>	<i>Walking Speed (ft/s)</i>
Cane or crutch	2.62
Walker	2.07
Wheelchair	3.55
Immobilized knee	3.50
Below knee amputee	2.46
Above knee amputee	1.97
Hip arthritis	2.24 to 3.66
Rheumatoid arthritis (knee)	2.46

1 ft/s = 0.305 m/s.

- Minimum clearance for wheelchairs;
- Use of nonskid surfaces;
- Gradients (e.g., ramps, sidewalks) not more than 5% maximum curb heights of about 25 cm (10 in.);
- Adequate lighting;
- Good access to pedestrian-activated signal controls (some designs are difficult to operate because they have small buttons, are out of reach for people in wheelchairs, or require excessive amounts of force to activate);
  - Reduction of physical barriers, such as street furniture, flower boxes, mail boxes, and garbage cans, but consistent placement of these barriers when used;
  - Adequate time to cross the street;
  - Proper orientation or wayfinding aids, such as signs and maps (a difficulty in finding one's way can lead to confusion and frustration);
  - Quick removal of snow from pedestrian paths; and
  - Consideration of the use of curb cuts, tactile strips, and auditory signals.

### Seasonal Effects

Winter conditions present many potential hazards for older pedestrians. The most obvious problems in winter walking conditions encountered by older pedestrians include poor footing and slower speeds where there are icy patches and piles of snow and slush (44). One of the main fears among elderly people is falling. Evidence has suggested that a considerable proportion of pedestrian injuries results from falling on public sidewalks, on streets, and in parking lots (12). This fear clearly is justified for a pedestrian in winter conditions; blowing snow also causes great difficulty because of reduced visibility and increased likelihood of a fall. Because of the need to step carefully, older pedestrians more likely are looking down at the road surface and not noticing turn-

ing or oncoming vehicles. These conditions not only make walking difficult and dangerous but also distract pedestrians' attention away from vehicles on the roadway. The presence of snow also leads to ill-defined curbs and hidden potholes and other small obstacles, increasing the chances of a slip or fall. Visual difficulties, not including the difficulties typically experienced by older people under nonwinter conditions, include more glare from snow and ice, poor contrast because of glare and light conditions, and more hours of darkness.

### Visibility of Pedestrians

Older pedestrians are more likely than younger pedestrians to be killed or injured in a pedestrian crash during the week and during daylight hours. But many crashes occur during the night as well (17). Often nighttime pedestrian crashes occur on roads where the only light is from vehicle headlights. Darkness presents problems for pedestrians, who cannot see the sidewalk and street and are not seen by drivers. Older pedestrians often are inconspicuous to drivers because, like other age groups, they favor dark clothing. A pedestrian in dark clothing blends in visually with the dark surroundings and dark road surface. Drivers tend to overdrive their headlights, and many drivers believe that they can see farther than they actually can at night.

Allen et al. (45) reported that the majority of drivers who struck a pedestrian at night claimed that they had experienced difficulty seeing the person; in daytime this claim was made for about 11% of the cases. About 25% of drivers were aware of striking a pedestrian at night only after the driver heard the impact. Pedestrians need to be aware of driver restrictions, including inattention and difficulty detecting pedestrians; drivers need to be aware that pedestrians overestimate the distance at which they can be seen at night by a factor of two (46).

A driver using low-beam headlights easily could miss a pedestrian at night. A pedestrian, or any person or object, to the left of a vehicle is illuminated less than a person or object on the right, thus creating even more of a hazard for pedestrians crossing the road from the left. Tidwell and Doyle (47) showed that about 80% of the surveyed subjects thought that wearing white clothing at night provided adequate visibility to drivers.

### Alcohol Involvement

In general, alcohol involvement among older pedestrians is less than alcohol involvement for other adult age groups. The National Road Trauma Advisory Council (48) in Australia reported that although the most common factor in pedestrian crashes was pedestrian error or misjudgment,

a substantial proportion of all-aged pedestrian crashes involved a pedestrian affected by alcohol or drugs, or both (28%). This study also reported that pedestrians in fatal crashes were more likely than the drivers to have been under the influence of alcohol and were far more likely to have been severely affected. The council reported that alcohol was a factor in a substantial number of deaths among adult pedestrians of all ages, but blood alcohol content (BAC) levels were lower for older pedestrians, compared with younger pedestrians.

In 1997 alcohol use was reported in slightly less than half of the U.S. crashes resulting in pedestrian fatalities: 29.5% of the pedestrians and 12.5% of the drivers involved were intoxicated, as defined by the maximum BAC allowed for drivers. In 5.3% of the crashes, both the driver and pedestrian were intoxicated (49). More than one-third of the pedestrians over age 16 killed in alcohol-related crashes were intoxicated; this proportion rose to 55% for people age 25–34. Alcohol involvement (for both drivers and pedestrians) was overrepresented for crashes in which the pedestrian was walking along the road; in most of the crashes, the pedestrian was struck from behind. In an on-road experiment, Allen et al. (45) examined the likelihood of sober drivers and drivers under the influence of alcohol (.06–.10 BAC) at night detecting a simulated pedestrian in time to stop. The effects of alcohol reduced visibility in almost all conditions, except when the vehicle was traveling at 20 mph or the pedestrian target was wearing reflectorized tape.

### Wayfinding in Transportation Terminals

Many large transportation terminals present a challenge to older people. Even though a variety of information, such as signs, maps, directories, and verbal directions at information booths, is available, significant proportions of people do not find, do not understand, or forget the information before reaching their destination.

Visual abilities, such as acuity, visual memory, and spatial orientation, come into play for wayfinding in terminals. Older pedestrians often have deficits in visual abilities, and they tend to become confused, lost, and distressed in strange buildings more easily than younger pedestrians do. In addition, people often are in a hurry to catch a train, plane, or bus. The stress associated with being in a hurry adds to the potential for making wayfinding errors. Lack of confidence in wayfinding also can play a part in older people becoming lost or confused.

Noise is a particular problem for older travelers, who have a limited ability to filter out background noise and more difficulty hearing in noisy environments than do younger travelers with similar hearing ability. Excess noise adds to the confusion experienced by many older travelers in terminals. In addition to the

general annoyance and tiring aspects of noise, noise often interferes with hearing announcements.

Consideration also must be given to the cognitive deficits of many older travelers. The major difficulties with cognitive deficits are confusion, distraction, attention, disorientation, and forgetting, which can lead to difficulties in noticing and locating visual information in visually cluttered environments and in encoding provided information. Hunt and Roll (50) showed that older people with lower mental status scores had lower confidence in their ability to find destinations in an unfamiliar building.

Some attempts have been made to develop transportation facilities with an emphasis on both physical design of facilities and availability of assisting devices for people with disabilities (51, 52). However, in general, there appears to be relatively little regard for older and disabled pedestrians with the many unreadable signs and incomprehensible maps. Signs often are designed or placed poorly, hidden in visual clutter of the surrounding environment, in unexpected places, too small to be read, or pictographs that are not well understood. Many maps lack accompanying directories, often use a grid pattern for location information that leads to visual clutter, and use too many colors, resulting in messages that often are difficult to find.

The design and implementation of an information system in a public transportation terminal should take into account the needs of older pedestrians. The size, form (letter font, symbol design), length, and familiarity of letters and digits and the length and complexity of word messages should accommodate older pedestrians. The size of letters and digits should be 5 mm of character height for every 1 m of reading distance (the readable size for people with 20/60 visual acuity). When possible, symbols should be used instead of words, but only symbols that are likely to be understood by most travelers. In addition, it is better to use solid, instead of outlined, figures because outlined figures are much more difficult to read at a distance. Word messages should be as simple as possible, without losing the intended meaning; messages should use short words and sentences aimed at people with a Grade 8 reading level and the same wording for similar messages in different transportation modes. Phrases peculiar to the language of a country should be avoided.

### AGING, BEHAVIOR, AND CRASH RISK

Aging is a complex process, resulting in reduced performance in a variety of areas, and the changes may be related to a general decline in road user skills. A safe road crossing requires intact visual, auditory, perceptual, and cognitive systems to make the decision when to cross safely and good motor skills to cross the road

quickly. Walking in a traffic environment can be a hazardous activity for elderly people for many reasons, including slower walking speeds, longer times required to process information, stricter criteria (therefore longer reaction times) for interpreting uncertain or ambiguous input, and slower decision making. Inefficient scanning and visual search of the traffic environment also are issues, as are difficulties in estimating vehicle distance and speed, especially at dusk and in darkness. Age-related declines in any of these functions can result in poor detection of oncoming vehicles and failure to cross the road quickly enough to evade oncoming traffic. McKnight (53) identified several problems that can lead to crashes for older pedestrians:

- Gap judgment—misjudging the distances of and intervals between approaching vehicles;
- Attention—stepping off the sidewalk when distracted;
- Visual search—watching the traffic signal instead of the traffic;
- Expectation—misinterpreting the movement of vehicles and assuming that drivers will yield; and
- Haste—impatiently crossing after waiting for a short time and crossing midblock between parked cars.

### Road-Crossing Behavior

Given the difficulty in determining the causal factors of pedestrian crashes from crash statistics alone, some research has focused on road-crossing characteristics of older pedestrians to determine if and how such characteristics differ from the characteristics of younger pedestrians. Many studies have used observational techniques to understand pedestrian behavior when crossing roads and to identify risky behavior (14, 17, 21, 54, 55). But the findings have not been consistent. Some researchers have found that older pedestrians tend to behave more carefully than other pedestrians do when crossing roads (54, 18). Older pedestrians more likely stop at the curb and spend more time at the curb (19), make use of controlled crossings and other aides, and cross directly instead of diagonally (20).

In an effort to identify age differences in road-crossing behavior, Wilson and Grayson filmed 11,000 road crossings by adults in the United Kingdom and recorded their specific behavior (56). Elderly pedestrians (age 60 or older) were more likely to delay before crossing, took longer to cross the road, and made more head movements before and during the crossing. Females looked slightly more often than did males and were less likely to cross with small gaps in the oncoming traffic. The authors concluded that elderly pedestrians tend to adopt less efficient crossing strategies than the strategies of

young pedestrians. It also has been suggested that older pedestrians are represented disproportionately in potentially unsafe crossings, which is often the result of crossing the first half of the road without consideration of the outcome for the second half (14). Similarly, Oxley et al. (21) found that the older pedestrians interacted with traffic in the farside lane more frequently than younger pedestrians did. They also noted that the slowest older pedestrians experienced difficulty in selecting safe gaps in the nearside lane of two-way traffic. They concluded that older and less-fit pedestrians displayed behaviors likely to put them at higher risk of collision than their younger counterparts.

In a survey of crashes, Sheppard and Pattinson summarized the perceptual, cognitive, and motor difficulties experienced by 473 older pedestrians, whose average age was 75 (24). Failure to see—or to see in time to take evasive action—the vehicle that struck them was reported by 63% of the respondents. About two-thirds of the respondents who did see the vehicle that struck them first saw the vehicle when the vehicle was within about 9 m (30 ft); for 17% the vehicle was not more than a car length away, by their estimates. Of the respondents who saw the vehicle before being hit, 41% noted that the vehicle was doing something unusual. The most frequent replies were “the vehicle reversed into me” (30%), “I expected the driver to stop or alter course” (20%), “I thought the vehicle was not moving” (11%), and “the vehicle came from behind a corner or parked car” (10%).

Errors in judgment of the speed or course of vehicles and unwarranted expectancies about the behavior of drivers were central factors. It also is possible that the reduction in peripheral visual information processing was a contributing factor. When asked about the ability to judge speeds of approaching cars, 30% said that they could “not do this well at all.” This reply was much more common among respondents who had never driven or who had stopped driving. Only 44% said that they could make this judgment “fairly well”—the most positive response category. The problems also reflect the replies of 204 people who said that the location of the crash was a difficult place to cross: 25% reported that it was hard to see, 14% indicated that the intersection was confusing, and 25% said the traffic came too quickly. When queried about difficulties in seeing, hearing, or walking, about one-third of the participants indicated that they had such problems—33% walking, 45% seeing, and 51% hearing.

### Sensory and Physical Abilities

The experiences of older pedestrians are different substantially from the experiences of younger pedestrians.



Two limitations that have received the most attention by the traffic safety community are failing sensory and physical capacities.

### *Vision Loss*

Given that traffic participation is a highly visual task (57, 58), conceivably the higher incidence of visual problems in older adults may be an important factor in the appropriate detection of potential hazards when older adults cross the road. But the role of age-related deterioration or visual disease losses in crash risk is not well understood (46, 59). Moreover, it is difficult to determine what specific visual skills are essential for safe pedestrian travel, and little research is available to associate unequivocally any aspects of visual processing with increased pedestrian crash risk. With the importance of vision in the performance of daily activities, in detection of potential hazards, and in balance and ambulation, changes in the visual system are likely to have profound effects on an older person's ability to walk safely in traffic. Furthermore, given that good depth perception allows for an estimation of the distance of vehicles from the person and that accurate motion perception allows for an accurate prediction of the motion of approaching vehicles and selection of safe gaps in the traffic, it can be argued that good dynamic visual acuity, contrast sensitivity, and effective visual field in the periphery and visual search skills are most important for safe pedestrian travel.

### *Hearing Loss*

Like vision loss, little research has examined the relationship between age-related hearing loss and safe participation in traffic. Hearing deficits may cause problems for older pedestrians to localize sounds and ascertain consequently from which direction a vehicle is approaching. Carthy et al. (14) found that many older pedestrians believed that they had a noticeable hearing loss and that this loss influenced their mobility. Further, the authors suggested that if visual and auditory information is incongruent, confusion may result and lead older pedestrians to panic.

### *Physical Declines*

Motor control and physical agility have prime importance to a pedestrian when crossing a road, particularly the ability to adjust walking pace and execute actions quickly when faced with traffic emergencies. Good motor performance depends on a pedestrian's ability to

coordinate movements with changing visual inputs such as interacting with fast-moving traffic. But aging results in muscular and strength declines and instability. For older pedestrians, physical restrictions may play a role in increased crash risk, particularly in fast-moving traffic and other times when actions must be executed quickly.

Elderly people often experience general physical weakening: loss of agility and endurance, cardiovascular degeneration, musculoskeletal wasting, and neuromuscular weakening. Furthermore, poor balance-control mechanisms and declines in postural reflexes result in impaired mobility and increased injury risk. Effective posture depends on visual, proprioceptive, and vestibular functions. These functions may fail, resulting in older pedestrians having difficulty with balance and postural stability. Vision is thought to be the most important source of information for balance control and locomotion, which becomes relevant because a major fear among elderly people is failing vision—an inevitable part of aging. Vision deficits in older people include decreased visual field, loss of contrast sensitivity and sensitivity for fine details, and slower horizontal eye movements.

For older pedestrians, decreased foot pickup, toe clearance, and stride length result in slower walking speeds and increased chances of tripping. Older people tend to sway more than younger people (60) and are less able to correct their balance after stumbling (61). Further, a loss of righting reflexes and inefficient functioning of sensory organs that monitor balance cause instability; this instability can be accentuated when older people are confronted with fast-moving traffic. It is likely that older people plan and prepare for movement differently from younger people; older people's action sequences become more complex and involve additional cognitive-motor processes. These physical changes may result in associated pain, stiffness, abnormal movements, and impaired coordination and reaction abilities, which are all essential for safe pedestrian travel. The older adult also is less resistant to fatigue, which may be a safety concern, for example, when emerging from a vehicle and walking after a long drive.

Arthritis sufferers experience further reductions in physical well-being. Arthritis is common among older people and a leading cause of disability, affecting one of every two people older than age 65 in the United States (62). Arthritis results in restrictions in the range of motion, particularly a loss of joint motion, reduced physical endurance and strength, pain, and fatigue (63). For older pedestrians, this condition can restrict greatly the range of movement (head and neck movement, difficulty in walking, and involuntary hesitancy) and can reduce strength and physical endurance—the result of which can be a difficulty in or slowing of the detection of approaching vehicles (64). In addition, arthritis can



reduce walking speed and the ability to increase walking pace to comply with traffic conditions. A related discomfort and pain can be a distraction for older pedestrians and can lead to fatigue.

### Crossing Times

An important consideration for older pedestrian safety is walking speed. The duration of pedestrian walk signals generally is based on the assumption that the mean walking speed of pedestrians is 1.3 m/s (4 ft/s), but most pedestrians walk slower than that. Estimates suggest that the mean speed should be 1.13 m/s (3.7 ft/s) because as many as 35% of pedestrians walk slower than the 1.3-m/s design standard (65). A study in Sweden (66) found that when asked to cross an intersection very fast, fast, or normally, pedestrians age 70 or older considered fast to be slower than 1.3 m/s (4 ft/s). For 15%, the normal (comfortable) walking speed was 0.67 m/s (2.2 ft/s).

Eubanks and Hill (67) studied the walking and running speeds of pedestrians of varying age by observing the pedestrians walk and run specified distances. Average walking speeds increased gradually from approximately 3.1 ft/s at age 2 to approximately 5.5 ft/s at age 10 and remained fairly steady until age 40. As age increased, walking speeds decreased substantially, to around 4.1 ft/s for people age 60 or older.

Another large study of walking speed and start-up times gathered data on the behavior of several thousand pedestrians; more than half were older than age 65 (44). Observations of pedestrian behavior were made at a variety of urban intersections under various conditions. Factors included street width, traffic volume, posted speed, signal type, crosswalk type, and environmental condition (e.g., rain, snow). Older pedestrians walked significantly slower than pedestrians younger than age 65 and also walked more slowly when it was snowing or when the street was snow covered than under other weather conditions. The mean and 15th percentile walking speeds were 1.46 m/s (4.79 ft/s) and 1.21 m/s (3.97 ft/s), respectively, for young pedestrians (younger than age 65) and 1.20 m/s (3.94 ft/s) and 0.94 m/s (3.08 ft/s), respectively, for older pedestrians. Mean start-up time (from the start of the "Walk" signal to the time the pedestrian steps off the curb and starts to cross) was longer for older pedestrians (2.48 s) than for younger pedestrians (1.93 s). Inattention or slow response may account for this slower start-up time.

Mean walking speeds around 1.0 m/s (3.3 ft/s) have been reported in another study (68), suggesting that a design speed of 1.3 m/s (4 ft/s) for elderly pedestrians based on this mean may be too high because many elderly pedestrians walk slower than this speed.

Although the walking speeds reported in the studies above varied somewhat depending on the specific study, clearly many older pedestrians will find it difficult or impossible to cross most signalized intersections at the expected 1.3-m/s (4-ft/s) rate.

### Cognitive Abilities

To cross the road safely, pedestrians, when nearing or stopping at the edge of the road, must inspect the roadway in both directions and look for approaching vehicles. This part of the task involves detecting objects and motion, ascertaining the direction and velocity of the moving objects, identifying the object (e.g., vehicle or person), and estimating when the vehicle will arrive at the crossing point. This involves calculation of distance, velocity, acceleration, and deceleration. To perform these calculations, a pedestrian relies on reasonably intact perceptual and attentional skills. Furthermore, on many roads pedestrians must integrate and remember information about traffic in both directions and in multiple lanes as well as combine vehicle arrival times with walking speed to come to a decision on when to cross safely. This decision requires the pedestrian to focus and refocus attention to the traffic in both directions, switch attention from one source of information to another, and select and integrate the relevant information to arrive at a safe decision. Once a crossing has been initiated, the near and far sides of the road have to be rescanned to verify or update earlier estimates of vehicle arrival times, and walking speed may have to be adjusted. These operations require the ability to process complex information rapidly to make and update decisions, initiate walking, and control walking speed.

### *Judging Speed and Distance*

Some older pedestrians overestimate their safety by not always allowing sufficient gaps in the traffic when crossing a road. A central factor in many traffic crashes is excess speed. Older pedestrians often have difficulty in assessing the speed of approaching vehicles, thus misjudging when it is safe to cross. The relative contribution of vision and hearing to speed judgments was examined in a Japanese study (69); passengers rated vehicle speeds (20–60 km/h) under normal perception, deprived of hearing, deprived of vision, or deprived of both. The most accurate perception of speed occurred under the normal condition, with a slight reduction without hearing, and a further slight reduction without vision. Judgments of the last possible safe moment to cross on a divided highway decreased with the increasing speed of the oncoming vehicle, indicating that more

risks likely were taken in the presence of high-speed traffic. It was found that high speeds (faster than 50 mph) usually were underestimated and low speeds, overestimated. Although this study was conducted with vehicle occupants, similar findings likely would apply to pedestrians; however, no study to date has compared pedestrian judgments at high and low speeds.

Carthy et al. (14) found that distance information is used predominantly to determine time gaps. Oxley et al. (70) found similar results in their study, adding that younger pedestrians were able to integrate distance and speed information quickly and instantaneously. When given enough time, the oldest pedestrians (age 75 or older) also were able to integrate distance and velocity information for oncoming vehicles in a simple traffic environment. But they appeared to experience greater difficulty with integrating the information when in more complex traffic, when under time pressure, and when vehicles were farther away. The authors concluded that older pedestrians had fewer available resources than younger pedestrians did to process distance and speed information simultaneously. They suggested that older-pedestrians' age-related reduced ability to integrate the speed information in complex traffic might result in distance-based errors in road-crossing decisions, particularly when faced with making quick decisions.

### *Role of Complexity*

The literature on aging clearly documents the effect of task complexity on performance. Older adults appear to be more affected than younger adults when the conditions of a task become more complex and demanding (71). Complex situations can provide further interference to a person's information-processing system, which may be affected by the aging process (15). Some traffic environments cause more difficulty than others for older road users, resulting in an overrepresentation of older road user crashes in these situations. For example, older drivers experience difficulty turning across traffic (left-hand turns in the United States, Canada, and most European countries; right-hand turns in the United Kingdom, Australia, and New Zealand). Older drivers also are overrepresented in crashes at intersections and when merging into traffic, changing lanes, and backing up (6, 72, 73). These types of traffic situations are complex, presenting multiple sources of information that must be sampled continuously to decide on a safe course of action.

Complex traffic also hampers older-pedestrians' ability to cross the road safely. The majority of pedestrians in Sheppard and Pattinson's (24) study complained of difficulty in crossing because of busy and fast traffic, difficulty

in seeing traffic, and confusion from many roads joining or from the traffic light. Several road situations have been identified as potential hazards for older pedestrians because of the difficulty the situations present.

Intersections often cause difficulty for older pedestrians, despite the availability of signal lights, walk lights, marked walkways, and stop signs (74, 75). At intersections pedestrians must look not only left and right on the road to cross but also forward and backward for turning vehicles from the intersecting road.

Older pedestrians are overinvolved in crashes with vehicles backing up (28), particularly vehicles backing out of parking lot spaces and driveways. This type of crash often results from inattention by the driver and the pedestrian and from problems older pedestrians have in anticipating unexpected events.

Undivided roads also cause problems for older pedestrians (14, 21). Oxley et al. (21) found that pedestrians older than age 75 were at more of a disadvantage than younger pedestrians in complex two-way traffic compared with one-way traffic. It appears that in two-way traffic, older pedestrians have difficulty integrating all of the information to select a safe gap in the nearside traffic, while considering the traffic in the farside lane. The authors suggested that an increase in environmental complexity and sources of information placed overwhelming demands on the older-pedestrians' restricted mental faculties. On divided roads (with a median strip) where a safe crossing to the center of the road necessitated only consideration of one direction of traffic, older pedestrians were able to select a safe gap, as did their younger counterparts. Installation of median strips would benefit older pedestrians to a large extent.

Because several sources of information must be sampled periodically, the pedestrian must be able to attend to these sources selectively. Selective attention mechanisms become less efficient with age, so an older pedestrian may have difficulty locating task-relevant information in a complex environment. Likewise, a pedestrian must be able to divide attention among many information sources when crossing a road: the speed and distance of oncoming vehicles, the curb height, and the road surface conditions (especially in winter). Older people are known to have difficulty with multitask performance, and this difficulty increases as task complexity increases.

Other complex traffic situations present an increased risk of collision for older pedestrians compared with younger pedestrians. However, little available evidence associates other traffic situations with poor road-crossing skill. It is possible that fast-moving, heavy traffic and multilane roads provide too much information for older pedestrians to cross these roads safely. Further research on the role of complexity and its effect on risk of collision is warranted.

### *Role of Self-Perception*

Self-perception and perception of risk are associated with pedestrian crash risk. Although reduced skills can affect pedestrian safety, possibly a reduced awareness of the impact of aging on task performance also can accentuate risk of collision. It has been suggested that some elderly people deny their age and tend to identify themselves as younger (76). In his investigation of the relationship between perceived skills and confidence in driving abilities and perceived risk as a function of age, Matthews (77) found that older drivers—as well as younger drivers—saw crash risk as a problem for their peers but not for themselves. Similarly, older drivers believed that they possessed the necessary skills and abilities to avoid crashes but that their peers did not. Jonah and Engels (78) reported that elderly people expressed the least fear about crossing roads, suggesting that elderly people may cross in a risky fashion because they are overconfident and fail to recognize the extent of the dangers around them.

Mathey (13) assessed the attitudes and behavior of older pedestrians from 200 interviews and traffic observations of 800 elderly pedestrians. The findings suggest that although elderly pedestrians know the rules and regulations, they generously interpret the rules when applied to themselves. Many crashes occurred in familiar areas, where the pedestrians had a subjective feeling of safety and where their attention and caution were low. Older pedestrians' risky behaviors in traffic included underestimating the speed and overestimating the distance of vehicles (especially on wide roadways), crossing abruptly after waiting a long time to cross, entering a pedestrian crossing with indecisive behavior, and walking in traffic under temporal or emotional stress. This extreme view of older pedestrians as incompetent, risky, and unaware of potential hazards cannot be accepted unequivocally, however, because Mathey did not provide empirical data to support his assertions.

Others also have associated cognitive deficits with risk perception (79, 80). Van der Plight (81) has described the estimation of risk as a complex task when the decision maker actively has to search for relevant information in the environment. With the previous evidence that older adults are at a disadvantage when presented with a complex task, it may be argued that older pedestrians have limited abilities to perceive risk appropriately. Holland and Rabbitt (80) added that the reduced information capacity of elderly people makes them less efficient at monitoring their performance, less aware of mistakes, and less able to remember making mistakes.

Conversely, older adults may be able to perceive risk and compensate for functional changes successfully. Because of the gradual nature of changes over the life span, most aging adults appear to adapt and compensate

successfully, making appropriate adjustments to behavior to maintain a similar level of performance (82, 83). A substantial amount of literature supports the view that older drivers can and do compensate well for their restrictions. These compensatory strategies include increasing cautiousness and conservativeness, reducing driving and driving slower, and restricting driving to only optimal conditions (84, 85). Pedestrians also may adopt strategies to compensate for restrictions, such as avoiding complex traffic, crossing only at formal crossings, planning routes, and selecting very large gaps in traffic; however, there is little conclusive evidence. In their investigation of the effect of age on road-crossing decisions, Oxley et al. (70) found that pedestrians in their 60s overcompensated for perceived restrictions by selecting very large gaps in traffic, thus demonstrating an awareness of their changing abilities. In contrast, however, some older pedestrians (age 75 or older) failed to recognize traffic hazards and crossed at potentially dangerous situations. This finding supports the suggestion that losses occur in the compensatory senses in the oldest of old people to a point when the losses overwhelm normal attempts at compensation (86).

### **Health**

The general health of a pedestrian often is considered a predictor of crash risk. According to a physician in Sweden (87), elderly people who are mobile and drive have less risk of osteoporosis, less obesity, less constipation, and fewer hip fractures; they also use prescription drugs less. But few studies unequivocally have associated poor health with increased crash risk for older pedestrians. Moreover, despite the good reviews on the examinations of the role of impairing medical conditions—such as dementia, cardio- and cerebrovascular diseases, ocular disorders, pulmonary diseases, and diabetes (62, 88)—in crash risk for older drivers, consistent associations between these conditions and crash risk have not been established.

The most widely researched risk factor in driving is dementia—discussion of its possible effect on pedestrian travel is warranted. Although the prevalence of active older pedestrians with dementia is unknown, research estimates that a substantial proportion of older people with dementia still drives (89). Likely, there also are active older pedestrians with dementia. Dementia involves the impairment of memory in association with impairment in judgment or abstract thinking, other disturbances of higher cortical function, and personality change. Dementia is estimated to occur in as many as 15% of people older than age 65 (23, 90). The most prevalent form of dementia, Alzheimer's disease, usually results in slower performance on timed tasks and

problems with switching visual selective attention from one source of information to another, so this disease probably would affect pedestrian safety.

Parkinson's disease results in slowness of movement, rigidity, tremors, and extraocular motor abnormalities. This disease may be debilitating for older pedestrians particularly because of the effects on neuromuscular performance. Other ramifications of Parkinson's disease include mental slowness, lack of initiative, forgetfulness, impairment of cognition, and mood disturbance.

Another consideration is the role that medication may play in pedestrian crash risk. Elderly people use a larger proportion of all prescriptions than any other age group (approximately three times as many as younger people). Elderly people more often take several drugs together (polypharmacy) than younger age groups, particularly cardiovascular drugs, analgesics, and alimentary tract drugs (91–93). Many prescription medications have the potential to affect driving skills adversely, but many older people require continual medication for health and quality of life.

Although the quantifying of risks or the proving of a cause-and-effect relationship between medication use and crash risk is difficult, there are good reasons to conclude that some drugs may contribute to the risk of older-pedestrian crashes. Use of prescription medications may constitute a real risk for older pedestrians because of harmful interactions, pharmacokinetics, and pharmacodynamics. The use of psychotropic medication, a widely prescribed antidepressant, has been associated with falls, confusion, and morbidity in the elderly population (93, 94). Medications may contribute to crash risk because sedation slows reaction time and diminishes awareness of hazards; moreover, impaired postural stability is associated with drug use, and impaired balance may result from the use of aminoglycoside antibiotics, aspirin, quinine, and furosemide. Further, it has been suggested that elderly people are more sensitive to the effects of medications than are younger people because of an unfavorable toxicity profile in elderly people (95, 96).

## FACTORS AFFECTING PEDESTRIAN CRASHES

Many factors affect older-pedestrian safety, including road and vehicle design, ITS technology developments, behavioral countermeasures, and enforcement.

### Infrastructure and Land Use: Road Design for Pedestrians

Road design has long been recognized as a contributing factor in road crashes, with high associations of pedestrian crash occurrence with road environment type and

geographic location. Although practices to produce pedestrian-friendly zones have been adopted throughout OECD nations, many design features to meet elderly people's needs appear lacking, and questions have been raised about whether the roads are equipped to match the needs and abilities of older users. These questionable features include the lack of convenient crossing facilities, fast walk cycles for pedestrian crossings, poor legibility of road signs, difficult entries and exits on public transportation, and high speed limits on roads frequented by older pedestrians. In addition, little thought has been given to the ergonomic requirements of older pedestrians who experience difficulty walking. For instance, the placement of resting places, curb height, amount and height of steps, slope of ramps, pavement widths, and maintenance of sidewalk surfaces all need to be considered in relation to the physical restrictions of older pedestrians.

Since older pedestrians experience more difficulty in terms of walking pace, seeing oncoming traffic, judging safe gaps in which to cross, and negotiating complex road environments, improvements to the road environment have been encouraged as a means to improve the mobility and safety of older pedestrians. The adoption of these improvements is not an easy task, however. Urban planners and traffic engineers often do not consider pedestrians—particularly older pedestrians—when designing roadways. The provision of a safer environment should receive a greater emphasis for areas with a high proportion of older pedestrians. A redefinition of the traffic function of a road would reduce the conflicts between people and vehicles without unnecessary restrictions on the movements of pedestrians. Many Western European countries, particularly the Netherlands with the *Woonerf* concept, have introduced a range of innovative countermeasures to achieve sustainable safety for pedestrians through proper road infrastructure.

### *Pedestrian Signs, Signals, and Markings*

Signs, signals, and pavement markings should control pedestrian movement as well as vehicle traffic. Although signalized pedestrian facilities commonly are regarded as a safety initiative, most older-pedestrian crashes still occur at these sites (28). Older people usually experience difficulty at signalized crossings because the walk phase is too short for completing the road crossing and the phase signals are confusing. This issue proves to be sensitive for traffic planning, especially where the capacity of traffic flow is important. Although a longer walk cycle time would accommodate the slower walking speeds of older pedestrians, it is argued that this change would impose delays on drivers.

As indicated earlier, many pedestrians have insufficient time to cross safely at signalized intersections, and



conflicts between pedestrians and turning vehicles occur because drivers fail to notice the pedestrian. Would pedestrians have an advantage if they could start crossing before the vehicles could begin turning? To examine this question, van Houten et al. (97) introduced a 3-s leading pedestrian interval (LPI) so that pedestrians could start crossing 3 s before drivers could start turning. This LPI gives pedestrians the opportunity to be further along in the crosswalk and hence more visible before vehicles begin to turn.

When the “Walk” signal came on 3 s before vehicles could proceed, a 95% reduction was found for the number of conflicts experienced by pedestrians who started to cross at the beginning of the walk interval. This reduction was slightly less for seniors (89%) when compared with nonseniors (97%). The introduction of the LPI reduced the odds of a pedestrian having to yield to a vehicle by approximately 60%. Use of the LPI not only would increase safety for pedestrians but also may give pedestrians an increased sense of comfort and perceived safety. The distance traveled by pedestrians during the LPI would be sufficient to assert the right-of-way over vehicles. The use of a 3-s LPI appears appropriate in view of the finding that older pedestrians delay for about 2.5 s before starting to cross (44).

In addition, the intended messages at signalized intersections and crossings are not always clear. From a questionnaire survey of more than 4,700 people, Tidwell and Doyle (47) showed that pedestrian laws and traffic-control devices are poorly understood. Just less than half of the respondents indicated that the flashing “Don’t Walk” signal meant to return to the curb. The intent of the message, “don’t start to cross,” is not obvious to many pedestrians. Nearly half of the respondents surveyed thought a “Walk” signal meant that there were no turning conflicts.

Pedestrians often are confused about how to interpret “Walk” and “Don’t Walk” signals in the steady and flashing modes. Some pedestrians, especially older pedestrians, sometimes are confused about how to respond to the “Don’t Walk” signal when the signal comes on after they have started to cross the street. Tidwell and Doyle (47) found that about half of the people surveyed thought that the “Walk” signal guaranteed their safety.

Auditory signals for pedestrians have been designed primarily for people who are blind or who have low vision, but the signals could be effective safety devices for sighted pedestrians as well. In their study, van Houten et al. (97) examined the influence of three verbal messages on pedestrians at intersections. The authors found that the provision of a message spoken immediately before illumination of the “Walk” signal reduced the number of pedestrian–vehicle conflicts at the intersections.

### *Crossing Barriers*

Most pedestrian crashes occur at midblock sections of the road. Many measures are used to prevent midblock crossings, including restrictive fencing and guardrails. Barrier fencing often has been used to allow access to the road only at formal crossing points, such as in shopping areas where there is high conflict between vehicles and pedestrians. Although side streets and driveways necessitate breaks in the fencing and hence limit the effectiveness, fencing still may reduce the incidence of pedestrians crossing at risky locations. In some location types, alternative barriers may be used for aesthetic reasons and may achieve greater compliance from pedestrians. Barriers in the form of garden beds, raised planter boxes, outdoor seating, and so forth, may result in higher levels of acceptance from pedestrians because the barriers appear as natural elements of the streetscape, not as overt attempts to redirect pedestrians from the most convenient path.

Guardrails installed between opposing lanes of traffic discourage midblock crossings and concentrate pedestrian traffic at formal crossing points. Stewart examined the effectiveness of guardrails in reducing crash risk by using a traditional design of closely spaced vertical bars at eight sites in London (98). The results showed a 33% decrease in adult casualties. This design, however, works to the disadvantage of short pedestrians who may have difficulty seeing over the vertical rails and being seen by approaching drivers. Any movement beyond the guardrail by the pedestrian may result in both the pedestrian and the driver having insufficient time to avoid a collision. Stewart also examined the effectiveness of guardrails with vertical “windows,” which can allow up to 80% transparency at 40 m ahead of a driver. He found that this design led to a significant improvement over traditional designs—namely, a casualty reduction of nearly 50%.

### **Median Refuges**

The provision of median refuges throughout hazardous sections of wider, multilane roads, particularly in areas with many older pedestrians, has been identified as a potentially effective countermeasure for pedestrian safety (19, 27). Refuges not only provide pedestrians a safe section in which to rest in the center of the road but also simplify the crossing task, enabling a more manageable two-stage crossing with attention focused in only one direction at a time. The provision of medians also may reduce vehicle travel speeds, further enhancing safety for pedestrians.



## One-Way Roads

Wide, multilane roads are hazardous for all pedestrians but particularly for older pedestrians. Wide roads mean that slower-walking older pedestrians are on the road and exposed to potential collision for a longer time than are faster-walking younger pedestrians. In addition, multilane roads represent a complex traffic environment for older pedestrians. In contrast, one-way roads—often used in urban areas to speed the flow of traffic—may benefit the safety of older pedestrians. However, use of one-way roads has been controversial, with arguments that one-way roads create congestion and limit the mobility of drivers. Stemley (99) discussed the merits of one-way roads, pointing out the many advantages over two-way roads:

- One-way roads are safer as a result of fewer conflict points at intersections (fewer turning movements).
- One-way roads offer more available gaps for crossing pedestrians because pedestrians only need to look in one direction.
  - Pedestrians cannot be caught between opposing lines of traffic when crossing one-way roads.
  - One-way roads make it easier for drivers and pedestrians to see each other.
  - Pedestrians are less likely to become frustrated waiting to cross and are less likely to engage in dangerous crossing behavior.
  - Turning drivers can monitor pedestrian movements more easily because drivers do not need to look for a gap in oncoming traffic.

However, one-way roads also have the following disadvantages:

- Transit passengers have longer walks and may be confused about where to get return service.
- Left-turning drivers hit more pedestrians because the A-pillar blocks the driver's visibility of the crosswalk.

## Car-Free Pedestrian Zones and Traffic Calming

Several road-modification techniques known as traffic-calming devices—designed to redirect or slow traffic and increase the safety and the livability of streets—have been implemented in recent decades, especially in Europe. These devices have been placed in residential areas to reduce the intrusion of vehicles into urban life and in town centers that have high rates of pedestrian activity, to reduce the number and the speed of vehicles. Clearly, increased pedestrian safety can be achieved by reducing traffic speed and volume in high-pedestrian areas.

A common practice to moderate vehicle speed in some European countries—particularly in Denmark and the Netherlands—is to widen sidewalks, protect parking lanes, and provide fewer traffic lanes. This practice has been adopted in other countries, such as Singapore and Australia, and to a lesser extent in the United States, but the practice depends on land use and traffic management. Other street modifications include roundabouts, speed humps, slow points (horizontal displacement through narrow or angled paths, which usually are heavily landscaped), single lanes, and full or partial street closures. The desired outcomes of these modifications are to reduce collisions, conflict points, speeds, traffic volumes, and traffic noise; and to increase safety (real and perceived), driver sensitivity to the environment, ease of pedestrian movement, and the friendliness of residential environments.

Urban speed limits in Europe generally are 50 km/h for innercity and town roads, and many residential street speed limits are 30 km/h, with appropriate signage and other traffic controls. In Australia, the state of Victoria recently lowered the speed limit on residential streets to 50 km/h. In a recent Australian evaluation of countermeasures designed to moderate excessive vehicle speeds in high-pedestrian activity areas, average speeds were reduced overall by 8 km/h—from 28 km/h to 20 km/h. This reduction was associated with predicted declines of 2% to 3% in fatal pedestrian crashes and of 15% in serious injury pedestrian crashes (100).

Although many devices can accomplish these objectives, there are some disadvantages. For example, traffic noise increases as traffic slows for speed humps. In roundabouts, the movement of large vehicles may be restricted and drivers may fail to yield to pedestrians. Bicyclists may experience difficulty on speed humps. Inappropriately placed landscaping may obscure drivers' view of pedestrians. Local residents may be inconvenienced by road closures.

The reduction of traffic on specific streets often leads to increased traffic on nearby streets, with accompanying increases in crashes. Residents, not drivers, favor the devices that reduce volume. Reduced volume and speed lead to increased pedestrian safety. Consideration also needs to be given to the impact of these devices on emergency vehicles and snow removal equipment. O'Brien and Brindle have provided a detailed review of traffic-calming techniques and the effects (101). For additional information, consult Zegeer et al. (102), *Design and Safety of Pedestrian Facilities* (103), and Harkey (104).

## Vehicle Design

A vehicle's design can have a marked effect on the nature and severity of the injuries sustained by a pedestrian in

a crash. An area addressed in pedestrian protection internationally is the design of vehicles to provide pedestrians with “optimum” crash conditions. However, the mechanisms of injury to pedestrians are more complex than the mechanisms of injury to vehicle occupants. Pedestrians normally experience a series of separate impacts, each of which potentially is injurious and could affect the kinematics of the next impact in the sequence. In many crashes, therefore, improved vehicle design may offer only limited protection to pedestrians.

### *Recent Trends*

A marked change in the overall frontal shapes of passenger cars during the past two or three decades has benefited pedestrians, but the recent trend for large recreational and four-wheel-drive vehicles may affect pedestrian safety negatively. For instance, it has been suggested that bull bars (an inverted U-shaped bar often added to the front grill of four-wheel-drive vehicles) present a particular problem in pedestrian crashes. McFadden (35) found 12% of the vehicles involved in fatal pedestrian crashes had bull bars, but the author believed that the overall use of vehicles with this feature could be higher, up to 20%.

With the recent changes in vehicle design and in the types of vehicles on the road, little is known about the outcomes for pedestrians in crashes involving more modern vehicle designs. It is apparent, however, that leg injury still is the most frequently recorded injury in pedestrian crashes, closely followed by head injury (32). Jarrett and Saul (31) compared 1974–1983 vehicle design crash data with 1995 data; they identified a reduction in the most serious injuries for all age groups for newer vehicle designs and identical impact violence. Although the authors did not find any overall reduction in fatality rates between the data, they did find a significant reduction in mortality rates for the age 49 and older group. In another comparative study in France, a significant reduction in less severe injuries to the head, neck, pelvis, femurs, and tibias was noted for the advent of new vehicle designs (105). No difference for injuries to the abdomen, thorax, and knees was found.

More recently, Otte (106) in Germany noted that in newer car models (post-1990), injuries to the majority of body regions decreased, although there was an increase in injuries in the lumbar vertebra region (including the abdomen and cervical vertebra) and in the ankle and foot. Otte also noted that a slight reduction in the proportion of severe head injuries was found for impacts at speeds below 40 km/h, but the proportion remained at a similar high level with both pre- and post-1990 vehicle designs at higher collision speeds.

### *Design Standard and Tests*

Over the past three decades, progress has been made in the examination of the causes of pedestrian injuries, the biomechanical mechanisms of pedestrian impact, and the development of test procedures for the assessment of the degree of pedestrian protection afforded by modern vehicles. Three main groups have influenced this work: the National Highway Traffic Safety Administration in the United States, the European Experimental Vehicle Committee, and the International Organization for Standardization. The essential development from the findings of these groups is the introduction of pedestrian component testing in the New Car Assessment Program used in Europe, the United States, and Japan. Australia has proposed similar testing in the short term.

A set of component tests has been designed to represent the three most important mechanisms of injury: (a) lower leg against the bumper, (b) upper leg against the hood edge, and (c) head against the hood and the top of the wing, or fender. With the introduction of these tests, questions of validity have been raised. For example, one of the main criticisms involves head form tests and the limitation in only the assessment of linear impacts, not rotational forces—a main pedestrian injury mechanism. As a consequence, the tests assist in limiting the stiffness of the hood but not for overall pedestrian protection. Use of a Head Injury Criteria of 1,000 also has been questioned for child head form tests, because the tolerances are unknown and could be too conservative. The argument is that a hood structure optimized for adult head impact may be excessively stiff for child head impact because the adult head is approximately double the mass of the child head (107). Although this difference also may apply to older-adult head form tests, age-related changes in tolerance are poorly understood.

### **ITS**

Although pedestrian deaths and injuries constitute a significant road safety problem and there is a need to improve pedestrian safety, limited ITS technologies are directed specifically to this road user group. However, several ITS initiatives may affect pedestrian safety both positively and negatively. For example, advanced traveler information and traffic management systems that aim to increase vehicle speed and traffic flow tend to increase the frequency and severity of pedestrian crashes and injuries.

Carsten (108) reviewed the potential contribution of ITS to pedestrian safety and identified three categories of technologies: in-vehicle devices that detect pedestrians and warn the driver or intervene to prevent a collision, devices carried by the pedestrian that detect approaching

vehicles and advise when it is safe to cross, and devices that affect pedestrian–vehicle interaction. But all types of systems have problems. For instance, although in-vehicle vision enhancement and emergency braking systems may benefit the detection of pedestrians, there are problems with excessive false alarms in areas of high-pedestrian activity and with the impossibility of determining pedestrian intentions. For the second category, drivers may come to expect pedestrians to use these devices and thus become less vigilant in detecting pedestrians—although few pedestrians, apart from those with acknowledged vision or physical impairment, probably would use these devices.

Many ITS developments affect the pedestrian–vehicle interaction. The pedestrian user-friendly intelligent (or Puffin) signalized pedestrian crossing was first developed in the United Kingdom (109) to improve the safety of pedestrians, particularly older pedestrians. In its most conventional form, the Puffin crossing uses infrared detection of pedestrians on the crosswalk to vary intelligently the length of the clearance interval according to the needs of the pedestrian crossing on each cycle. A full Puffin crossing detects the pedestrians on the sidewalk waiting to cross and the pedestrians crossing the road.

In Australia, an evaluation of the effectiveness of Puffin crossings was conducted by observing pedestrian and driver behavior at Puffin crossings and by interviewing users of Puffin crossings (110). The study found that a longer display of the green signal for pedestrians resulted in a large increase of crossing completions without seeing a flashing “Don’t Walk” signal. In addition, the extension of the “Walk” interval did not lead to any change in the length of time taken by pedestrians to cross, and the change in signal operation led to only a small decrease in the average duration of the red signal for vehicles. For usability, pedestrians appeared happy with the change in operation, and any concerns about the adequacy of the time available for crossing were eliminated. However, signal control strategies of Puffin crossings could lead to an increase in delays for vehicles at high-pedestrian activity sites.

Belanger-Bonneau et al. evaluated the digital countdown device, installed at crossings near Montreal, Quebec, Canada, which displays the amount of time left to complete a crossing (111). Interviews with pedestrians revealed no differences in the understanding of normal crossing signals and of signals with the countdown device, but the countdown device appeared to increase compliance and reduce conflicts. Although there was an overall reduction in pedestrian–vehicle conflicts at the sites, the authors concluded that this occurred partly because of other factors.

The vehicle–pedestrian interaction also can be influenced by ITS in other ways. Ultimately, speed warning and limiting systems are likely the most effective coun-

termeasure to reduce the incidence and severity of pedestrian crashes. Also, the capacity of a car to limit pedestrian injury in a collision has been the focus of a recent European Union research and development project (112). The research focuses on three ways to make vehicles more pedestrian friendly: redesigning the vehicle structure to reduce the impact forces on the pedestrian in a crash; developing pedestrian impact-avoidance technologies, such as optical or radar detection systems, image processing, and feature recognition to detect pedestrians; and developing ITS applications such as pedestrian airbags mounted in the front of vehicles. In Japan, ITS initiatives also are being developed to improve pedestrian safety. Technologies such as a vehicle-based laser–radar system that can detect pedestrians, a rear-collision warning system capable of detecting pedestrians, pedestrian-friendly front bumper bars, and road–pedestrian–vehicle communication devices currently are being examined (113).

### Behavioral Countermeasures

Safe pedestrian travel must be incorporated into infrastructure and land use planning and supported by programs that encourage walking and that train people to walk safely. Behavior-training programs probably have limited success with older adults (114) because of the difficulties in getting older people to respond to educational campaigns to learn new strategies and change habits developed over many years. Evans (115), however, has argued that behavioral factors are playing an increasingly larger role in traffic safety and that more emphasis should be put on intervention programs that alter driver and pedestrian behavior and attitudes. Findings from some studies indicate that with practice, the performance of older adults can improve considerably (15, 116). Programs that promote safe walking practices along with training in judging the speed and distances of approaching vehicles, making appropriate decisions in complex environments, attending to relevant sources of information, and crossing undivided roads in two stages may have the potential to reduce crashes among older pedestrians.

The state of Victoria introduced the Walk-with-Care program in the early 1990s to address older-pedestrian crash issues. With local government support, the program combines educational, promotional, and engineering countermeasures to reduce the frequency and severity of older-pedestrian crashes. Although an evaluation of content and delivery has been conducted, no examination of road safety countermeasures has been attempted (117).

One of the more effective ways to reduce pedestrian crashes at night is through the use of retroreflective

clothing, patches, or tags, thus increasing the chance drivers will detect the pedestrians on the road. Light hitting a retroreflective object returns to the source, making the object highly visible. The use of lamps attached to the body of or carried by pedestrians also enhances conspicuity at night. However, some older adults might be reluctant to use these materials because they may feel more vulnerable to crime (being robbed, mugged, etc.).

## Enforcement

Enforcement can be effective in reducing the frequency and severity of pedestrian crashes and should be well suited to the needs of pedestrians. At this moment, legislation seems to be focusing on the needs of vehicles instead of on the needs of pedestrians. Although few laws currently target pedestrian safety, legal and enforcement opportunities should be considered. These opportunities include reduction of vehicle speed in high-pedestrian areas, enforcement of regulations against crossing the road near signalized crossings or intersections, and restrictions on street parking in shopping centers frequented by older pedestrians. Pedestrians and drivers also need to learn the road laws that apply to both groups. The European Transport Safety Council (118) noted that both drivers and pedestrians cause safety problems at pedestrian crossings and that measures can be taken to reduce the risk. The council also noted that police usually enforce driver violations but not pedestrian violations when pedestrians disobey traffic signals (usually because of difficulty in identifying the pedestrians). However, intervention in the form of warnings for pedestrian offenses has proved effective in controlling behavior.

## STRATEGIC APPROACH

In the last decade, a growing awareness of the vulnerability of pedestrians has increased emphasis on improving pedestrian safety and maintaining mobility.

Rosenbloom (119) has described the key components of quality of life, including the ability to move about at will, to engage in social and recreational activities, and to use business and social services. Therefore, a strategic approach is needed—particularly through research and the implementation of programs—to reduce the extent and severity of injuries to pedestrians of all ages and yet maintain quality of life.

## Research Priorities

In an effort to provide direction for future intervention and research efforts focused on improving the safety of older pedestrians in Australia, Oxley and Fildes (16) conducted a strategic review of the research and action items identified by an international panel of agency, research, and community groups involved in pedestrian safety. One of the goals of the review was to prioritize the research items on the likely importance for future work in this area. Table 2 lists the top eight research items. The two research items judged most important by the panel of experts emphasized (a) a greater understanding of the exposure and travel patterns of older pedestrians to permit more accurate assessments of crash involvement rates and mobility needs and (b) a better appreciation of pedestrian performance and behavior in complex road environments.

## Implementation Priorities

The safety of older pedestrians in a traffic environment is a pressing issue that needs immediate attention. In addition to reviewing the research needs for older pedestrian safety, Oxley and Fildes (16) also identified and prioritized action or implementation items. Again, a panel of international experts prioritized the action items; Table 3 lists the top eight action items. The first three priority action items related to the provision of a safer and more pedestrian-friendly environment in

TABLE 2 Older-Pedestrian Strategy: Research Item Priorities (16)

Priority	Research Item
1	Investigate crash involvement patterns in more detail
2	Expand understanding of older pedestrian performance in complex settings
3	Examine the role of inappropriate behavior in older-pedestrian crashes
4	Evaluate the effectiveness of speed reduction measures for older pedestrians
5	Evaluate the effectiveness of median strips for older pedestrians
6	Assess older-pedestrian mobility needs and patterns
7	Examine the suitability of road and highway design for older pedestrians
8	Develop countermeasures at tram and bus stops

TABLE 3 Older-Pedestrian Strategy: Action Item Priorities (16)

Priority	Action/Implementation Item
1	Increase effort to provide a safe traffic environment for older pedestrians
2	Reduce travel speed in high density pedestrian areas
3	Reduce traffic in high density pedestrian areas
4	Develop alternative mobility options for older pedestrians
5	Develop guidelines for adequate crossing times for older pedestrians
6	Improve maintenance of sidewalks, surrounds, and street lighting
7	Develop safer access for older people at bus and tram stops
8	Improve public transportation access for older people

high-density traffic areas. Many innovative designs of malls and pedestrian and car precincts have addressed the specific needs of vulnerable road users, but more attention to these efforts appears warranted based on these findings; of particular interest is this need for more attention to pedestrians in these environments.

## SUMMARY

Although the overall number of pedestrian crashes has declined over the last 20 years, pedestrian safety remains a serious community concern. Furthermore, because of the anticipated increase in the mobility and in the proportion of older people in the community, road safety problems among elderly people are expected to become more substantial in the years ahead. By identifying and addressing older-pedestrian safety issues now, strategies can be designed to improve pedestrian safety in the future.

This paper has provided an overview of the relevant issues for the safety of older pedestrians and has identified several ways to improve mobility and safety problems of elderly people. A greater emphasis on improving roads and vehicles to accommodate the needs of older pedestrians, developing ITS technologies to reduce conflicts between pedestrians and vehicles, and developing programs to promote safe walking practices are recommendations to improve the safety of older pedestrians.

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# Land Use and Travel Patterns Among the Elderly

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Land use planning is increasingly seen as an important strategy for solving transportation problems. It is argued that low-density, dispersed land use patterns foster automobile dependence. Decades of such development in U.S. metropolitan areas is both the cause and result of the dominance of automobile travel and the consequent decline of both public transport and the use of non-motorized modes. Many problems are associated with automobile dependence, among them the mobility of the transportation-disadvantaged—those who do not have access to a car or who are unwilling or unable to drive a car. Transportation disadvantage has become more critical as an increasing share of the U.S. population resides in suburban, lower density areas and as alternative modes become less competitive with the private automobile.

Other papers in this volume demonstrate that the elderly are likely to become transportation disadvantaged as the aging process takes its toll. Rosenbloom shows that the automobile is the dominant mode for all elderly age cohorts; this pattern is intensifying over time. The baby boomers will enter retirement with near-universal access to a driver's license, and most never will have used public transit. Rosenbloom notes that population location trends indicate that the elderly increasingly will reside in the suburbs or in rural areas, where the automobile is critical to everyday mobility.

Aging often leads to physical disabilities that make driving difficult, hazardous, or impossible. Elderly drivers are more likely to be involved in crashes (based on exposure, but not per year) and are more likely to suf-

fer serious or fatal injury in crashes. The elderly may compensate for deteriorating driving skills by restricting travel to certain destinations, routes, or times of day. When the elderly can no longer drive, mobility is seriously compromised, especially in areas where there is no suitable alternative to the car. Since mobility is critical to quality of life, those without mobility may suffer isolation, depression, and other ills.

Is land use policy a viable strategy for addressing the mobility needs of the U.S. elderly? Will policies that promote higher-density, mixed-used environments provide increased levels of accessibility and reduce reliance on the automobile? Will such environments be sufficiently attractive to the elderly that they will relocate? Will the elderly be more likely to walk or use public transit when walking is convenient and transit is available?

Empirical research on the relationship between land use and travel patterns among the elderly is almost nonexistent. The 1995 Nationwide Personal Transportation Survey (NPTS) can be used to explore relationships between some general measures of urban form and travel. It shows that land use and travel relationships are largely the same for the elderly as for the nonelderly, although there is some evidence that the oldest elderly are more sensitive to local accessibility. The potential effectiveness of various land use strategies may depend on these findings. Promoting more transit-friendly, mixed-use communities will increase local accessibility, but current preferences for automobile travel, low-density living environments, and the benefits of aging in place suggest that such strategies will play a limited role in addressing mobility problems of the elderly.



This paper presents

- A brief summary of the literature on land use and travel patterns and some contextual description of larger urban development trends;
- Descriptive information on basic measures of travel by local and regional location characteristics;
- Results of total daily travel models as a function of selected land use characteristics, since public transit use is such an important aspect of land use policy discussions, results from various models of transit use are included; and
- The potential of land use policy to promote accessibility and reduce reliance on the private automobile.

### LAND USE AND TRAVEL PATTERNS (1)

The relationship between land use and transportation has been subject to extensive research by geographers, planners, urban economists, and others (2–4). The history of the 20th century is one of growing car ownership and use, declining use of transit and other modes, and the decentralization of both population and employment. Trends in travel and land use have complemented and reinforced one another: growing car ownership generated demand for highways, development of the highway system changed accessibility patterns, and population and jobs responded to these new patterns of accessibility (5–7). By 1990, the suburbs of U.S. metropolitan areas were home to about 62 percent of the metropolitan population and 52 percent of the jobs, while per capita car ownership and travel had reached all-time highs (8).

There is no question that from a broad perspective, land use and transportation trends are closely related. However, the historical record does not necessarily provide useful evidence for understanding land use and transportation at a single point in time, and the empirical research on relationships between daily travel and land use characteristics is even less clear. The empirical literature is reviewed in two parts: metropolitan and neighborhood level characteristics.

#### Metropolitan Characteristics: Size and Density

Extensive research has been conducted on the relationships between metropolitan density and modal split, commute trip length, and total automobile travel. Newman et al. (9–11) conducted comparative studies of per capita gasoline consumption and metropolitan densities. A comparison of cities around the world yielded a nonlinear relationship of increasing per capita gasoline consumption with declining density. Their work has been extensively criticized, primarily because per capita fuel

consumption is an indirect measure of automobile travel, and because they fail to account for many other factors that affect automobile use, such as the employment rate or household size (12, 13).

Pushkarev and Zupan (14) documented a positive relationship between population density and transit use with data from 105 urbanized areas for 1960 and 1970. Later studies by Transport and Road Research Laboratory (15) and others show similar results. Gordon et al. (16) found that cities with higher average densities have longer automobile commute times than those with lower average densities. Noting that density is a measure of concentration, the authors conclude that shorter commutes indicate greater efficiency of low-density urban form. Decentralization of both population and jobs allows people to economize to a greater extent in selecting jobs and housing locations. However, city size is correlated with density, so the densest cities are also the largest cities, and longer commutes are expected characteristics of large cities.

Pushkarev and Zupan (14) also found a significant but small relationship between residential density and car ownership: a large increase in residential density is associated with a small decrease in car ownership. Jones et al. (17) reported similar results. Schimek (18) found a modest relationship between the two variables and concluded that the primary determinants of household car ownership were household income, household size, and the number of workers per household. Transit availability also was found to be significant. Schimek also examined the relationship between residential density, vehicle miles traveled (VMT), and the number of vehicle trips. Results showed that both VMT and vehicle trips have a significant but small relationship with density: a 10 percent increase in density is associated with a 0.7 percent decrease in VMT. Downs (19) used simple simulation studies to demonstrate the same result for commuting distance and found that very large increases in metropolitan density are required to achieve rather modest reductions in average commute length.

Niemeier and Rutherford (20) examined nonmotorized travel. Higher density is associated with fewer daily VMT and fewer daily trips by all modes. The daily walking trip rate increases with population density greater than 5,000 persons per square mile. Walking trips are most frequent in urban areas with a population of 1 million or more and the presence of rail transit. However, the observed relationships do not control for demographic factors that are also related to urban density—for example, age, family size, and household income—and therefore are likely to overstate the actual relationship of density to trip rates and VMT. Residents of high-density areas are more likely to be elderly, have low income, and live in single person households—all factors associated with less travel.

## Neighborhood Characteristics

The New Urbanism movement has generated great interest in the relationship between travel and the spatial characteristics of the local environment. Although widely embraced by urban planners, the movement was the creation of architects, and its claims regarding transportation-related environmental benefits remain largely unproven (4, 21). New Urbanism focuses on the neighborhood environment and emphasizes mixed use around a defined center, a fine network of streets, and convenient pedestrian and transit access (22). These accessible neighborhood designs are expected to reduce automobile travel and increase transit and nonmotorized travel.

Several studies have compared automobile travel in new urbanist-type communities with traditional suburban communities. Simple comparisons show substantially less VMT in the new urbanist-type communities, but when household and other characteristics are considered, differences in travel are much smaller and in some cases not significant (23–25). Hanson and Schwab (26) used data from Uppsala, Sweden, and found that people living in areas with convenient access to local services made a higher proportion of nonwork trips by nonmotorized modes than people living in areas with low access to local services. Handy conducted a series of studies of local travel and neighborhood characteristics (27–29). She found that shopping trips increase with accessibility, but that walking trips are not necessarily substitutes for car trips—that is, the walk trips may be additional trips taken in response to high accessibility. In contrast, shopping and other discretionary travel become more efficient when accessibility is low; people are more likely to combine trips for different purposes into tours (30).

Kitamura et al. (31) analyzed total daily travel across five San Francisco metropolitan area neighborhoods of widely divergent spatial form and transit access. They found significant relationships between person trips and transit trips and specific geographic factors, such as location within the region, Bay Area Rapid Transit access, and high density. Also included in the model were general attitudinal measures—indicators of whether the person was protransit, preferred a suburban lifestyle, and more. The attitudinal factors had the strongest explanatory power of all groups of factors examined. None of the existing studies have specifically addressed elderly travel patterns.

## Trends in Urban Development Patterns

The major trend in urban spatial patterns for several decades has been decentralization. Suburbanization of population and employment has been evident in the

United States throughout the 20th century. Large-scale population suburbanization was followed by large-scale employment decentralization and by the emergence of major agglomerations outside the traditional downtown (7). More recently, decentralization has been accompanied by dispersion, with most growth occurring outside major centers. The U.S. Census 2000 figures indicate that these trends continued in the 1990s. Although population increases have occurred for the first time in several decades in some of the nation's largest cities, such as New York and Chicago, much larger increases were documented in the suburbs of these cities and in the smaller metropolitan areas.

Population decentralization has been accompanied by employment decentralization. Empirical evidence of this trend is extensive. Giuliano and Gillespie (32) used annual county-level employment data from 1969 through 1997 to compare growth rates across metropolitan areas. They found that core counties (those including the central city) of the largest metropolitan areas had the slowest growth rates throughout the series, relative to noncore counties and smaller metropolitan areas. Using the same county-level private employment data, Gordon et al. (33) compared growth rates of metropolitan areas with nonmetropolitan areas. They found higher rates for nonmetro areas for 1969–1977 and 1988–1994, but not for 1977–1988. The authors conclude that while the trend away from core counties is clear, whether job growth will shift more to smaller metro areas or to nonmetro areas remains to be determined.

U.S. patterns of retailing have changed. The suburban shopping mall is in competition with “big box” retail centers, grocery chains are competing with large discount “club” stores, and large-scale retailers such as WalMart and Target have all but eliminated small-scale retailers in rural and exurban areas. These new forms of large-scale retailing have given consumers more variety and lower prices, and their success attests to consumer preferences. Small shops have been relegated to niche markets, such as high-end specialty stores serving the boutique consumer and low-end independents serving poor inner city neighborhoods avoided by the national chains. There is a clear connection between retailing trends and development patterns. The increasing scale of retailing is built around the private vehicle and plentiful home storage capacity.

There is little evidence to suggest that these trends will turn around. Major explanatory factors include rising real household income; social change—for example, the decline of the nuclear family; increased population diversity; and a shift to an information-based economy, which has led to increased location mobility of economic activity and a corresponding decline in agglomeration benefits.

Preferences among households for low-density living continue to be strong, and rising incomes allow more consumption of single-family housing. Annual housing surveys conducted by Fannie Mae consistently show that people prefer suburbs to cities and small cities to large cities. For example, the 1997 survey asked, "Where would you prefer to live?" As shown in Table 1, more than two-thirds of the respondents preferred a rural area, a small town not near a city, or a small to medium city. When asked whether they would consider buying a home in the central city closest to where they currently live, nearly two-thirds responded negatively.

If location preferences are consistent across age (a plausible assumption), those with strong preferences may relocate to lower-density, more remote areas once retirement frees them from employment access consideration. Others may be drawn to centers of smaller metro areas that offer attractive cultural or natural environments, such as Boise, Idaho; Charlotte, North Carolina; and Santa Fe, New Mexico. Only a small portion of the elderly may be drawn back to the central parts of larger cities, and these will be the cities that remain attractive as centers of culture or diversity.

## ELDERLY TRAVEL PATTERNS AND LAND USE

Rosenbloom has provided a comprehensive picture of elderly travel patterns; the focus in this paper is on comparing travel patterns across different land use environments using 1995 NPTS data. The NPTS is a telephone survey that collects one-day travel diary data for all individuals five years old or older from randomly selected households throughout the United States. Extensive personal and household data are also collected. The 1995 survey includes 42,000 households, 93,560 persons, and more than 400,000 person-trips. Of the persons in the sample, 13.6 percent are elderly.

The travel diary data makes it possible to examine the total amount of travel that takes place over the course of a day for each person. This analysis combines all trips to generate measures of "total daily travel," number of trips, total miles traveled, and total time spent traveling for each person. Travel by mode and transit use is included in the analysis. Two types of comparisons are

made: (a) elderly versus nonelderly (persons 65 years and over versus persons 16–64), and (b) elderly cohorts, including "pre-elderly" (55–64 years), "younger elderly" (65–74 years), and "older elderly" (75 years and over). The sample size of the oldest category (85 years and older) is too small for separate analysis.

The 1995 NPTS provides relatively rich land use data. All households are located according to U.S. census block, and information on urban area location, as well as census tract and block level population, housing, and employment characteristics are appended to each household record. Neighborhood characteristic variables are 1995 estimates from a proprietary database based largely on 1990 U.S. Census data.<sup>1</sup>

Two levels of land use data are explored—metropolitan and neighborhood. Metropolitan measures include size (population) of the metropolitan statistical area (MSA), location inside or outside a central city, and inside or outside an MSA, all with respect to place of residence. In addition, an "urban/rural" five-category code was developed as an indicator of both population density and spatial relationship of each block group to population centers.<sup>2</sup> Neighborhood variables include population density, employment density, and various measures of housing characteristics, all measured at the census tract level. In addition, the analysis generated a "local services access" measure based on zip code level 1992 Economic Census data, which is measured as the density of service and retail establishments per square mile. Highly localized land use characteristics, such as presence or absence of sidewalks or mix of local activities, are not available in the NPTS data and are therefore beyond the scope of this report.

## Total Daily Travel and Metropolitan Form

Table 2 shows total daily trips, travel distance (person-miles), and travel time (person-minutes) by metropolitan area size for three age cohorts. These measures of travel include all modes, but exclude long distance trips more than 75 miles long. The share of people who made at least one trip on the survey day is also included. Table 2 shows that differences between age cohorts are greater than differences within age cohorts across all travel measures. The trend of decreased trip making with age is evi-

TABLE 1 Living Preference

Type of Area	Percent
Rural area	22
Small town not near a city	24
Small or medium-size city	22
Suburb near large city	23
Large city	9

<sup>1</sup> The proprietary data were prepared by Claritas. See Appendix L of the 1995 NPTS User's Guide.

<sup>2</sup> Prepared by Claritas, Inc. See Appendix L of the 1995 NPTS User's Guide, which references Miller, D. R., and K. Hodges. 1994. A Population Density Approach to Incorporating an Urban-Rural Dimension into Small Area Lifestyle Clusters. Paper presented at the Annual Meeting of the Population Association of America, Miami, Fla., May.

TABLE 2 Daily Trips, Distance, Travel Time, and Share: Travel by MSA Size<sup>a</sup>

<i>Age Group</i>	<i>MSA Size</i>	<i>Daily Trips</i>	<i>Distance</i>	<i>Travel Time</i>	<i>% Traveled</i>
55–64	Not in MSA	3.6	29.5	55.4	81
	<250,000	4.1	27.7	59.0	85
	250,000–500,000	3.8	26.2	56.4	84
	500,000–1,000,000	3.8	24.6	55.6	85
	1,000,000–3,000,000	3.8	26.6	57.2	83
	>3,000,000	3.5	23.9	57.8	83
65–74	Not in MSA	3.6	26.4	54.9	77
	<250,000	3.7	22.6	52.5	79
	250,000–500,000	3.7	20.7	49.3	78
	500,000–1,000,000	3.4	23.1	54.1	76
	1,000,000–3,000,000	3.5	20.5	50.5	77
	>3,000,000	3.4	20.8	53.7	77
75 and over	Not in MSA	2.4	15.1	37.2	59
	<250,000	2.8	14.7	38.4	66
	250,000–500,000	2.2	13.4	32.5	61
	500,000–1,000,000	2.5	14.4	37.6	62
	1,000,000–3,000,000	2.4	12.8	36.2	65
	>3,000,000	2.3	12.3	35.7	61

<sup>a</sup> Distance in person-miles, time in person-minutes.

dent, with the drop-off particularly marked for the oldest cohort. The oldest cohort has the lowest trip rate as well as the largest share of people who did not travel on the travel diary day. It bears noting that the decline in work travel occurs between the 55–64 and 65–74 cohorts, but the big reduction in travel occurs in the 75 and over cohort. Looking within each age cohort, travel distance varies more than travel time, reflecting use of slower modes in the largest MSAs. As expected, those living outside metro areas travel the most miles in all cases. Note that those living in the smallest MSAs have the highest average trip rate.

The same measures of travel for people living inside and outside the central city are also compared. As expected, those residing inside the central city travel less than those residing outside the central city, but this difference declines with age. For example, total travel distance is 29 and 23 miles, respectively, for the 55–64 cohort, and 15 and 12 miles for the 75 and over cohort. Apparently the wealth and household composition effects represented by central city residence disappear or are offset by the general decline in travel demand among the oldest travelers.

The NPTS also provides an “urban/rural” variable (as described earlier) that categorizes census tracts on the basis of contextual density. Rural areas have the lowest density, followed by towns. Second cities are higher density than towns, and urban areas have the highest density. Suburban areas have lower density than urban areas but are physically proximate to urban

areas. The urban/rural categorization is used to compare travel measures across age cohorts, using both total travel and nonwork travel. The findings are similar to those for MSA size: differences between elderly and nonelderly decline as size/density increases. For example, Figure 1 shows total daily nonwork travel distance by urban/rural category for elderly and nonelderly. In urban areas, nonwork travel distance is virtually the same for both groups. Figure 2 gives total daily nonwork trip rates by urban/rural category. The pattern is similar for both groups, but the elderly have somewhat lower trip rates in rural areas and urban areas. In the case of rural areas, this may suggest that the elderly tend to compensate for less access by making fewer trips. On the other hand, this may simply reflect household income differences associated with residential location.

### Total Daily Travel and Local Density

Local density (persons per square mile in census tract place of residence) serves as a general measure of neighborhood form. A four-category density measure based on prior research is used: low (less than 500 persons/square mile), medium (500 to 2,000 persons/square mile), high (2,000 to 10,000 persons/square mile), and very high (more than 10,000 persons/square mile). Total trips and nonwork trips, use trips, miles, and time as measures of travel are compared. Table 3 shows information for total

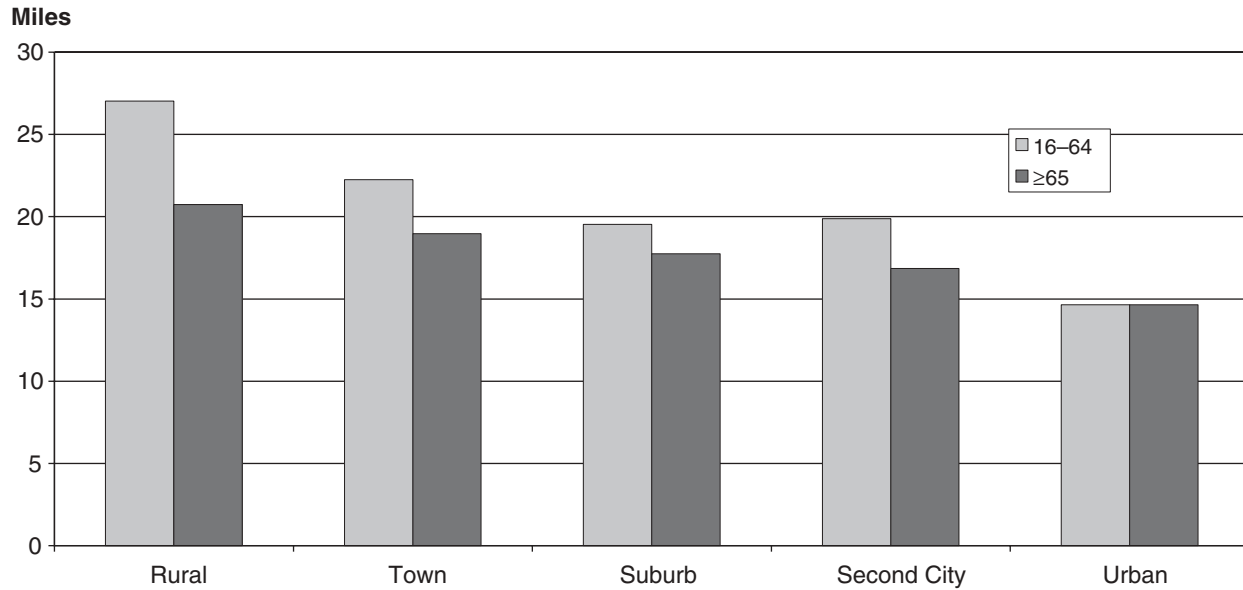


FIGURE 1 Total daily nonwork travel distance, elderly and nonelderly, by urban or rural category.

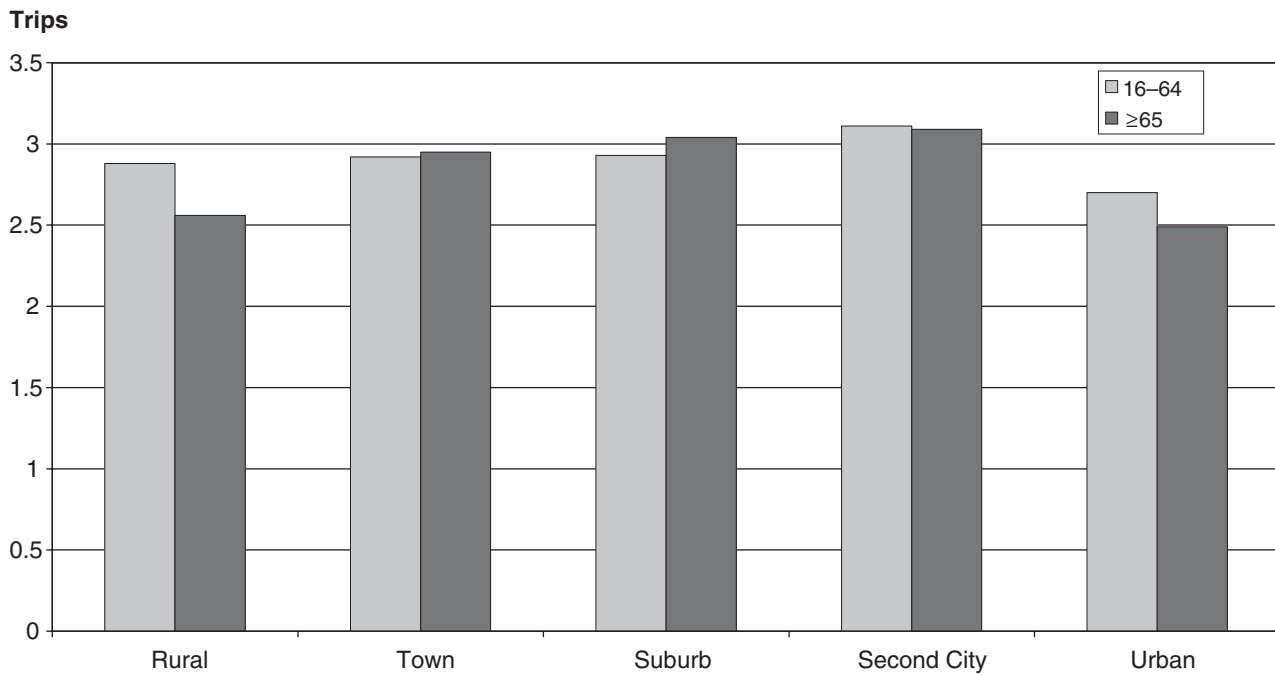


FIGURE 2 Total daily nonwork trips, elderly and nonelderly, by urban or rural category.

trips. Again the effect of lower trip rates for the elderly are reflected in lower average total travel time and distance across density categories. For both the elderly and nonelderly, travel distance declines with density.

If nonwork trips are removed, there is far less difference between the elderly and nonelderly, as shown in

Table 4. Trip rates are quite comparable, as are travel times. Trip distance is higher in each density category for the nonelderly, but the pattern of declining distance with increasing density is similar.

Segmenting the elderly again shows that the pre-elderly and younger elderly behave very much the same, although



there appears to be some substitution of nonwork trips for work trips among the younger elderly, while the older elderly travel less distance more because of fewer trips than responses to density. As was evident in the urban/rural comparisons, it appears that the elderly in low-density areas (less accessible areas) travel fewer miles, because they make fewer trips see Figures 3 and 4. The oldest elderly make fewer and shorter trips in low-density areas relative to the other age cohorts. Comparing across

density categories, the oldest elderly make the shortest trips in high-density areas, but make the most trips in medium density areas. The relationship between trips and density and between distance traveled and density are similar across age cohorts. Taken together, it is unclear whether the oldest elderly are more sensitive to density and the accessibility it represents than others, or whether these patterns simply reflect different demographics that may be correlated with residential density.

TABLE 3 Trips, Distance, Time by Density: Elderly and Nonelderly

Age Group	Density	Trips	Distance	Time
Non-elderly	Low (<500/mi <sup>2</sup> )	4.1	39.8	65.9
	Med. (500–2,000/mi <sup>2</sup> )	4.3	35.0	64.4
	High (2,000–10,000/mi <sup>2</sup> )	4.4	30.4	63.9
	Very high (>10,000/mi <sup>2</sup> )	3.7	21.9	65.4
Elderly	Low (<500/mi <sup>2</sup> )	2.9	22.3	46.4
	Med. (500–2,000/mi <sup>2</sup> )	3.3	20.7	49.5
	High (2,000–10,000/mi <sup>2</sup> )	3.2	16.9	45.9
	Very high (>10,000/mi <sup>2</sup> )	2.7	13.3	46.6

TABLE 4 Nonwork Trips, Distance, Time by Density: Elderly and Nonelderly<sup>a</sup>

Age Group	Density	Trips	Distance	Time
Non-elderly	Low (<500/mi <sup>2</sup> )	2.9	25.2	42.9
	Med. (500–2,000/mi <sup>2</sup> )	3.0	21.9	41.5
	High (2,000–10,000/mi <sup>2</sup> )	3.0	18.7	40.4
	Very high (>10,000/mi <sup>2</sup> )	2.6	13.3	41.1
Elderly	Low (<500/mi <sup>2</sup> )	2.7	20.6	42.9
	Med. (500–2,000/mi <sup>2</sup> )	3.0	18.9	45.5
	High (2,000–10,000/mi <sup>2</sup> )	3.0	15.5	42.3
	Very high (>10,000/mi <sup>2</sup> )	2.5	12.0	42.2

<sup>a</sup> Nonwork travel is obtained by removing all trips taken from home to work and from work to home, including intermediate stops.

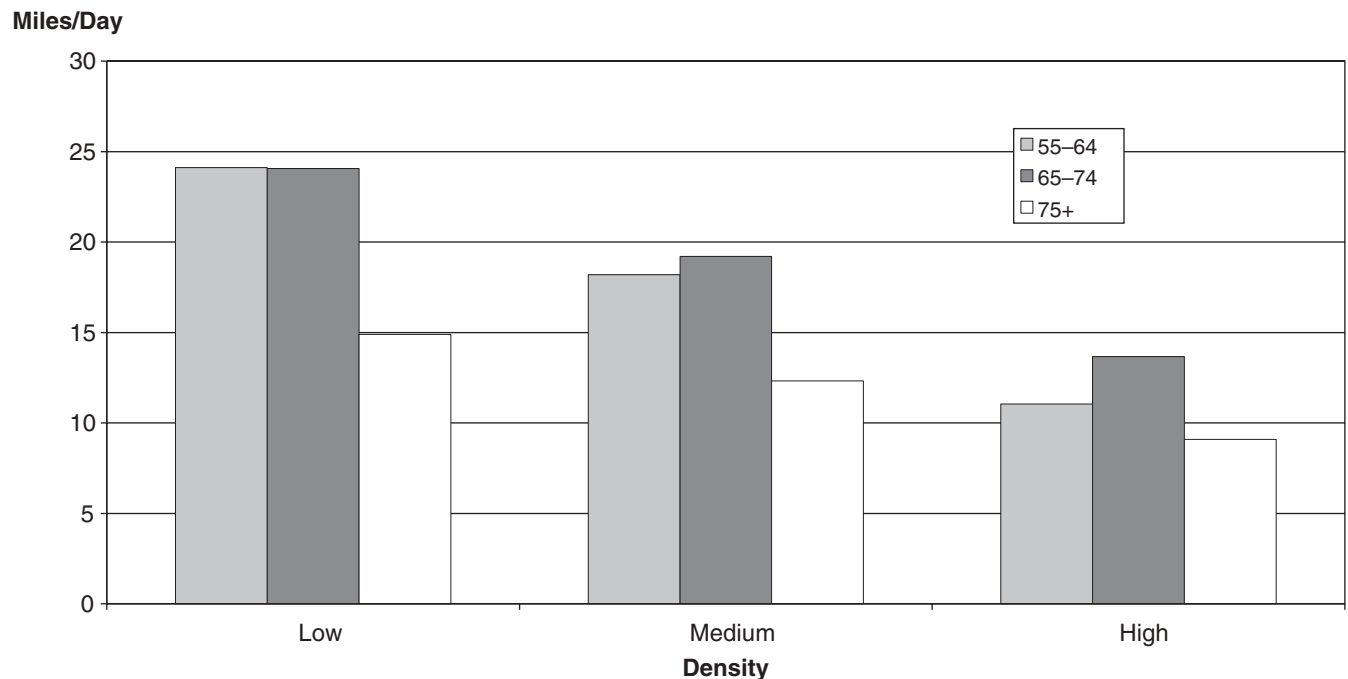


FIGURE 3 Total daily nonwork distance, elderly age cohorts, by residential density.

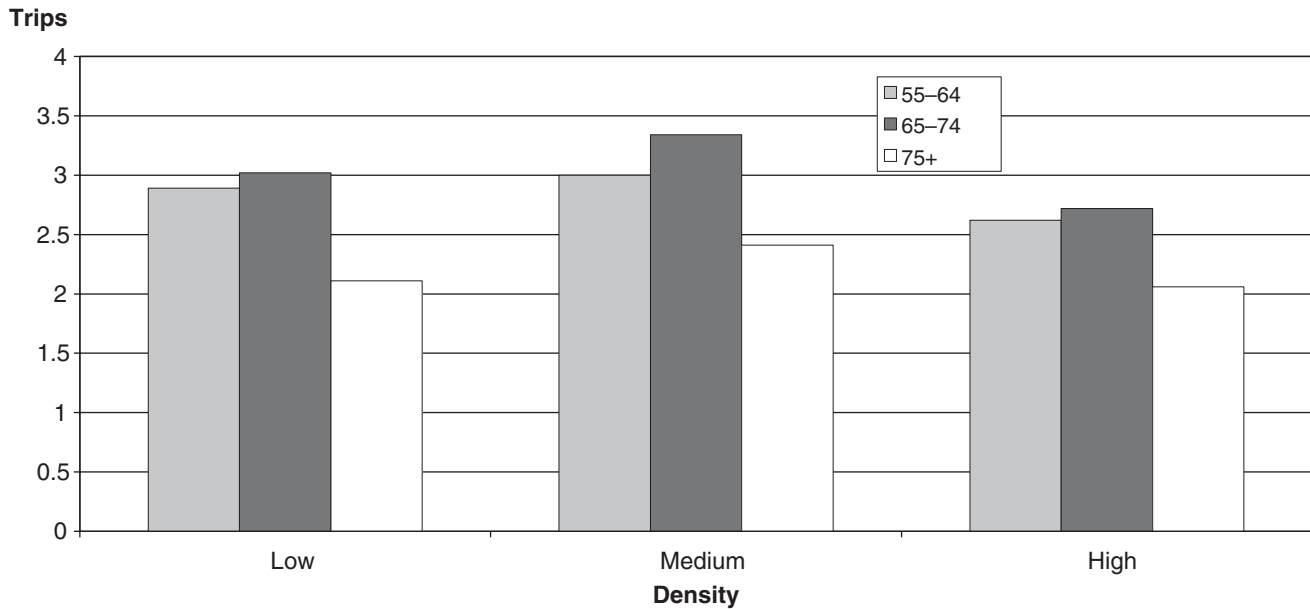


FIGURE 4 Total daily nonwork trips, elderly cohorts, by residential density.

### Land Use and Modal Shares

The emphasis on land use planning stems in part from the assumption that higher-density, mixed-use environments promote the use of alternative modes, such as public transit and walking. Comparing mode shares for all trips across metropolitan size categories, for nonelderly and elderly age cohorts (Table 5), shows that the privately owned vehicle (POV) share is above 90 percent for all MSA categories except those of more than three million. In the largest metropolitan areas, the POV share drops below 90 percent, and the combined total of transit and walk is in the 11–12 percent range. There is little difference in this pattern across age cohorts. The transit share ranges from 3.6 in the youngest group to 2.7 in the eldest group. It is only in the eldest group that transit mode share is greater than two percent for MSAs in the lower size categories. Similarly, the walk share in the largest MSAs ranges from 7.7% in the youngest group to 8.7% in the eldest.<sup>3</sup>

These patterns suggest that MSA size has the same effect for all age groups. There are large differences in the relative shares of driver and passenger trips across age cohorts; this may be indicative of household size and lifestyle differences. If only nonwork trips are

examined, the same patterns are evident, except that nonwork trips in general are more likely to have higher vehicle occupancy; hence, the share of POV passenger trips is higher (data not shown).

Population density is a standard measure of urban form and the one most frequently used as a measure of transit-friendly environments. Tables 6 and 7 give mode shares by population density categories, again by age cohorts. Categories were chosen based on previous work, which indicates that only very high densities (by U.S. standards) are supportive of transit. Transit use within the first two density categories is almost nonexistent, and the walk share varies between two and three percent for all but the older elderly. Transit use ranges from 8.5 to 11.6 percent in the very high-density category, while the walk share ranges from 18 to 22 percent. The POV share is lower across all categories for the older elderly, as more persons become unable or unwilling to drive. If we look only at nonwork trips, the transit share is lower and the walk share is higher. Public transit is oriented to commuting. Transit routes are usually oriented to serve downtown job centers, and service frequency is highest during peak commuting periods. Hence, transit is less likely to be used for nonwork travel. Tables 6 and 7 suggest that transit may be used more frequently by those 65–74 years, but as travel becomes more physically difficult, the older elderly shift to walking and traveling as POV passengers.

Further examination of the transit role for the elderly is based on frequency of transit use and transit access, as measured by distance to the nearest transit stop. For

<sup>3</sup> The NPTS Survey likely understates short walk trips, because short trips are most likely to be omitted from travel diaries. If the central portion of large MSAs is more amenable to short walk trips, the observed walk shares may be biased across MSA size categories.

TABLE 5 Mode Share (percent): All Trips by MSA Size<sup>a</sup>

<i>Age Group</i>	<i>MSA</i>	<i>POV Driver</i>	<i>POV Passenger</i>	<i>Bus/Rail</i>	<i>Walk</i>
<55	Not in MSA	78.7	17.4	0.1	2.7
	<250,000	76.5	18.3	0.5	3.2
	250,000–500,000	76.4	18.3	0.3	3.4
	500,000–1,000,000	77.3	18.4	0.7	2.8
	1,000,000–3,000,000	76.3	17.9	0.9	3.6
	>3,000,000	71.0	16.3	3.6	7.7
55–64	Not in MSA	77.6	19.3	0.1	2.5
	<250,000	70.7	24.4	0.5	3.5
	250,000–500,000	79.2	16.6	1.2	3.0
	500,000–1,000,000	78.5	17.9	0.6	2.7
	1,000,000–3,000,000	77.6	18.2	1.0	2.6
	>3,000,000	73.6	16.3	2.6	6.8
65–74	Not in MSA	75.5	20.5	0.4	3.3
	<250,000	78.5	18.2	0.6	2.4
	250,000–500,000	72.6	22.5	0.3	4.3
	500,000–1,000,000	74.1	19.4	0.4	4.3
	1,000,000–3,000,000	72.0	21.2	0.6	5.4
	>3,000,000	67.0	20.5	3.6	8.1
75 and over	Not in MSA	60.4	29.6	1.0	8.6
	<250,000	67.6	28.4	0.7	3.1
	250,000–500,000	67.5	26.9	0.4	4.8
	500,000–1,000,000	66.7	27.4	2.4	2.5
	1,000,000–3,000,000	63.4	26.6	2.6	7.1
	>3,000,000	59.0	28.5	2.7	8.7

<sup>a</sup> The “other” mode category is not included.

TABLE 6 Mode Share and Percent of All Trips by Density<sup>a</sup>

<i>Age Group</i>	<i>Density</i>	<i>POV Driver</i>	<i>POV Passenger</i>	<i>Bus/Rail</i>	<i>Walk</i>
<55	Low (<500/mi <sup>2</sup> )	79.0	17.5	0.2	2.2
	Med. (500–2,000/mi <sup>2</sup> )	78.4	17.4	0.5	2.5
	High (2,000–10,000/mi <sup>2</sup> )	75.3	17.5	1.4	4.7
	Very high (>10,000/mi <sup>2</sup> )	50.5	15.7	10.8	20.0
55–64	Low (<500/mi <sup>2</sup> )	77.8	19.3	0.1	2.2
	Med. (500–2,000/mi <sup>2</sup> )	78.2	18.8	0.6	1.9
	High (2,000–10,000/mi <sup>2</sup> )	76.8	17.2	1.1	4.2
	Very high (>10,000/mi <sup>2</sup> )	56.3	16.5	8.5	17.9
65–74	Low (<500/mi <sup>2</sup> )	74.8	21.6	0.2	3.0
	Med. (500–2,000/mi <sup>2</sup> )	75.4	19.9	0.4	3.3
	High (2,000–10,000/mi <sup>2</sup> )	72.4	19.9	1.2	6.0
	Very high (>10,000/mi <sup>2</sup> )	48.4	21.1	11.6	17.8
75 and over	Low (<500/mi <sup>2</sup> )	60.7	32.0	0.9	6.0
	Med. (500–2,000/mi <sup>2</sup> )	64.8	29.1	0.7	4.6
	High (2,000–10,000/mi <sup>2</sup> )	65.7	25.9	1.9	6.1
	Very high (>10,000/mi <sup>2</sup> )	42.3	24.8	9.0	22.1

<sup>a</sup> The “other” mode category is not included.

**TABLE 7 Mode Share and Nonwork Trips by Density**

<i>Age Group</i>	<i>Density</i>	<i>POV Driver</i>	<i>POV Passenger</i>	<i>Bus/Rail</i>	<i>Walk</i>
<55	Low (<500/mi <sup>2</sup> )	74.1	21.8	0.2	2.6
	Med. (500–2,000/mi <sup>2</sup> )	73.8	21.3	0.4	3.1
	High (2,000–10,000/mi <sup>2</sup> )	70.6	21.2	1.0	5.8
	Very high (>10,000/mi <sup>2</sup> )	46.9	18.4	7.6	24.0
55–64	Low (<500/mi <sup>2</sup> )	74.1	23.0	0.1	2.4
	Med. (500–2,000/mi <sup>2</sup> )	75.1	22.0	0.6	1.8
	High (2,000–10,000/mi <sup>2</sup> )	73.2	20.1	0.9	5.1
	Very high (>10,000/mi <sup>2</sup> )	54.0	18.2	6.2	20.5
65–74	Low (<500/mi <sup>2</sup> )	73.2	23.2	0.2	3.1
	Med. (500–2,000/mi <sup>2</sup> )	73.9	21.4	0.4	3.3
	High (2,000–10,000/mi <sup>2</sup> )	71.2	21.0	1.0	6.1
	Very high (>10,000/mi <sup>2</sup> )	47.0	22.7	10.7	18.5
75 and over	Low (<500/mi <sup>2</sup> )	60.3	32.1	0.9	6.2
	Med. (500–2,000/mi <sup>2</sup> )	64.3	29.6	0.7	4.5
	High (2,000–10,000/mi <sup>2</sup> )	65.1	26.3	1.8	6.4
	Very high (>10,000/mi <sup>2</sup> )	42.0	25.5	8.4	22.3

the entire NPTS sample, about 38% of all persons reported that there was no transit available in their community, and for the elderly the percentage is 40. As would be expected, the likelihood of living near a transit stop increases with metropolitan size and location within the metro area. Interestingly, controlling for metropolitan size, the elderly are more likely to live within 0.5 mile of a transit stop than the nonelderly, within every metro size category (Table 8). It would appear that this is more a function of aging in place (older people are more likely to live in older neighborhoods) than of locating to take advantage of transit access.

It might be argued that since transit trips are not likely to be taken every day, and since many elderly did not make any trips on the travel day, the mode share data provide a limited picture of transit use among the elderly. Examining stated frequency of transit use and defining a “regular user” as a person who uses transit at least once per week and an “occasional user” as using transit at least once in two months, and controlling for metropolitan size, show that the elderly are more likely not to use transit than the nonelderly (Table 9). Part of the difference is explained by the absence of work trips among the elderly, but this should be offset

**TABLE 8 Percent Share Within 0.5 Mile of Transit Stop by MSA Size<sup>a</sup>**

	<i>Not in MSA</i>	<i>&lt;1,000,000</i>	<i>1,000,000–3,000,000</i>	<i>&gt;3,000,000</i>
Nonelderly	52.6	64.5	63.3	74.9
Elderly	60.7	73.9	68.8	79.1

<sup>a</sup>It may be argued that 0.5 mile is too great a distance to use in measuring access to a transit stop; the rule of thumb used by transit agencies is 0.25 mile. The NPTS data allow use of either 0.5 or 0.1 mile. Since 0.1 mile seems too restrictive, the more generous measure is used here.

**TABLE 9 Transit Use: Elderly and Nonelderly by MSA Size**

		<i>Not in MSA</i>	<i>&lt;1,000,000</i>	<i>1,000,000–3,000,000</i>	<i>&gt;3,000,000</i>
Nonelderly	Regular	8.7	5.6	6.1	23.2
	Occasional	6.9	6.5	6.2	14.3
	Never	84.4	87.9	87.7	62.6
Elderly	Regular	4.2	4.1	3.9	14.2
	Occasional	6.8	4.8	5.0	11.8
	Never	89.0	91.1	91.0	74.0

somewhat by lower levels of household income and car ownership among the elderly.

## MODEL RESULTS

The appropriate way to examine the extent to which land use affects travel is to control all the other factors known to be important. The analysis therefore estimates a series of models to determine whether land use characteristics explain travel patterns of the elderly, and whether these characteristics operate differently for the elderly than the nonelderly. Three sets of models are estimated: one for making any trip on the travel day, one for total daily travel distance, and one for using transit.

### Trips on the Travel Day

It was noted earlier that the elderly have lower rates of travel overall, and that they are more likely not to have made any trips on the travel day. What are the relationships, if any, of metropolitan location or local land use patterns to the propensity to travel? Rosenbloom noted that the observed decline in trip making with age might be due to physical or other difficulties. If walking is more feasible, or if better transit service is available, will the elderly be more likely to travel? Conversely, it could be argued that the decision to travel is more a function of overall life circumstances, and land use factors are more relevant to how and where one travels.

A simple binary probability choice model is estimated to determine whether the person took at least one trip on the travel day. The model uses controls for gender, income, employment status, driver's license ownership,

and car access. The metropolitan form measures are MSA by size category, live in the central city, live outside an MSA. The neighborhood form measures are

- Residence census tract population density,
- Local service accessibility (density of retail and service activity within the home zip code area),
- Share of housing built within 10 years (surrogate for dispersed land use patterns), and
- Share of homeowners (surrogate for higher income neighborhood and lower housing density).

Population density is measured in four categories as before. Models for all trips and for nonwork trips are estimated, as well as separate models for each age cohort: not elderly (ages 16–64 years), younger elderly (65–74 years), and older elderly (75 years and older).

Results for total trips and nonwork trips are consistent. Selected results for nonwork trips are shown in Table 10. Only the constants and land use variables are included in the table.<sup>4</sup> The constant indicates the overall likelihood of making a trip and, as expected, declines across the age cohorts. For nonelderly adults, living in the largest MSAs or in low-density areas is associated with less likelihood of making a trip. For the elderly groups, MSA size and density have no effect. In contrast, living outside an MSA is associated with greater likelihood of making a trip for the elderly. It appears that our land use variables are reflecting demographics—for example, the concentration of poverty in the largest MSAs. Access to local services has a positive effect for all

<sup>4</sup> Complete results for all models (Tables 10, 11, 12) are available from the author.

TABLE 10 Nonwork Trip Probability Choice Model: Selected Results

<i>Land Use Variable</i>	<i>Age 16–64</i>	<i>Age 65–74</i>	<i>Age 75 and Over</i>
Constant	Positive	NS <sup>a</sup>	Negative
Live outside MSA	NS <sup>a</sup>	Positive	Positive
Live MSA 250,000–500,000	NS <sup>a</sup>	NS <sup>a</sup>	NS <sup>a</sup>
Live MSA 500,000–1,000,000	Negative	NS <sup>a</sup>	NS <sup>a</sup>
Live MSA 1,000,000–3,000,000	Negative	NS <sup>a</sup>	NS <sup>a</sup>
Live MSA >3,000,000	Negative	NS <sup>a</sup>	NS <sup>a</sup>
Live in central city	NS <sup>a</sup>	NS <sup>a</sup>	NS <sup>a</sup>
Local access	Positive	Positive	Positive
Low density	Negative	NS <sup>a</sup>	NS <sup>a</sup>
High density	NS <sup>a</sup>	NS <sup>a</sup>	NS <sup>a</sup>
Very high density	NS <sup>a</sup>	NS <sup>a</sup>	NS <sup>a</sup>
Share new housing	NS <sup>a</sup>	NS <sup>a</sup>	NS <sup>a</sup>
Share owners	NS <sup>a</sup>	NS <sup>a</sup>	NS <sup>a</sup>

<sup>a</sup>NS = coefficient not statistically significant at  $p < .05$ .



groups, but none of the other neighborhood form variables have significant effects. Metropolitan and neighborhood form characteristics have little effect on trip making. In contrast, the control variables are significant and of the expected sign (not shown in table). These results indicate that trip making declines with age, even when controlling other factors, and that this decline is independent of land use, at least as it is measured here.

### Total Daily Travel Distance, Nonwork Daily Travel Distance

Regression models are estimated to examine the effects of land use characteristics on total daily travel distance and total daily nonwork travel distance. In this case only those who traveled on the survey day are included. If travel becomes more onerous as people age, the elderly could be expected to be more sensitive than the nonelderly to geographic characteristics; hence, they economize on travel in environments where shorter trips are possible. As noted earlier, other relevant factors must be controlled to test this idea. A similar set of control variables is used as with the previous model: demographic characteristics, income, car access, and driver license status. Number of trips taken was also controlled. The metropolitan form and neighborhood form measures are the same as in the previous model. Once again separate models are estimated for each age cohort. As before, results for total travel and total nonwork travel are consistent. Selected model results for nonwork travel distance are shown in Table 11.

The control variables had the expected effects: nonwork travel distance is positively associated with male sex, having a driver's license, and car access. It is nega-

tively associated with low income. Table 11 shows that for nonelderly adults travel distance is positively associated with location within a larger MSA, and the effect is consistent across MSA size categories. Location within the central city is negatively associated with daily travel distance. Results are as expected also for the neighborhood form variables. Turning to the 65–74 cohort, fewer of the land use variables are significantly related to travel distance. For the older elderly, living outside an MSA is associated with less travel distance, which is inconsistent with the previous model and the descriptive data. High density has a more negative effect for this age group, suggesting that the older elderly are more likely to economize on travel when it is convenient to do so. The two measures of affluent, dispersed suburbs have significant positive effects on total travel distance. These measures may be picking up submarkets, for example, the healthy older elderly living in new retirement communities.

A general observation to be drawn from Table 11 is that metropolitan form factors are less significant for the elderly than the nonelderly. As mentioned in the previous section, these MSA variables may reflect other demographic characteristics that become less important with age. Neighborhood form factors are generally more significant for the elderly when other factors are held constant. It is important to note that the land use variables as a group explain very little of the variation in nonwork travel distance. Most of the explanatory power of this model is from the overall trip rate (lower for the elderly) and socioeconomic characteristics of the individual. As with trips, using total daily travel distance, including work and work-related travel, gives similar results.<sup>5</sup>

<sup>5</sup> These results are not presented here.

TABLE 11 Nonwork Travel Distance Regression Model: Selected Results

<i>Land Use Variable<sup>a</sup></i>	<i>Age 16–64</i>	<i>Age 65–74</i>	<i>Age 75 and Over</i>
Live outside MSA	NS <sup>a</sup>	NS <sup>a</sup>	Negative
Live MSA 250,000–500,000	Positive	NS <sup>a</sup>	NS <sup>a</sup>
Live MSA 500,000–1,000,000	Positive	Positive	NS <sup>a</sup>
Live MSA 1,000,000–3,000,000	Positive	NS <sup>a</sup>	NS <sup>a</sup>
Live MSA >3,000,000	Positive	NS <sup>a</sup>	NS <sup>a</sup>
Live in central city	Negative	NS <sup>a</sup>	NS <sup>a</sup>
Local access	Negative	Negative	NS <sup>a</sup>
Low density <sup>b</sup>	Positive	Less positive	NS <sup>a</sup>
High density	Negative	NS <sup>a</sup>	More negative
Very high density	Negative	NS <sup>a</sup>	More negative
Share new housing	Positive	More positive	More positive
Share owners	Positive	Positive	More positive

<sup>a</sup> NS = coefficient not statistically significant at  $p < .05$ .

<sup>b</sup> Medium density is not included.

The results may be summarized as follows:

1. Differences between the elderly and nonelderly are explained primarily by age itself and by differences in socioeconomic and demographic characteristics.
2. The big difference in elderly travel patterns is less trip-making, rather than shorter trips, when other factors are controlled.
3. There is some evidence that the older elderly economize on travel in high-density areas.
4. Local neighborhood characteristics have a small but significant effect for all age groups.

### Transit Use

As noted previously, public transit is a key aspect of proposed land use strategies that promote higher density, mixed-use patterns. It is therefore important to examine whether the elderly are more likely to use transit when it is accessible and when land use patterns support it. We estimated a binary choice model for transit use based on the reported frequency of transit use. Separate models were estimated for each age cohort. In this case, anyone who reports using transit at least once in two months is defined as a transit user. Prior research has shown that transit use is highest in the central parts of the largest metropolitan areas and among low income households (34). Land use measures are therefore limited to large metropolitan size, living in the central city and high local density. Transit access was measured as a transit stop located within 0.5 mile of the residence.

The results showed that for nonelderly adults (16–64 years), the likelihood of being a transit user is related positively to low income, having no car, and having a transit stop nearby (Table 12). Transit use also is related positively to the land use variables, for example, living in large metropolitan areas and in places of high population density. Results for the 65–74 year-old cohort are similar, but with some notable differences. Low income is related negatively to likelihood of transit use, and the

effect of having no car is less positive. It can be surmised that low income is not as good a measure of overall resources for retired people. It is possible that the effect of having no car for the elderly is less strong because the elderly travel less overall, and because not having a car may be related to physical limitations.

Results for the 75 and older cohort are similar to those for the younger elderly, but suggest more sensitivity to travel convenience and less likelihood overall of being a transit user. Access to a transit stop is significant. Models using 0.5-mile distance and 0.1-mile distance (the only options available in the NPTS data) and short distance to a transit stop are quite significant. In addition, high local density has a stronger effect for this cohort.

These results are quite consistent with the descriptive information presented previously. They show good news and bad news with respect to the potential role of transit in serving the mobility needs of the elderly. The elderly are less likely to be regular transit users, even when transit is accessible (at least as measured here) and when land use patterns are more favorable to transit. In addition, the older elderly are more likely to be transit users when transit stops are close to home and when local access to goods and services is high. This is not surprising; transit is less convenient than the private automobile under most circumstances. It is also a more physically challenging mode of travel. Walking to and from the bus stop or train station, waiting and transferring, and boarding and alighting vehicles all make transit use more difficult for those with limited physical stamina. It seems reasonable that the elderly prefer automobile travel and compensate for physical limitations by traveling less, instead of shifting modes. These results suggest caution in considering more transit environments as a mobility strategy for the elderly. A very high level of access and service quality would be required to attract the older elderly to transit.<sup>6</sup>

<sup>6</sup> Another key argument for higher density, mixed-use land use is to facilitate walk trips. Analysis of walk trips is beyond the scope of this report.

TABLE 12 Probability Models for Transit Use: Summary Results

<i>Variable</i>	<i>Age 16–64</i>	<i>Age 65–74</i>	<i>Age 75 and Over</i>
Male	Negative	NS <sup>a</sup>	NS <sup>a</sup>
Employed	Negative	Not applicable	Not applicable
Low-income household	Positive	Negative	Negative
Zero-car household	Positive	Less positive	Less positive
Distance to stop <0.5 mile or <0.1 mile	Positive	Positive	More positive
Live in central city	Positive	Positive	NS <sup>a</sup>
Live in large MSA	Positive	Positive	NS <sup>a</sup>
Live in high population density area	Positive	Positive	More positive

<sup>a</sup> NS = coefficient not statistically significant at  $p < .05$ .

**Land Use and Transit Use in Great Britain:  
A Comparison**

To consider public transit another way, the United States can be compared with other countries where transit access and the mode share are much greater overall. Data from Great Britain are illustrative.<sup>7</sup> Figure 5 gives total journeys per year by metropolitan location for persons 70 years and older. London includes the 33 boroughs of London; “metro areas” include six provincial conurbations.<sup>8</sup> The remaining location categories are in descending order of population: large urban, 250,000 or more; urban, 25,000–250,000; small urban, 3,000–25,000; rural, fewer than 3,000. Figure 5 shows that walking is a major mode in all categories. Walk share averages about 30% in Great Britain, compared with about 7% in the United States. Transit use is higher in the largest metro areas, and car use either as passenger or driver is lower in the largest metro areas. These differences across British metro areas are much greater than for the United States (Table 5). Data based on all age groups show a similar pattern but with far higher shares for car modes across all areas and smaller differences in modal distribution across all areas. It would appear that the greater availability of public transit in London and other large metro areas makes it possible for the elderly to use transit more extensively in these areas.

<sup>7</sup> C. G. B. (Kit) Mitchell provided a portion of the data discussed in this section. The remaining data were drawn from National Transport Survey data and prepared by the authors.

<sup>8</sup> Provincial conurbations: West Midlands, Greater Manchester, Merseyside, South Yorkshire, Tyne and Wear, and Glasgow.

Figure 6 gives mode shares for all trips by age. It clearly shows that car use starts to decline with the 60–69 year cohort, and for those 70 years and older, the car share (driver plus passenger) drops below 50 percent. Conversely, walking and transit use greatly increase after age 60. One might conclude from these figures that the availability of transit alternatives makes it possible for the elderly to shift away from cars as driving becomes more difficult, but this is not the whole story. First, the British came later to car ownership and having driver licenses; hence, people over age 60 have much lower rates of license holding than younger people have. As younger cohorts age, far less transit use is likely among the British elderly. Second, per capita income is much lower in Britain. Comparable figures for 1999 median household income are \$33,900 for the United States and \$21,800 for Great Britain. Third, the cost of owning and operating a private vehicle is much greater in Britain. The 1995 fuel price per liter was \$0.30 for the United States and \$0.90 for Great Britain (35). Thus the price of travel as a proportion of income is much higher in Great Britain, and the rate of car ownership is much lower. The outcome is much lower rates of mobility overall as measured in daily trips or miles traveled, as shown in Table 13. The difference in total time spent traveling is small, due to greater use of slower modes in Great Britain.

This brief comparison illustrates the complexity of the issue of land use and transit. It is certainly the case that transit access and service availability are greater in Britain than in the United States, and consequently, provide a more competitive alternative to the car than in

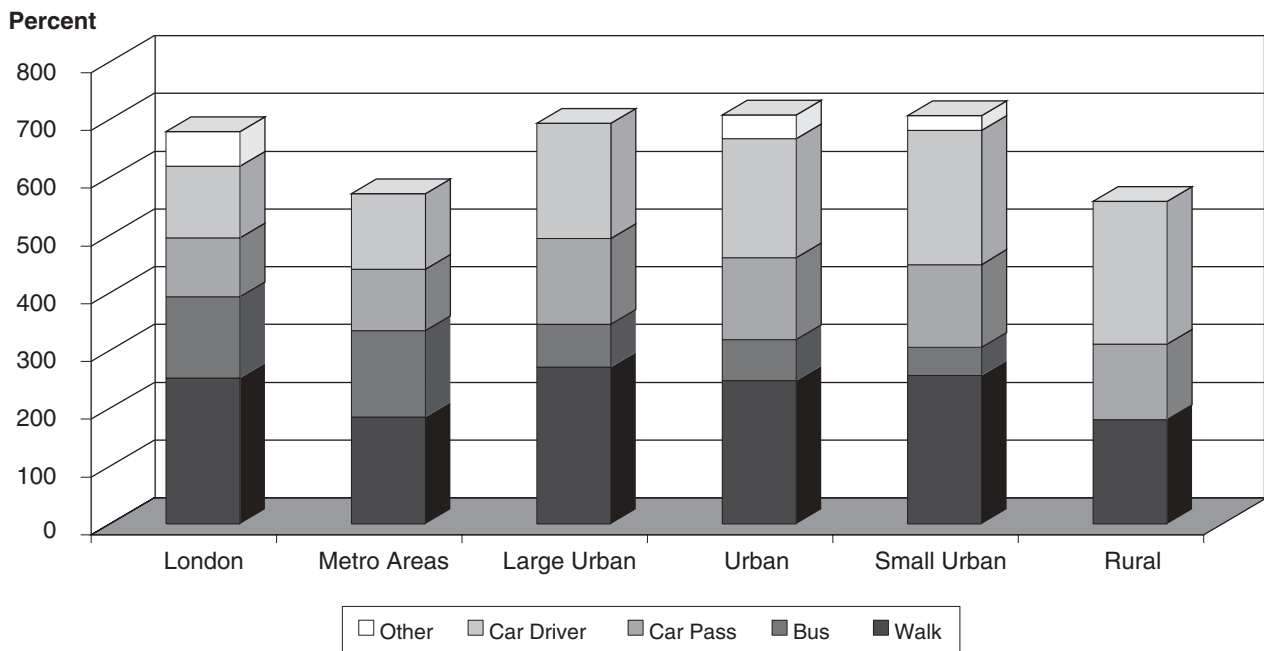


FIGURE 5 Journeys per year, by mode, Great Britain, all persons 70 or older.

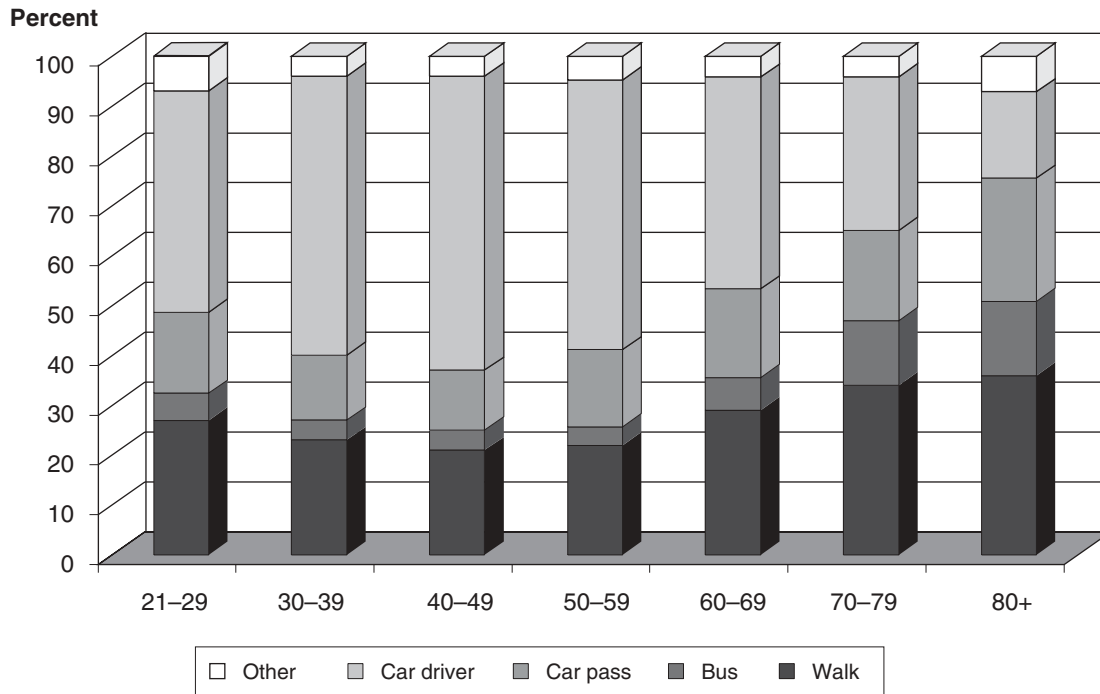


FIGURE 6 Mode share by age, Great Britain.

the United States. It is also the case that limited car ownership (mostly a function of low per capita income and high prices) makes possible a much greater demand for transit, which makes its more extensive supply more economically viable. These conditions are not replicable in the United States and are changing in Britain and throughout the developed world, as per capita income and car ownership continue to rise (36–38).

#### LAND USE AND TRANSPORTATION POLICY IMPLICATIONS

Although promoting the use of public transit is an important objective of land use strategies, it is not the only objective. Higher-density, mixed-use land use patterns improve accessibility for all modes, including walking and driving. These results showed that total daily travel distance declines in places where such land use patterns exist. If it is assumed that travel behavior is influenced by land use patterns (as opposed to land use patterns acting as surrogates for unobserved preferences that lead some people to seek out such neighborhoods because they prefer to travel less), then the more pedestrian-friendly, mixed-use development expands, the more travel distances will be reduced. However, with a few notable exceptions, the elderly are no more likely to take advantage of these potential economies

than the nonelderly. The older elderly travel less wherever they live. What then can be said about the potential of land use policy to address mobility problems of the elderly, especially the oldest elderly, as described by Rosenbloom?

#### Land Use Policy Issues

Rosenbloom and others in this volume note that most elderly age in place, preferring to remain in the homes or apartments selected in earlier stages of the life cycle. Since population shifts of the last several decades have been toward decentralization, aging in place means aging in the suburbs for the majority of the elderly (39). In addition, there is substantial evidence that aging in place promotes well being and quality of life (40, 41).

TABLE 13 Average Daily Person Trips: Travel Distance, Time (30)

	<i>United States</i>		<i>Great Britain</i>	
	<i>Mean</i>	<i>Median</i>	<i>Mean</i>	<i>Median</i>
Trips/day	3.8	4.0	2.9	2.0
Miles/day	28.7	17.0	14.0	6.0
Minutes/day	58.4	46.0	54.4	40.0
Share no trip days	16.0		21.0	
N	95,360		23,167	

Aging in place allows people to maintain local friendships and ties in the community, to shop and obtain medical care in familiar places, and to rely on neighbors for emergency support. As the geographically proximate extended family becomes increasingly rare, these neighborhood relationships may become more important. For many elderly, friends and neighbors are more readily accessible than children or siblings. Therefore, any policy proposal to encourage the elderly to relocate to more accessible places must consider whether the marginal increase in travel opportunities is worth the loss of an established social network and the comfort and familiarity of a long-established neighborhood.

Another way of looking at this issue is to observe what choices the elderly are making now. When the elderly move, where do they go? Data from the March 2000 U.S. Census Current Population Survey (CPS) comparing moving patterns of the elderly and nonelderly show, as Rosenbloom noted, that the elderly are far less likely to move than the nonelderly; 4.7% for the elderly versus 16% for total population in the 2000 CPS. Table 14 shows some differences in migration patterns of the elderly and nonelderly. In this case, the elderly are those 60 years and older. The elderly make fewer moves within MSAs, more moves between MSAs, and more moves from MSAs to nonmetropolitan areas. This suggests relatively more long distance moves for the elderly. Comparing moving within the MSA groups, there are no differences between the elderly and the total population. That is, the elderly are no more likely to move from suburb to city, or from city to suburb, than the general population (data not shown). Taken together, the migration data are consistent with expectations for continued decentralization of the elderly population and movement to smaller urban areas (not shown in table). These areas not only offer lower housing and living costs, but less congestion and traffic and a slower pace of life. Driving is easier in these areas. People can avoid high-speed freeway travel, and there are fewer rush hours to avoid in scheduling trips. Such places allow the elderly to maintain their automobility and the lifestyle that goes with it.

Therefore, land use policy must address improving the accessibility of suburban and smaller urban areas. Such policies must of necessity be highly context-specific. A few examples may be instructive. Pasadena, California, is located about 15 miles north of Los Angeles. Once an affluent suburb, it is now a diverse city with a population of about 130,000. For more than 20 years, the city has pursued an aggressive redevelopment policy to revitalize the downtown. Pasadena uses a variety of incentives to attract elderly housing to the downtown core area. Senior housing projects are given density bonuses of up to 50 percent, and parking requirements have been reduced to a minimum of 0.5

space per unit. In return, such developments are expected to offer subsidized transit passes to residents. Pasadena's General Plan has an explicit policy of promoting accessible location of public and private services and of considering transit accessibility in the location of housing. As a result, the downtown area is pedestrian-friendly, and the mix of housing, retail, commercial, and medical services makes it very accessible.

Irvine, California, is a much newer city, established in the 1960s as the largest planned community in the United States. Unlike Pasadena, Irvine has no "center" (despite a population of more than 140,000), but was designed as a collection of "villages," each with its own commercial center, connected to one another by "activity corridors" (major arterials). Irvine typifies suburban land use—segmented land use, walled residential communities, and circulation oriented around the car. Irvine has several senior housing developments, and they are located in the activity corridors and adjacent to neighborhood shopping centers. Consequently, basic goods and services are within walking distance of each development, and each development has transit access, though transit service is limited (few routes, long headways). Essentially, in a transit and pedestrian-unfriendly environment, the senior housing has been placed in the best possible locations. The challenge for land use planning is how to improve accessibility of such locations.

There is little evidence regarding how such policies actually affect the travel patterns or well-being of the elderly. Although intuitively, benefits could be expected, whether Pasadena or Irvine senior housing residents are relatively more mobile or are enjoying significantly better quality of life as a result of having greater accessibility remains to be demonstrated.

### Implications for Transportation Policy

What does this imply for transportation policy? As other contributors to this volume have noted, it is clear that the elderly both now and in the future will want to

TABLE 14 Migration Patterns: Total Population and Elderly (Percent Shares)

<i>Move</i>	<i>Total Population</i>	<i>Elderly (Age 60 and Older)</i>
Within same MSA	54	47
Between MSAs	21	25
From MSA to nonmetro area	4	7
From nonmetro area to MSA	5	6
Within/between nonmetro area	12	11
From abroad	4	3



retain the ability to drive for as long as possible. This is rational, since the comfort, convenience, and flexibility of the automobile is even more valued by the elderly than by the nonelderly. It seems that the focus should be on driver-friendly (as well as pedestrian- and transit-friendly) urban design alternatives: street widths that protect pedestrians, more and better signage and traffic control, and easily negotiated parking facilities. None of this is inconsistent with promoting safe and pleasant environments for pedestrians or transit.

It is clear that efforts to improve the safety of older drivers and their vehicles should continue. New technology such as collision avoidance, enhanced night vision, lateral guidance, and automated vehicles will provide enormous benefits to the elderly. We also should be thinking about a further differentiated private-vehicle fleet, with smaller (but safer) “town cars” that would suffice for everyday errands and other activities.

Trends in travel patterns suggest that conventional transit’s potential for offering an acceptable substitute to the private vehicle is limited outside of niche markets in the core of large metropolitan areas. Most elderly will not be living in places where fixed-route transit is efficient or effective. Hence transit alternatives of the future must mimic the car. This is an old notion. Efforts to develop viable forms of paratransit have been in progress for more than 25 years. There have been two main barriers to paratransit. First, there is the problem of serving sparse, dispersed travel demand patterns in a cost-efficient manner. New technology provides the potential for developing more efficient dispatching and routing and for accommodating real-time, “on the fly” trip requests. Combined with private contracting or other strategies that reduce costs, new technology may generate cost-effective paratransit options. Second, there is the array of regulatory and institutional barriers that prevents jitneys, shared-ride taxis, or other privately provided paratransit services from operating within the service areas of conventional transit operators or in competition with local taxi services. These institutional barriers will have to be reduced if innovative automobile-like modes are to emerge. Finally, transit will have to mimic the car in comfort—for example, by providing easy access and egress for the less physically fit and by offering smooth rides.

Again, what people are doing now provides some insights. A recent case study of a low-income area in Los Angeles revealed that private organizations—churches, senior centers, and others—provide rides for members, but generally only for specific purposes (42). Interestingly, many churches report abandoning these services in response to rising insurance and liability costs. Again, legal and institutional barriers will have to be reduced if these more informal forms of transit are to expand. The Los Angeles study also revealed that

many trips are accomplished via informal carpools—people providing rides to neighbors and relatives for a fee. In more affluent neighborhoods, we surmise that ridesharing less frequently involves cash payments. These informal arrangements emphasize the importance of social networks (and by implication aging in place) in retaining mobility.

It is worth considering how these more informal forms of transport might be extended. For example, many suburban communities today have some type of governance structure, such as homeowners associations. It might be possible to enlist such organizations as centers for neighborhood ridesharing. Some markets in high-poverty areas offer rides to customers. Why not expand this concept to markets in places with high concentrations of elderly population? An area that may provide insights on such services is Los Angeles County. Cities in the county receive a portion of a local sales tax earmarked for transportation, and this funding may be used for any transportation purpose. As a result, the cities provide a wide variety of local transit services. It may be worthwhile to examine these services and determine their applicability in other metropolitan areas.

### Further Research

An understanding of the relationship between land use and transportation among the elderly is limited. The literature review revealed that almost no empirical research on this topic exists. The results presented here are based on a single (but comprehensive and representative) cross section, and land use characteristics were represented in approximate ways. There are many questions yet to be answered. For example,

- How do the elderly adapt to declining driving skills in low-accessibility areas?
- Are the elderly who reside in such areas significantly more mobility-disadvantaged than those who live in neighborhoods with higher accessibility?
- When the elderly move, how much consideration is given to future mobility needs?
- How sensitive are the developers of senior communities to mobility and accessibility?
- What are cities doing to encourage the location of senior communities in appropriate places?
- How much does land use really matter, relative to social networks and support systems?

Given the state of knowledge on this topic, further research is in order. Some possibilities include

1. Longitudinal case studies of residents in different types of neighborhoods to trace shifts in travel behavior

over time and how these may vary across neighborhood or community type,

2. Cross-sectional studies of senior community residents in various locations to determine how different levels of accessibility affect travel patterns and car use,

3. Studies of urban planning practice related to senior housing development, and

4. Studies of mixed-use development that examine who locates in such developments and why.

This paper has summarized the literature and presented a brief analysis of land use and transportation relationships among the elderly. The results suggest that land use effects are small and largely consistent across age groups. There is much that is not known; yet many planners and policy makers assume that land use policy is an effective tool for addressing the mobility problems of the elderly. Further research is clearly in order.

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# Vehicle Design and Intelligent Transportation Systems

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# Reducing Injuries and Fatalities to Older Drivers

## Vehicle Concepts

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Population projections for 2000 through 2030 indicate that the number of people in the age 55–64 range will increase by about 50% and the numbers in the age ranges of 65–74, 75–84, and 85 or older will approximately double. The number in the age 85 and older range will continue to see phenomenal growth for the following two decades as well. Between 2030 and 2050, the number in the age 85 or older range will again double in size. If all the people in the ranges older than age 65 are added together, the number in this segment of the population will more than double in the next 30 years.

Figure 1 shows that the number of miles driven per year is increasing for men and women in all the age ranges. Figure 2 demonstrates that fatality rates versus age fluctuates for drivers, with higher values for the younger- and older-driver segments of the population. The figure also shows an increase in older-driver fatality rates for drivers at age 65 and a greater increase at 75 or older. Projections for elderly highway user fatalities in 2000 to 2030 show a steady increase (Figure 3)—a trend that is consistent with the expected increase in the number of people age 65 or older (Table 1).

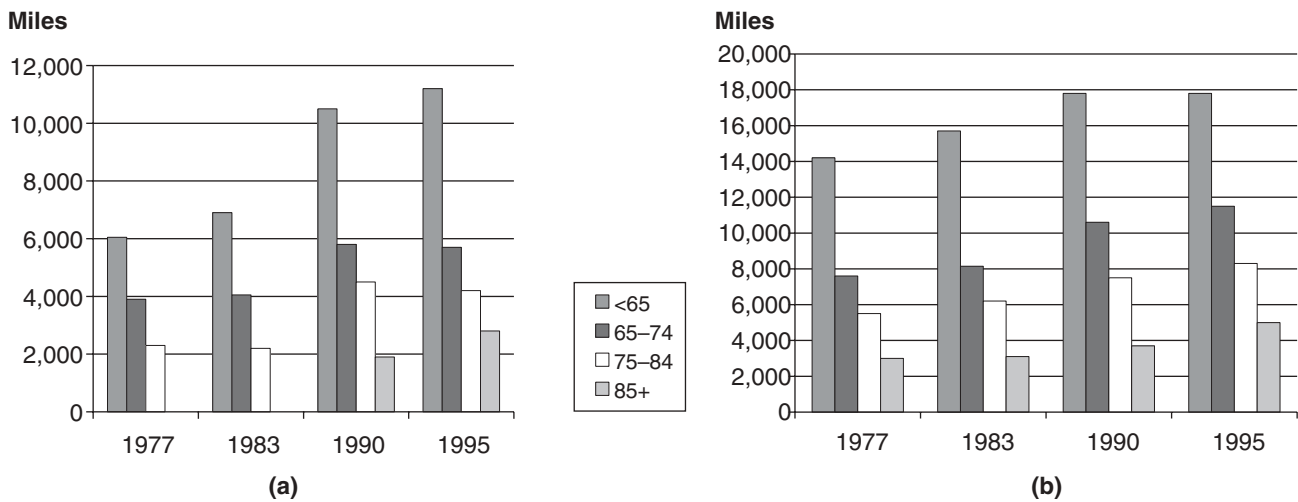


FIGURE 1 Average annual miles driven, 1977–1995: (a) women; (b) men (1).

Fatalities per 100,000 population

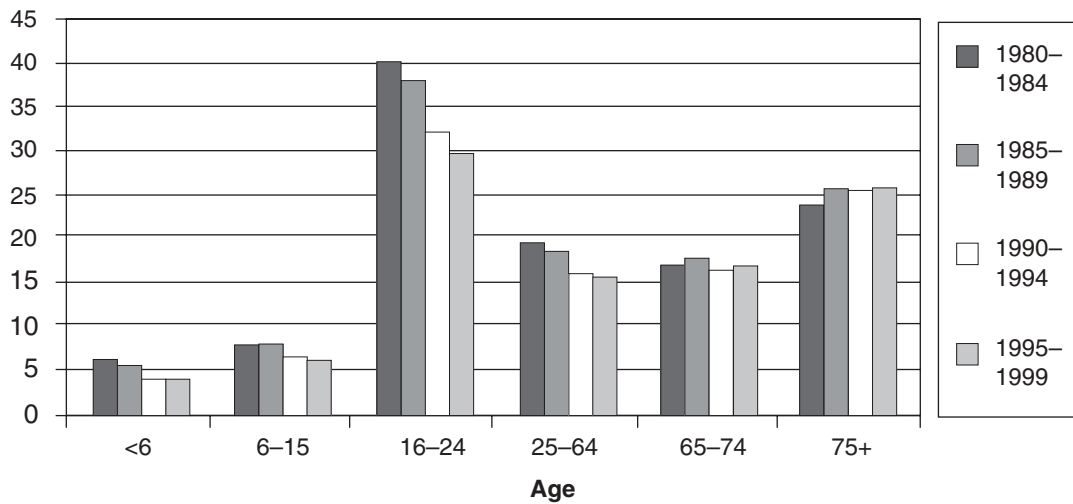


FIGURE 2 Driver fatality rate by age, 1980-1999 (1).

Fatalities

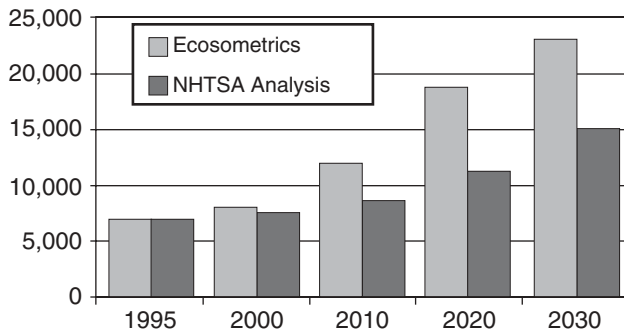


FIGURE 3 Projected elderly highway user fatalities, 1995-2030 (1).

TABLE 1 Population Projections (Millions) by Age, 2000-2050 (2)

	55-64	65-74	75-84	85+	65+
2000	24.0	18.1	12.3	4.3	34.7
2010	35.2	21.1	12.7	5.7	39.4
2030	36.3	37.4	23.5	8.5	69.4
2050	42.4	34.7	25.9	18.2	78.9

The purpose of this paper is to address the increasing older-driver fatality rate from the vehicle perspective. In other words, this paper is an overview of past, current, and future vehicle concepts and initiatives that may have the potential for mitigating both the frequency and the injury severity of older-driver crashes.

### OCCUPANT PROTECTION

Occupant protection concepts can be grouped into three categories that follow a time line of the crash event: crash avoidance, crashworthiness, and postcrash assistance. In general, because of sensory, cognitive, and motor function changes, older drivers are less able to avoid crashes. Because of human structural and functional changes, older drivers and passengers are more likely to be injured in a crash. Finally, because of functional changes and perhaps changes in social support networks, older drivers and passengers are less able to recover from injury (3-5). As a partial counterbalance to having reduced accident avoidance capability and greater frailty, older drivers have the benefit of experience. But many older drivers—and most likely some of the next generation of older drivers—are new drivers (6), who drove little if any until their spouse had to stop driving.

### Crash Avoidance

Crash or accident avoidance can be interpreted broadly to include any feature or capability that helps avoid a crash directly or indirectly. Direct avoidance includes concepts such as a speed control that automatically slows the vehicle if the vehicle is getting too close to another vehicle and—somewhat less directly—a speed control device that warns the driver that the vehicle is getting too close to another vehicle. The indirect category includes a variety of comfort and convenience features that may help reduce fatigue, aid concentration, and generally improve driver attentiveness and performance or may provide input to the driver that will help avoid a crash.

Thus, any feature that may reduce distractions, help the driver to concentrate on the driving tasks, provide useful information, or enable the driver to make quicker driving decisions provides an element of accident avoidance. As is often the case with engineering, a particular feature may fit into the accident avoidance category in some instances but not in others. In other words, a trade-off is involved. For example, additional sound insulation in general may reduce distractions and improve driver concentration, but this reduced sound sensitivity also may reduce the likelihood that the driver receives an audible warning of an impending crash (e.g., the sound of a screeching tire). Additional sound insulation also may obstruct the driver's field of view.

Concepts being considered—and in some cases implemented—in the crash avoidance category include

- Headlamps and mirrors that produce less glare;
- Headlamps that automatically turn on and off as needed;
- Easier-to-read controls;
- Larger character size on labels and gauges;
- Labels that contrast better with background colors;
- Reduced glare from instrument panel;
- Better display contrast;
- Head-up displays that enable drivers to see information through the windshield, so that locating the in-vehicle display does not require refocusing;
  - Daytime running lights to improve visibility to other vehicles;
  - Easier-to-reach controls that require less attention to locate and operate;
  - More comfortable seats that reduce fatigue; and
  - Various levels of smart or adaptive cruise control, containing one or more of the following features:
    - Maintaining a constant distance from another vehicle instead of a constant speed;
    - Maintaining a distance that is proportional to speed;
    - Warning the driver if the vehicle is getting too close to another vehicle;
    - Automatically slowing the vehicle if the driver does not heed the “too close” warning;
    - Possibly warning the driver of the vehicle ahead, for example, by automatically flashing the lights of the vehicle;
    - Warning the driver that the vehicle is wandering out of a lane or headed into an already or soon-to-be occupied lane;
    - Warning the driver when backing up that there is another vehicle or a pedestrian behind; and
    - Warning during nighttime, rain, or other poor visibility conditions that the vehicle is getting too close to another vehicle too rapidly or is approaching an obstacle in the road.

These warning features may have particular benefit for older drivers, who are overrepresented in crashes that involve failure to yield, unseen objects, unheeded stop signs and signals, turns, and lane changes (7). A more advanced version of a crash avoidance concept could provide a display in the vehicle that shows the road ahead and indicates the approximate location of any obstacles on a small display or TV screen in the vehicle, with multiple other uses. One use could be in-vehicle signage: for example, as the vehicle approaches a road sign, the sign appears on the display in the vehicle. The display also could be used as a navigation aid, showing current position and guiding the driver to a destination. These concepts typically include digital road maps and satellite-based positioning systems. The ability of driver assistance systems to determine a vehicle's location continues to improve, with some researchers envisioning accuracy within 1 to 5 cm (0.4 to 2.0 in.) (8).

These driver assistance systems also may be applied to functions such as headlamp use by automatically directing the headlamp beam to illuminate the area in which the vehicle is heading. On a curved road, for example, this redirection would not always match the direction in which the front of the vehicle is pointing (Figure 4; 8).

Many structural, functional, and perceptual changes have been identified with the aging process (9–17); how-



(a)



(b)

FIGURE 4 (a) Conventional headlamp versus (b) adaptive light control (8).

ever, only contrast sensitivity (18, 19), peripheral vision (20), and divided attention or the effect of multitasking on information processing (21) have been related to driving performance. A statistically significant correlation also has been found between actual accident involvement and peripheral vision measures (20). Surprisingly, a 1988 study reported that visual acuity was not related to driving performance (22), but more recent research has shown a statistically significant correlation between actual accident involvement and visual acuity (23). More specifically, injury-producing crashes among elderly people have been found to correlate with useful field of view—a measure of the region in which a person can detect and process target movements. Useful field of view also reflects the visual sensory function, processing speed and attention (24, 25), and self-reported glaucoma (26). Another recent study examined the likelihood of crash-involved drivers being at fault. The authors found that older drivers had a particularly high at-fault rate for left-turn, right-turn, and angled collisions (27).

### Crashworthiness

Crashworthiness refers to the safety performance of the vehicle in crashes and relates to a range of concepts, including

- Safety belts that are easier to put on, more comfortable to wear, and easier to take off;
- Safety belts and airbags that adapt to characteristics of the vehicle and driver (e.g., speed of the vehicle, driver seating height,<sup>1</sup> driver weight and age);
- Seat designs that offer improved protection to the neck in case of rear impact, such as a special seat structure that deforms to limit neck motion in low-speed rear impacts;
- Inflatable head restraints that limit rearward head motion;
- “Donor” bags in the torso portion of the seat back that use the rearward motion of the torso to compress and transmit gas into a “recipient” bag in the head restraint; and
- Side airbags to help protect the head, thorax, and pelvis.

### Postcrash Assistance

Postcrash assistance concepts include an automatic system that signals for help and indicates the vehi-

<sup>1</sup> This adjustment could be based on a parameter value within a certain range (e.g., seating height for short, average, and tall people) or on a specific value (e.g., seating height = 34 in.).

cle’s location. Other examples of these concepts include

- Automatically activating the emergency flashers
- Unlocking the doors when a crash occurs
- Using the airbag deployment as a threshold for the vehicle’s cell phone to send a distress signal automatically to a central location, which in turn sends assistance as required, such as an ambulance, and includes methods to avoid false alarms:
  - A brief waiting period during which drivers can cancel the distress signal if they are uninjured or do not require help
  - Automatic contact with an emergency dispatcher who then calls the driver to discuss the details
- Using an automatic system to summon a tow truck

### RECENT ADVANCES IN OCCUPANT PROTECTION

Since the release of *Special Report 218* in 1988, many developments in the area of occupant protection have benefited the general population, with some benefiting elderly people in particular (28). Some developments have been in response to or in anticipation of societal changes; these developments often are reflected in federal rule making. In other instances, safety developments have appeared to lead the way before society is aware of or is interested in the potential safety benefits

Table 2 lists safety innovations and puts safety feature development in a historical perspective. Many of these safety features now are ingrained, and it may be difficult to imagine when they did not exist. However, when introduced, these features were considered quite daring. Most of the features were introduced in the absence of regulation and sometimes were greeted with skepticism or disinterest.

Many vehicle safety features have been developed and implemented during the last half century; many of the features addressed the topics that received additional attention since the release of *Special Report 218*. These topics include frontal, side, and rear vehicle impacts; vehicle rollover; and driving while intoxicated. Included under the topic of frontal vehicle impacts are the topics of head impact protection and restraint systems and rating systems (e.g., “stars”).

### Frontal Vehicle Impacts

Frontal vehicle impacts are encountered in a significant proportion of crashes. For this area of the vehicle, safety concepts include controlled deformation of the front of the vehicle, padded and deforming instrument panels and other interior vehicle surfaces, and occupant

TABLE 2 Historical Perspective on Safety Innovations

<i>Safety Innovation</i>	<i>Date<sup>a</sup></i>
Turn signals for passenger cars	early 1950s
Kiddy locks for rear doors	mid-1950s
Safety packages including such features as energy absorbing steering wheels, shatter resistant rear-view mirrors and impact-resistant door latches	mid-1950s
Factory installed front and rear safety belts	mid-1950s
Child restraint vests	mid-1950s
Reduced laceration safety tempered side and rear glass	about 1960
Safety belt retractors on webbing	early 1960s
Power front disc brakes	mid-1960s
Emergency flashers	mid-1960s
Padded instrument panels and padded sun visors	mid-1960s
Reduced-glare surfaces on instrument panels and wipers	mid-1960s
Energy absorbing armrests	mid-1960s
Remote control side view mirrors	mid-1960s
Rear window defoggers	late 1960s
Steel belted radial-ply tires	1970
Side-guard door beams	early 1970s
Antitheft decklid locks	mid-1970s
Rear window wipers/washer	late 1970s
Traveler's advisory band on radios	1980
4-wheel antilock brakes	mid-1980s
Driver side airbags	mid-1980s
Dual heated mirrors	mid-1980s
Rear door child safety locks	mid-1980s
Passenger side airbags	late 1980s
Electrochromatic mirrors	early 1990s
Integrated child safety seats	early 1990s
Antisubmarine seats	mid-1990s

<sup>a</sup> Approximate dates the innovations were introduced in domestic motor vehicles.

restraints (safety belts and airbags). Although front-end stiffness is an important factor affecting front-to-front vehicle collisions, in some instances front-end stiffness may be even more important when the front of one vehicle hits the side of another vehicle. Front-end stiffness is different, however, if the vehicle hits a pedestrian. (Front-end stiffness is discussed further in the section on side impact.) Elderly pedestrians may be suitable candidates for various concepts of pedestrian-friendly crosswalks. Compared with other age groups, pedestrians age 65 or older tend to receive a high percentage (about 30%) of injuries when crossing or entering intersections and a relatively lower percentage of injuries (about 5%) when walking along the roadway (29).

### **Head Impact Protection**

Head impact efforts have focused on restraint systems (e.g., safety belts and airbags), which reduce the likeli-

hood and severity of head injuries from an impact with the vehicle interior, and vehicle structural changes, which further reduce the head acceleration if the head makes impact with the interior of the vehicle. The energy-absorbing properties of the vehicle interior currently must be tested, according to a recently enacted regulatory requirement for occupant protection in interior impact (30). The regulatory requirement was promulgated after considerable discussion on several important issues, including the speed at which a dummy headform should impact the vehicle interior, the vehicle interior points that should be impacted, and the acceptable performance level of impact (31).

The regulatory test procedure (30) used to evaluate head impact basically involves impact with a number of points distributed over the upper front interior (i.e., the pillars and metal framing around the windshield) and side glass. A dummy headform impacts with the various points at a speed of 15 mph, and the acceleration measured on the headform cannot exceed a limit of 1,000



head injury criteria (HIC).<sup>2</sup> The HIC has evolved over time, and further development has been proposed, including what the maximum time interval should be (32) and if there should be different tolerance limits of the HIC for different segments of the population (33). The same criteria measured on a different headform or during a different test procedure may correspond to a different impact. Thus far, efforts to scale the HIC have focused on adults of various sizes and children of various ages. It may be possible in the future to adapt tolerance parameters and values to older drivers and passengers.

### *Safety Belt Use and Features*

**Safety Belt Use** Since the release of *Special Report 218*, U.S. safety belt use has increased from about 45% to more than 70% (34). During that time, various public education buckle-up programs have been implemented and expanded to encourage safety belt use, such as the popular Vince and Larry test dummies. Typically, these programs are cooperative efforts among various groups, including academia, government, insurance agencies, the media (for public service announcements), restraint system suppliers, sports celebrities and other public figures, and vehicle manufacturers.<sup>3</sup> Currently, vehicles have a mandatory safety belt reminder light that illuminates for about 8 s when the vehicle is first started. This light can be supplemented with an additional reminder, such as a buzzer or blinking light, which starts if the person is not belted after the initial 8-s reminder. To improve acceptance and effectiveness, this supplemental reminder could be programmed by the driver.

Another important change since the release of *Special Report 218* has been an increase in the number of states that have standard enforcement laws. These laws permit the police to stop a motorist, check for safety belt usage, and issue a citation if appropriate without the involvement of other infractions.<sup>4</sup> Perhaps not surprisingly, studies have shown that states with standard enforcement safety belt laws have higher use rates than do states with secondary enforcement laws.<sup>5</sup> States with either category have higher usage rates than states without any enforcement provision (34, 35).

<sup>2</sup> The HIC is a weighted function of the head acceleration and the duration of the acceleration. A HIC of 1,000 is intended to correspond to the threshold for head injury.

<sup>3</sup> The National Safety Council implemented a program in 1996. Airbag suppliers, insurance companies, and vehicle manufacturers working in partnership with the National Highway Traffic Safety Administration funded the Airbag and Seatbelt Safety Campaign.

<sup>4</sup> Currently, 16 states plus Washington, D.C., have standard or primary enforcement laws.

<sup>5</sup> Secondary enforcement requires that the police stop a motorist for a traffic infraction other than safety belt use. If unbelted, the motorist may be issued a second citation for not wearing a safety belt.

**Safety Belt Features** Changes also have been made to safety belts. One group of changes is intended to make the belts easier to wear. These changes include the use of belt webbing and D-ring<sup>6</sup> material and geometry that fosters easier sliding of the webbing through the D ring. This D ring has several benefits. The belt is easier to put on and requires less spring force to remove, so the belt has less tension when worn. Consequently, the belt is likely to be more comfortable and hence more likely to be worn. Another significant development is the adjustable shoulder belt. In some vehicles, the D ring can be raised and lowered to fit a range of occupant sizes. New belt webbing concepts include materials that provide several stages of belt restraint, depending on how the occupant adjusts the belt (36). According to statistics reported by the National Safety Council, safety belts have saved more than 100,000 lives since 1988 (29)—the year *Special Report 218* was released. This number does not include the millions of injuries that were mitigated, so the actual benefits from safety belt use during that time period have been even greater than the number of lives saved.

Additional safety belt features include adjustable belts, which automatically adjust to the occupant's size; load limiting, which limits the maximum restraining force that the belt will apply during a crash; and adaptive load limiting, which varies the load limit based on vehicle factors (e.g., crash speed) and occupant factors (e.g., weight and age). The feature of pretensioning also is being developed further and applied more widely; this feature automatically cinches the belt at the start of a crash, thereby removing excess belt slack and enabling the belt to begin to decelerate the vehicle occupant earlier and more gradually during a crash. Together, educational programs and vehicle changes have helped increase safety belt use to more than 70% in the United States. A presidential initiative established by President Bill Clinton set the future safety belt use goal at 90% by 2005 (34).

Biomechanical studies have started to develop specific tolerance differences based on age, which may be reflected suitably in restraint system parameters. For example, researchers have explored the concept of three levels of safety belt tolerance corresponding to three age ranges (37). The increased use of safety belts has enabled more effective use of other protective systems, such as airbags, as supplemental restraints.

### *Airbags*

Perhaps no single automotive safety topic has received more publicity in the last few years than airbags, espe-

<sup>6</sup> The anchor typically is shaped like a semi-oval or like the capital letter D.

cially when a vehicle occupant was close to a deploying airbag. The history of vehicle airbag development in the United States is approaching its fourth decade and has seen a number of dramatic shifts as well as gradual changes. During the early stages of airbag development, some thought that airbags should be able to work alone and perform as a replacement for safety belts (38). At the time, only 10% of the population wore safety belts. By 1983 safety belt use had increased to only 14% (34). Later, it generally was recognized that airbags were effective supplemental restraints when functioning in conjunction with safety belts. However, many questions remain about the best use of airbag technology to protect the overall population. The number and complexity of such questions may increase even more as the numbers of airbags and other inflatable devices increase.

As mentioned above, elderly people as a group are more likely to be injured in a crash. One injury worth noting almost exclusively affects elderly patients and others with degenerative spinal conditions. Thus, an airbag—or any other protective feature that limits injurious neck motion—may have particular benefit for older drivers and other susceptible passengers. The healthy vertebral column is a cylindrical spinal cord contained within a bony channel, which is formed by a column of ring-shaped bony vertebrae (Figure 5). One of the most frequent injury mechanisms, especially in the cervical region, is a compression of the spinal cord during the relative displacement of two adjacent vertebrae. The healthy spinal column has built-in protection from this occurrence because the spinal cord is narrower than the bony channel, so some vertebral displacement can occur without bony impingement on the

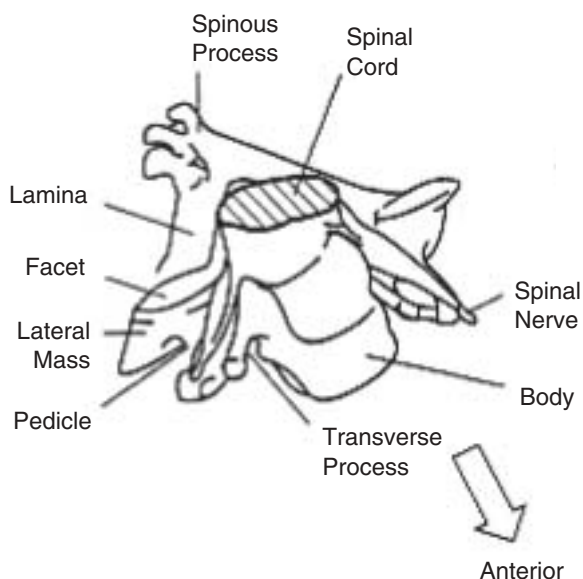


FIGURE 5 Spinal cord and vertebra (37).

spinal cord (39). But this extra space may be reduced or nonexistent in older drivers and passengers.

For more detail to the normal spine model, spongy intervertebral discs separate adjacent vertebrae, and the vertebrae are held in place by the discs and various elastic fibrous ligaments. Many vertebral ligaments attach to the outside surface of the vertebrae, but some ligaments, such as the ligamentum flavum, are located within the channel and attach to the inner surface of the vertebral rings. As part of the degenerative process, which to an extent is part of the aging process, these ligaments sometimes buckle and intrude into the extra space. Furthermore, also as part of the degenerative process, bony spurs (osteophytes) may project from the vertebrae. If these spurs are oriented inward (into the channel), the extra space also is reduced within the column. Therefore, even a minor impact, producing only minimal vertebral displacement,<sup>7</sup> can cause injury. This injury mechanism, involving the degenerated spine, may produce transient symptoms, such as a tingling sensation, or may on occasion produce a much more severe and permanent injury, central cord syndrome, which is associated with a paralysis of the limbs (39).

Recent developments include airbags that inflate in a variable manner (e.g., two levels of inflation), depending on crash or occupant characteristics, or both. An airbag restraining a large vehicle occupant in a high-speed crash would not inflate in the same manner as an airbag restraining a smaller vehicle occupant in a lower-speed crash. The requirements for the airbag would be different in two main ways. Because the lower-speed crash would involve slower occupant movement toward the interior of the vehicle, the airbag does not have to inflate as rapidly. Also the smaller occupant in the lower-speed crash would have less kinetic energy; hence, the airbag would have to absorb less energy and could be softer when inflated.

Additional airbag concepts under consideration and development include

- Airbags for the footwell to address lower-limb injuries,
- Airbags for the outside front of the vehicle for pedestrian protection,
- Airbags for side impacts to protect the torso, and
- Side-curtain inflatable restraints to help protect the head in side impacts.<sup>8</sup>

According to National Safety Council statistics, airbags have saved more than 2,500 lives since 1988 (29). This number does not include the number of

<sup>7</sup> Minimal vertebral displacement refers to any amount of displacement that can be tolerated without injury by a healthy spine.

<sup>8</sup> Side airbags are discussed further in the section on side impact.

injuries that were eliminated or mitigated, so the actual benefit of airbags during that period of time is even greater than the number of lives saved. The National Highway Traffic Safety Administration (NHTSA) reported that 145 fatalities have been attributed to airbags; the fatalities primarily involved unrestrained vehicle occupants in the front seat and infants improperly placed in rear-facing infant seats. Extensive efforts are under way to address the fatalities and injuries related to airbag deployments, including a change in federal test requirements to continue airbag depowering (40) and the option of an airbag on-off switch installed for people who meet the criteria established by NHTSA (41). The next step is likely to involve regulatory testing to include smaller-size test dummies, airbags with variable inflation characteristics, and the introduction of seat weight-occupant position sensing and safety belt use sensing, which would adjust airbag deployment characteristics according to occupant presence, safety belt use, and position (42). These types of developments also could mitigate the growing number of rib cage injuries from restraint devices.

Frontal crash protection is evaluated in the regulatory context by using instrumented test dummies in a vehicle that is crashed into a rigid, stationary barrier. For many years, these tests were conducted at speeds up to 30 mph. Recently, this requirement was changed to 25 mph for unbelted occupants and 35 mph for belted occupants (43, 44). This severe test condition is approximately equivalent to crashing at 60 mph into a similar stationary vehicle. The vast majority of crashes and most injury-producing crashes occur at speeds slower than 60 mph (45, 46).

### **Stars**

Legislation passed by Congress in 1972 required NHTSA to compare safety aspects of different vehicles and present this information to consumers for vehicle purchase decisions (47). This comparison has evolved into the star system, rating various vehicles on a basis of one to five stars, with five stars the highest. Separate ratings are provided for front and side impacts. These ratings are published in pamphlets and available on the NHTSA website ([www.nhtsa.dot.gov](http://www.nhtsa.dot.gov)). Consumer information test reporting also is conducted by other organizations, such as the Insurance Institute for Highway Safety, performs offset frontal crash tests.

### **Side Impact**

Considerable effort has been expended to address side-impact protection, including the development of new test

procedures, devices (test dummies), and criteria. U.S. regulations require side-impact crash-performance testing, with specific measurements for the acceleration to the pelvis and torso. The pelvic requirement is stated in multiples of the acceleration due to gravity (*g*); the torso requirement is stated in terms of the thoracic trauma index (TTI), a composite measure of acceleration to the spine and the ribs on the struck side. As a feature of the requirement, the measurements are different for two- and four-door vehicles (48), not due to any biomechanical differences between the occupants of these two types of vehicles but to a reflection of the inherent differences in vehicle structure between the two. The test device required by the U.S. Department of Transportation (DOT) for regulatory testing is the side-impact dummy (SID). To distinguish the SID from other side-impact dummies, the SID is sometimes referred to as DOT SID; because the SID is required for regulatory testing and is detailed in Part 572 of Title 49 of the U.S. Code of Federal Regulations, the SID also is referred to as the Part 572 SID. More recent side-impact test dummies include a test device developed primarily in Europe—designated as the EUROSID and more recently the EUROSID 1—and a test device developed to have greater biofidelity (i.e., having more humanlike characteristics in crash performance)—designated as the BIOSID. All of these side-impact dummies are intended to represent the average adult male or 50th percentile male.

The next step was the development of a side-impact dummy that represented smaller-structure vehicle occupants. The size selected was an average 12- to 13-year-old, which also represents the size of a small adult. This dummy is designated as the SID-II or SID Two Ess. The various dummies are associated with different test procedures and different test parameters (e.g., the SID requires the acceleration-based TTI). For example, the U.S. regulation requires a 3,000-lb barrier, and the European regulation requires a 2,100-lb barrier. The European regulation, European Commission for Europe standard (ECE) R95, uses the EUROSID-1, with a deflection-based criterion of about 1½-in. maximum rib deflection as well as abdominal and pelvic force measurements. The EUROSID-1 also has the measurement capability for another deflection-based criterion—the so-called viscous criterion—which is calculated as the product of chest compression and the velocity of chest compression. Currently, the viscous criterion is not included in ECE R95 requirements.

Because there are multiple test conditions, dummies, and criteria, a given vehicle may pass the regulatory requirements in one country but not in another. Therefore, one of the major issues concerning the proliferation of test procedures, devices, and parameters has been the approach of functional equivalence. In other words, can criteria be established to determine if two

different test procedures, different test dummies, and different test parameters correspond to essentially the same level of real-world vehicle occupant protection? After considerable debate regarding the definition and determination of functional equivalence, this approach was rejected for side-impact regulations by NHTSA in the spring of 1999. However, Australia sponsored a study that showed that Federal Motor Vehicle Safety Standard (FMVSS) 214 and ECE 95 are functionally equivalent. An alternate approach is being pursued—namely, the development of the WorldSID. This dummy would be developed by an international consortium of experts to have improved biofidelity and to be more universal. The WorldSID, thereby, would foster enhanced side-impact protection and international harmonization or the same side-impact performance requirements, regardless of jurisdiction or regulatory body.

Another aspect of side impact, compatibility, has received a great deal of attention since the release of *Special Report 218*. The three characteristics of vehicle crash compatibility are mass, geometry, and stiffness. Compatibility issues involve impacts between different parts and different types of vehicles, such as impacts between the front of one vehicle and the side of another or between a small car and a large truck, and the different vehicle crash characteristics that appear to be required under these conditions. For example, if a small, lightweight vehicle is involved in a high-speed frontal crash with a large, heavy vehicle, it is desirable that the small vehicle's front structure be stiff enough to absorb the crash energy by deforming as much as possible without allowing the large vehicle to intrude into the small vehicle's occupant space. On the other hand, if the front of a vehicle hits a relatively soft structure, such as the side of another vehicle, then the crash characteristics of the front of the vehicle should be relatively soft and have greater deformation under relatively mild impact conditions. In other words, the front of the striking vehicle needs to be relatively soft and produce relatively little intrusion into the side structure of the other vehicle. This difference in stiffness is compounded if there is a geometric misalignment of the crash structures or impacting elements of the two colliding vehicles (e.g., bumper heights in a frontal crash, bumper and rocker panel heights in a side crash). One way to improve geometric compatibility is to have a blocker beam in the front structure below the bumper of a small vehicle, so that when in a crash, the blocker beam can line up with and apply force to the structure of the vehicle.

## Rear Impact

Initial concerns regarding rear impact focused on fuel retention after very-high-speed impacts. FMVSS 301,

which requires rear-impact testing at 30 mph (49),<sup>9</sup> includes a test requirement to address this focus. Subsequently, the focus shifted to neck injury. Early response to rear-impact neck injury included the addition of a head restraint to the top of the seat back, either as an extension of the seat back—a so-called integral restraint—or as a separate, often adjustable restraint. A study by NHTSA indicated that both of these designs reduced neck injuries in rear vehicle impacts (51).<sup>10</sup> The early versions of the adjustable head restraint were adjustable up and down; later versions also had adjustment in the fore and aft directions. More recently, NHTSA issued a proposed rule that includes a limit on backset—that is, the distance between the back of the head and the head restraint (52).

Overall seat back stiffness is another parameter that has received attention, with most researchers agreeing that seat backs should not be overly rigid or overly flexible for the best overall safety performance. A recent study indicated that most contemporary seats are within the appropriate stiffness range (53).

The following concepts that reduce backset also are under consideration:

- Seats are shaped to reduce backset even more. If the head restraint is too close to the back of the head, the head restraint can be uncomfortable (54) and a source of distraction and fatigue.
- Seats are given more of an offset, between not only the head and head restraint but also the torso and upper seat back (Figure 6). These seats deform during the early stage of a rear impact to reduce backset and achieve spinal alignment before maximum loading occurs. Spinal alignment during rear impact also is affected by the lower seat stiffness. Some concepts include a pelvic support at the lower seat back to enhance early rebound of the pelvic region (54).<sup>11</sup>
- Seats are lined up with the head and torso during the early phase of a rear impact and then pivot backward. The WHIPS seat is an example of this concept applied to low-speed rear impacts (Figure 7) to avoid whiplash.
- Inflatable head restraints are added to seats to eliminate the head-to-head restraint offset. In this case, the head restraint inflates and moves toward the head (56). Perhaps an entire inflatable seat back also would help align the rest of the spine (57).

<sup>9</sup> A recent proposal by NHTSA would raise the test speed to 50 mph (50).

<sup>10</sup> The data in this study included high-speed and low-speed rear impacts.

<sup>11</sup> This concept may need to be combined with containment within the seat during high-speed impacts.



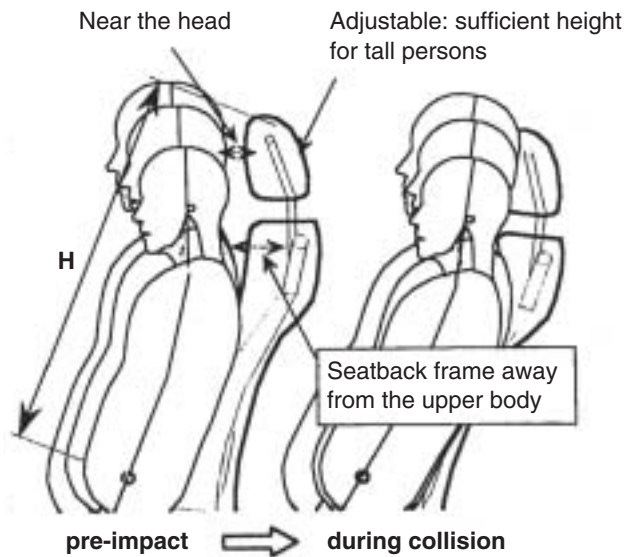


FIGURE 6 Concept with programmed deformation (49).

- Recent studies also have explored seats with different stiffness for different sections of the seat back, such as a higher stiffness for the lower or upper parts of the seat back. The goal is to enable the upper torso to move farther back and align better with the lower torso (58). Seats with a softer pelvic region would permit the pelvis to become embedded in the lower seat back, thus reducing the tendency to “ramp up” along the seat back.

- Seat back stiffness is adjustable based on crash characteristics, such as vehicle speed and occupant weight, age, and position.

These various concepts may prove beneficial under different circumstances (i.e., low-speed or high-speed crashes). To determine which, if any, concept will provide the best overall benefit presents a challenge.

### Rollover

Many efforts have been devoted to developing a metric that relates to a vehicle’s resistance to rollover during a crash, during an extreme steering maneuver, or when the vehicle runs off the road and “trips.” There has been considerable debate, involving issues such as

- What types of maneuvers occur before a rollover;
- Whether the metric needs to be derived from dynamic testing, because rollover is a dynamic phenomenon or a static measurement is adequate; and
- Whether the metric should be a pass–fail requirement or an informational reference used by consumers for vehicle purchase decisions.

The rollover curtain concept (see the section on side impact) may help to contain the vehicle occupant’s head and may be beneficial in some rollovers. Also accident avoidance concepts that detect early signs of decreased driver attention may be useful. These concepts include various approaches for monitoring driver drowsiness

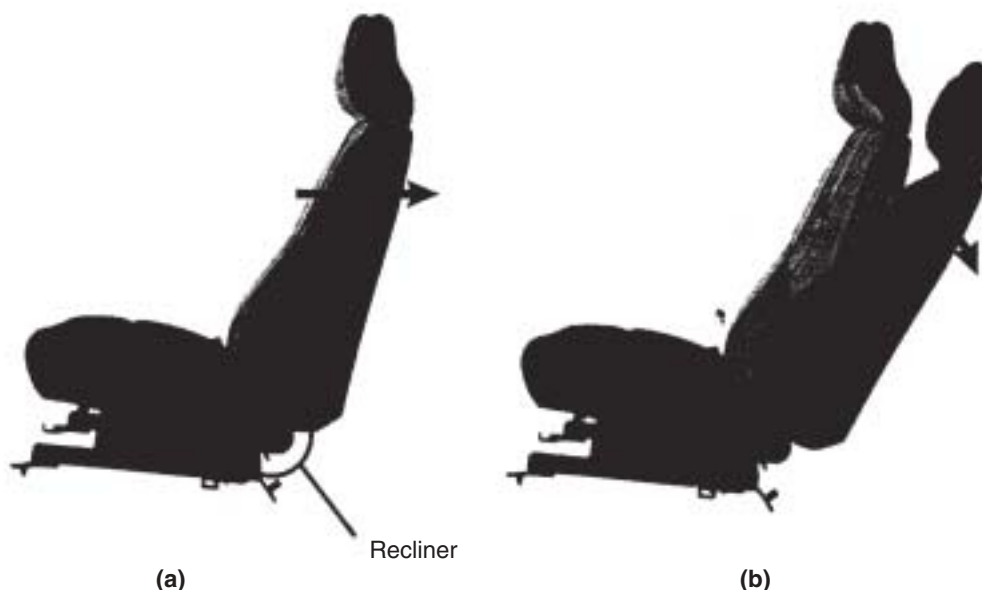


FIGURE 7 The WHIPS seat: (a) Phase 1; (b) Phase 2 (55).



(e.g., monitoring steering wheel movement patterns, vehicle speed patterns, or vehicle position to detect if the vehicle is drifting out of a lane or off the road).

### Driving While Intoxicated

Various programs have increased public awareness about the widespread involvement of alcohol in traffic-related deaths.<sup>12</sup> Educational and enforcement efforts have resulted in noticeable improvements. Although alcohol-related fatalities rose 4% from 1999 to 2000, accounting for 40% of all traffic fatalities, the proportion represents a 25% reduction since 1990, when alcohol-related fatalities were 50% of the total vehicle-related deaths (60).

Although drivers in the age 65 or older range—more than any other age range—reported that they “never drink and drive,” alcohol was involved in many older-driver crashes (61). This statistic may be an indicator of older-driver susceptibility to the effects of alcohol, which may add to this group’s already decreased ability to avoid and survive crashes. A recent study showed that older drivers tend to “clear” (metabolize) alcohol from their system faster than the rest of the population (62). Therefore, instances when driver blood alcohol level is measured after the event may underestimate older-driver alcohol involvement. Although ignition interlocks may be mandated judicially on an individual basis for convicted driving-while-intoxicated offenders, this vehicle feature does not appear likely for the general population.

### FUTURE CONCEPTS

Future restraint concepts include safety belts that are easier to reach, grasp, put on, wear, and take off. Various inflatable and deployable devices, similar to airbags, are likely to become more plentiful and perhaps more widely used in the vehicles of the future. The locations of these devices include

- Upper and lower frontal (upper and lower instrument panel),
- Roof,
- Footwell,
- Upper and lower side,<sup>13</sup>
- Head restraints and seat backs,
- Rear seat (air bags), and
- Outside of the vehicle (i.e., in the front bumper region to protect pedestrians).

These inflatable devices may have two or more levels of deployment, depending on crash and occupant parameters. Future seats may include additional rear-impact protection features, such as inflatable seat backs and head restraints, multilevel seat deformation characteristics, and seat backs with variable stiffness. All of these concepts could have more than one level of use, depending on crash and occupant parameters. Future accident avoidance concepts include vision enhancement for use at night and during bad weather, adaptive cruise control, navigation system, and automatic distress signal. Various future safety and security concepts may have particular benefits for older drivers and passengers, including drivable-when-flat tires, automatic door locks, panic button on remote-entry key fobs, and remote-entry-controlled vehicle interior lighting.

Sometimes concepts that seem like a good idea in general—and in particular for older drivers—turn out to have a potential downside. For example, the “hydrophobic” treatment to windows and outside mirrors reduces the effects of rain on the driver’s view. A recent study of hydrophobic treatments concluded that when viewing through treated surfaces, older people in particular had a tendency to underestimate distance—for example, to estimate that distances are safe for following another vehicle, changing lanes, turning across oncoming traffic, and so forth when the distances might not be (63).

### CONCLUSION

Two trends are noteworthy. Since 1925 there has been an incredibly consistent downward trend in the overall fatality rate, from about 22 to about 1.6 per 100,000,000 miles driven.<sup>14</sup> This statistic refers to the entire population and benefits the older segment in particular (28). More recently, in the time period approximately corresponding to the decade since the release of *Special Report 218*, vehicle fatality rates have decreased for all groups younger than age 65 but have increased for all groups older than age 65 (29). This is an aggregate result and reflects many random, uncontrollable, and even unidentified factors, involving the driver, roadway, and vehicle. Thus, this result should be examined.

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<sup>12</sup> Until the late 1980s, more than half of all traffic fatalities were alcohol related (59).

<sup>13</sup> The upper side could become more of a curtain basically to pad the side window region.

<sup>14</sup> This number constitutes a decrease over more than 75 years by a factor of about 22/1.6, which equals a little more than 13.

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# Automotive Adaptive Equipment and Vehicle Modifications

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Rehabilitation engineers research and develop assistive technology, which is defined in part as “any item, piece of equipment, or product system—whether acquired commercially, off the shelf, modified, or customized—that is used to increase, maintain, or improve functional capabilities of individuals with disabilities” (1).<sup>1</sup> Many rehabilitation engineers, and others who work in the field, are members of the Rehabilitation Engineering and Assistive Technology Society of North America, established in 1979 (2).

One of the most active areas in assistive technology research involves automotive adaptive equipment and vehicle modifications. Automotive adaptive equipment has a history almost as long as that of the automobile—the earliest adaptations date back to 1918, when Model T Fords were adapted for disabled World War I veterans (3). Simple mechanical hand controls and extension devices became available after World War II and the advent of the automatic transmission. Since 1970, the field has expanded to a multimillion-dollar industry dedicated to restoring driving capability to individuals who only a few years ago were confined to wheelchairs on the sidelines of society.

Almost everyone, no matter what age, has some degree of disability—even Clark Kent (also known as Superman) had to wear glasses! As other chapters in this monograph have stated, age is not intrinsically a disability, yet there are conditions correlated with or exacerbated by aging that can be addressed using appropriate assistive technology.

*Aging with a Disability*, by Treischmann (4), captures the interactions that arise when gerontological factors intersect physical and sensory disabilities. For example, progressive myopia, is reasonably correctable, except when complicated by cataract formation, which renders distance visual acuity marginal at best.

## AUTOMOTIVE ADAPTIVE EQUIPMENT

The state of the art in automotive adaptive equipment currently can compensate for great reductions in range of motion, dexterity, and strength that come about as increasing age compounds disability. Electronic and computer-mediated adaptive equipment is available but costly. A specially converted minivan for people with disabilities has a lowered floor, a power door, and power ramp. This conversion costs more than \$16,000, in addition to the price of the vehicle. Adaptive equipment to allow the driver to operate the vehicle from a wheelchair can cost as much as \$15,000 or \$20,000, in addition to the price of the vehicle modification. It is becoming easier every year to use modern technology to accommodate disabilities that worsen with increasing age. However, it costs a considerable amount of money, which is something older people no longer covered by state or provincial vocational rehabilitation programs may not have at their disposal.

Automotive adaptive equipment is designed to facilitate the following:

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<sup>1</sup> See 29 USC Sec. 2201 for a second definition.



- Access—getting into and out of a motor vehicle, particularly without assistance;
- Occupant protection—restraint system fastening and unfastening, including wheeled mobility aid tie down (major vehicle modification such as dropping the floor, however, may have negative consequences for vehicle crashworthiness features; some modifiers require crash simulation testing);
  - Subsystem control Mode A—controls that must be operated while the vehicle is in motion;
  - Subsystem control Mode B—controls that can wait until the vehicle is at rest, for example, idling at a traffic signal.
  - Subsystem control Mode C—controls that need not be operated unless the vehicle is parked or out of traffic.
- Primary controls—accelerating, braking, and steering; and
- Navigation or way finding.

An example of an elaborate yet well-integrated adaptive control approach for an individual who is severely disabled (tetraplegic) is shown in Figure 1. The equipment is installed in a van conversion and includes a lowered floor, a lift, power doors, and more. Most approaches for adapting equipment for older people and those with disabilities associated with aging would not be nearly so elaborate or expensive. However, this example illustrates what is possible with modern technology. The driver of this adapted vehicle is unable to transfer himself from his power wheelchair, feels no sensation below his upper chest line, has only limited arm mobility, and has hands that are completely limp; yet, he is a fully employed professional. If an automobile for a person with such profound disabilities can be adapted successfully to remove or reduce the handicap as far as independent driving goes, then it should be possible to supply adaptive technology to compensate for age-related disabilities in driving.



FIGURE 1 Integrated adaptive control approach.

## DRIVING DISABILITIES OF OLDER PERSONS

Drivers who were 65 in the year 2000 were born in the 1930s. Unlike the subjects of gerontology studies done just a few years ago—featuring people who came of driving age in the 1920s or earlier when far fewer people had cars and traffic was sparse—the older people of tomorrow started driving in the 1940s and after. They are and will be more affluent, better educated, and healthier and will reside in the same communities they lived in before becoming older drivers. They have driven under modern conditions and in the urban environment since their teens. Most of them have had driver education and defensive driving training. It is likely that they will continue to drive routinely almost until the end of their lives, which are lasting through ever-advancing ages. The disability trends briefly discussed below are highly variable in incidence and in their effect on driving performance. The future older driver may exhibit much less decline in many performance areas in which central processes are dominant. The perceptual decline outlook is less sanguine, but even replacement of cataract-scarred crystalline lenses with plastic substitutes is a routine office procedure for ophthalmologic surgeons, as is replacement of corneas, laser fixation of detached retinas, and more.

In addition to the discussions of age-related disabilities in other papers in this volume, two complete issues of *Human Factors* devoted articles to this subject in 1991 and 1992 (5), and Llaneras et al. published a comprehensive article in 1993 (6). The following discussion applies to the age-related disability taxonomy identified by Llaneras et al.

Llaneras et al. addressed 14 abilities that decline or change with age:

- Perceptual abilities:
  - Static visual acuity
  - Dynamic visual acuity
  - Contrast sensitivity
  - Useful field of view
  - Field dependence
  - Depth perception
  - Glare sensitivity
  - Night vision
- Psychomotor abilities:
  - Reaction time
  - Multilimb coordination and physical proficiency
  - Control precision
- Cognitive abilities:
  - Decision making
  - Selective attention
  - Attention sharing

Age-related conditions affect or degrade these abilities and lead to disability in each of these areas. In the perceptual abilities, such conditions as presbyopia, cataract, vitreous separation, glaucoma, functional monocularism, and macular degeneration affect performance. Central processing of visual information declines with age, hence the trend toward field dependence and narrowing of the useful field of view. Type I and Type II diabetes mellitus can affect visual performance.

The many forms of arthritis, osteoporosis, and loss of range of movement, as well as conditions such as Parkinson's disease and cerebral vascular accidents (i.e., strokes), affect psychomotor abilities. The latter conditions also have implications on cognitive and perceptual abilities.

A wide range of age-related conditions can affect cognitive abilities, and drugs and drug interactions also have an effect. At one extreme, there may be no significant impairment at all, or it may be that short-term memory may not be as efficient as it once was. At the other extreme, an older driver may be in the early stages of Alzheimer's disease or other age-related dementia.

Some of these conditions may be negated or assisted by adaptive equipment; others may not. The discussion here is limited to adaptive equipment designed to address a disability, and not the technology of intelligent transportation systems (ITS), covered elsewhere in this volume.

## AUTOMOTIVE ADAPTIVE APPROACHES FOR AGE-RELATED DISABILITIES

### Vehicle Selection

Many older persons retain the vehicle they had when they retired because the vehicle may be paid for and their incomes may decrease. With the trend toward longer, healthier lives, the older driver eventually will be in the market for a new vehicle. Price, brand loyalty, style, size, comfort, and uses for the vehicle will continue to be dominant factors in vehicle selection, but there are certain models in each manufacturer's stable that are designed to be more usable by the older driver. *Technology Review* (7) recently ran an article on Ford's "age suit," a restrictive garment that helps designers understand some of the limitations that old age places on drivers and passengers. The age suit has a pair of goggles to simulate the light loss, contrast loss, and yellowing of vision caused by cataract and vitreous changes. Other manufacturers have reported similar approaches. Although vehicle manufacturers try to build their products for as wide a range of ages and capabilities as possible, their expectations are that certain models will appeal more than others to older people.

### Adaptation Priorities

Previously mentioned were the different modes of vehicle operation that must be considered in adaptation Modes A, B, and C (8). Table 1 identifies the functions classified under each of these modes.

Adaptive approaches must take into account the priorities listed in Table 1. For example, the functions of Mode A are critical for operation while the vehicle is under active guidance by the driver; therefore, they require adaptation to make operation of those functions as easy for a person who is disabled as it is for a person who is not disabled. Depending on the disability pattern, functions may slip into Modes B or C without affecting safety of operation. Thus Table 1 represents minimums rather than desirable adaptation levels. Ideally, all functions should be accessible in Mode A to any driver regardless of the driver's level of disability. People who do not have disabilities can and do operate any of these functions as Mode A while the vehicle is under way.

### Addressing Vision Disabilities

Making controls and displays more discriminating and legible is central for adaptations to visual disabilities, such as loss of accommodating power (presbyopia) and for transmission losses that affect brightness contrast. Benjamin Franklin's invention of bifocals has been a boon for presbyopia compensation, but he probably never contemplated having to deal with the motor vehicle.

Glasses or contacts with different degrees of correction for close and far vision are designed for deskwork and for sharp focus at perceptual infinity. People who wear bifocals generally cannot read dashboard displays or other graphics clearly at the dashboard distance. To see the displays better, drivers with bifocals must lower their heads sufficiently to bring their gaze through the distance correction part of the glasses. In addition, many vehicle designs confront the driver with vast expanses of black or dark colors, with labels in small white or gray lettering. At best, little contrast is available for reaching operating controls or accurately reaching a cup holder. Figure 2 illustrates a typical homemade solution: the author has added white lines and dots to make the cup holders and radio knobs easier to see and use at night or when wearing sunglasses. Head-up displays on the windshield can be read with the distance correction portion of bifocals.

The functions that must be accommodated in Mode A generally are not affected by visual disabilities. Turn signal indicator lamps and high beam indicators should be as bright as possible. In Mode B, visibility and legibility of the transmission selector position require atten-

**TABLE 1** Priority of Motor Vehicle Controls for Adaptation and the Related Functions

*Mode A: Controls that must be accessible to the driver with the vehicle in motion*

Accelerator-brake-steering primary controls  
Cruise control-SET  
Headlamp beam selector  
Horn  
Turn signals  
Windshield washer/momentary wipe

*Mode B: Controls that are accessible to the driver with the vehicle not in motion*

Transmission (automatic)  
HVAC  
Exterior lamps  
Windshield wipers  
Parking brake

*Mode C: Controls that can wait until the vehicle is out of the travel way*

Ignition and engine start  
Seat controls  
Power windows  
Door locks  
Cruise control-ON  
Hazard flashers  
Interior lamps  
Mirrors  
Rear defrosters/wipers/washers

NOTE: If desired and feasible, Mode B or Mode C controls may be upgraded to Mode A or Mode B, but controls cannot be downgraded from their mode classification.

tion, since, for example, mistaking “P” for “R” can be catastrophic. In contrast, mistakenly selecting the wrong air distribution setting on the heating, ventilating, and air conditioning system (HVAC) can be irritating, but it is rarely critical.

Another adaptive approach that could be taken to provide better visibility for an otherwise dark control panel area is supplementary flood lamp illumination. Many cars come equipped with devices to provide illumination for map reading and other purposes. These lamps could be adapted, or aftermarket units could be installed in or around the original dome lamp or perhaps over the dash area only. The on-off control for the supplementary lamps should be integrated with the original equipment manufacturer’s (OEM) dome lamp switch rather than somewhere else, which might require the driver to grope around.

For many older drivers with diminished visual acuity (9), reading signage or other traffic controls built to minimum standard sizes can be difficult. Loss of visual



**FIGURE 2** Homemade solution using white markings.

acuity and contrast sensitivity arises from cataracts, vitreous separation, macular degeneration, and epiretinal membranes. The use of bioptic telescopic lenses could be helpful for drivers suffering visual losses but should be well practiced before the driver ventures into traffic. The telescopic lenses—which are expensive—are fitted to the driver’s standard corrective lenses and incorporate simple telescopes in several different forms along the upper edge. Some applications are binocular, and others are monocular. They are optically the same as an old-fashioned pair of opera glasses and magnify 1.5 to 2.5 times or even more. The spectacles are generally prescribed for people with low vision—corrected visual acuity is between 20/70 and 20/200 (10)—but could be used by others with better vision. Drivers lower their heads to bring the telescope, with a large exit pupil, into play when they want to discern a below-threshold sign or other object. A California study (11) has sounded a note of caution regarding accident experience with these devices, but it should be noted that the drivers in this study had low vision.<sup>2</sup> States have different regulations concerning the use of these lenses.

Functional monocularism occurs when a cataract is more advanced in one eye than in the other or if conditions such as epiretinal membranes occur; the driver is one-eyed for all practical purposes. For this, and for other restrictions in either field of view or head movements, wide-angle and multiplanar replacement rearview mirrors can be helpful at minimal cost.

With both left- and right-hand side mirrors all but universal today, the first strategy to try is a mirror adjustment procedure (12),<sup>3</sup> swinging both side mirrors out by approximately 15 degrees instead of adjusting them to be

<sup>2</sup> Restrictions in field of view caused by glaucoma and cerebral vascular accidents (strokes) require special prisms and mirrors mounted in eyewear, which is outside the scope of this discussion.

<sup>3</sup> Since many disabled drivers have considerable restriction in head movements even if they are not elderly, the author makes it a habit to teach every client this procedure to eliminate the blind spots in rear visibility.

redundant with the inside rearview mirror. To accomplish the adjustment, the driver leans against the B pillar and looks in the left side mirror. The mirror is adjusted until the side of the vehicle can just be glimpsed. The driver then leans to the right so that his or her head is in the middle of the vehicle. The right side mirror, even if it is a convex mirror, is adjusted until the side of the vehicle can just be seen. Thus, when a vehicle moves out of the range of rearview mirror, it is immediately picked up in either the right or left side mirrors, and blind spots are eliminated.

The effects of glare, including both excessive ambient light and extreme contrast, can best be mitigated by well-known expedients such as sunglasses and visored caps. Driving with the sun flaps down at all times also can help reduce glare. Side and rear tinted windows are advantageous for glare reduction in the daytime but may be confusing at night when, in the rearview mirror, oncoming traffic may appear farther away than it is. Electrochromatic mirrors, which are available on many models, do mitigate mirror glare effects.

### Tackling Hearing Disabilities

For older people with moderate hearing loss, one of the major problems inside the vehicle may be detecting turn signal indicator sounds and auditory warning signals, such as “key in ignition,” “headlamps on,” or “fuel low.” Some of the audio alarms and signals have visual signals paired with them. These alarms sometimes can be supplemented by aftermarket equipment, but drivers may not appreciate the obtrusiveness of the signal.

For drivers with severe hearing loss there is no alternative to providing a visual signal. A master alarm indicator, designed to flash in some pattern to draw attention, can be an effective approach and is not particularly expensive to implement. A device called E.A.R.S.<sup>4</sup> uses flashing warning lights to alert drivers to the approach of emergency equipment or police cars. In the future, one can imagine the vehicle computer setting off a master alarm when it detects any out-of-tolerance situation. The older driver will be aware that something is wrong and then can search for the specific indication.

### Adapting for Musculoskeletal Disabilities

#### Head Movement Limitations

Head movement limitations require special mirror positioning or supplementary mirrors. The driver, much like a commercial truck driver, must learn to trust the mir-

rors for the approach to be effective. Obstacle detection devices, now in development, could prove useful.

#### Range-of-Motion Limitations

For range-of-movement limitations, extensions or additions to the controls are the treatment of choice. Some of these approaches can be simple and cost-effective—for example, a simple worm drive hose clamp on a turn signal arm or wiper control can make it much easier to operate with an arthritic hand. An added extension handle could make HVAC controls easier to reach for a person with shoulder movement limitations. Steering assists can be installed easily on steering wheels to make slewing movements much easier, for example, in parking maneuvers. The assists can be purchased with knobs or with grips that are suitable for hands that have little or no grasping capability. Figure 3 illustrates two of these.

#### Strength Limitations

Limitations in arm or leg strength can be addressed with extensions and relocation of controls. Many motor vehicles have step-on parking brakes that may be difficult for an older person to operate. A clamp-on extension handle relocates this control action to the person’s left hand and arm with a considerable mechanical advantage (see Figure 4). The same thing can be done to the transmission selector lever (see Figure 5) by adding a clamp-on extension handle to increase the mechanical



FIGURE 3 Steering assists: (a) spinner knob, (b) grip device.



FIGURE 4 Control action relocated to steering column.

<sup>4</sup> Device is marketed by Hear More Products, telephone 1-800-881-HEAR.





FIGURE 5 Relocation of transmission selector.

advantage at the cost of considerably more travel. Turning the ignition key to start the vehicle can be very painful for an arthritic hand, but simple “quad” key extensions (see Figure 6) can render this operation much easier. These devices, with installation, cost anywhere from a few dollars to around \$100.

### *Leg Limitations*

Pedals can be extended easily to accommodate leg length. Several new vehicles, such as the Ford Expedition, offer pedals that can be moved back and forth with a positioning actuator, so that a pedal extension or seat relocation is unnecessary. There probably will be more manufacturers who offering this option in the future. For people who have had partial amputations, a left-hand accelerator pedal can be installed; however, this adaptation must be approached with considerable caution, since pedal operation expectations built up over a lifetime of driving are suddenly reversed.

A better approach, but one that has considerable implications of “disability” and consequently may be resisted, is to provide a simple set of hand controls (see Figure 7). These time-tested units sell and install for less



FIGURE 6 Quad key extensions.



FIGURE 7 Hand controls.

than \$800, and any person with normal driver skills can master use in a few days or less. If a hand control is installed, the driver should also have steering assists, since he or she will be steering with one hand, and fast steering inputs could result in loss of control. A caveat is in order: installing such adaptive equipment introduces hazards into the driver compartment that are not present in the unmodified vehicle, especially in the event of a crash. Steering assists may lead to other injuries.

### *Skeletal Malformations*

Osteoporosis may be less of a problem in the future than it is now, but accommodations need to be made for such conditions and for other skeletal malformations that may make the conventional motor vehicle seat unsuitable for driving. The simplest approach is to order a top-line power seat base or obtain such a base as an aftermarket or even salvage-yard purchase. A seat base can raise and lower, and can provide tilt, seatback adjustment, and fore-aft movement. Lumbar support adjustment also may be available. If the vehicle to be adapted is a minivan, a conventional van, a pickup, or an SUV, there are special seat bases for disabled drivers that provide four degrees of freedom: fore-aft movement, raise and lower, and swivel for easy access from inside the passenger compartment. A power seat from the OEM can be mounted on top of this base to provide almost unlimited combinations of positions. These seats cost up to \$2000 installed.

### *Reducing Access Problems*

Older people may have difficulty entering or alighting from a motor vehicle because of stiffness and loss of strength. Extra assist handles can be helpful and are relatively inexpensive to provide and install. Care must be taken not to introduce extra hazards that would cause people to bump their heads or otherwise injure themselves. Many top-line cars and most minivans provide assist handles that are effective. To assist access into truck-based vehicles, which may require as much as an 18-inch step up, exterior steps are readily available and can be ordered as a dealer-installed option. There are also power-operated steps that fold out of the way when not in use.

Powered access devices to assist older people are available but expensive. The Bruno Corporation makes a device called the EZ Rizer—a folding chair that moves up and down alongside the driver’s seat to allow easy transfer into the vehicle seat. In most applications, this device is teamed with a small crane for loading and unloading a wheeled mobility aid into the rear of the



van or bed of the pickup. The EZ Rizer would be above and beyond for many older people when steps and assist handles are available and appropriate, but it may be a solution for people with advanced osteoarthritis or rheumatoid arthritis. For many older people, getting into a car is reasonably easy but getting out can be difficult without assistance. A truck-type vehicle might be a better choice, although personal preferences, locale, and economics may dictate otherwise.

### Adjusting for Cognitive and Neurological Deficits

Various studies have found no compelling evidence for significantly longer perception-reaction times (PRT) for older drivers (13, 14), although the trend is toward longer PRT as a function of age, especially if decision making and response selection are involved. The strategies discussed previously for visual disabilities can help the older driver obtain timely information to assist a somewhat slower decision-time lag. Anything that reduces drivers' physical or mental workload enables better performance of the correct maneuver in time.

Time-sharing and resource allocation for mental workload supposedly becomes less efficient with age (15), hence many older (and younger) drivers use strategies such as turning off the stereo or asking vehicle occupants to be quiet when a traffic situation gets tense. The addition of cellular telephones and some types of ITS route guidance displays and the display of various types of information—such as tachometers in automatic transmission-equipped vehicles—which may or may not be of use to drivers, can push mental workload above distraction levels. On the other hand, “smart” cruise controls and other ITS technology can relieve drivers of some workload and provide a valuable edge for acting just in time.

Concerning the controversial subject of memory loss with age (16), the rapid development of solid-state sound recording suggests that drivers will be able to prerecord on a pocket recorder their route guidance in the form of commands (“8 miles on River Road, then turn left on SH 47”) that can be retrieved as often as needed at the touch of a button.<sup>5</sup>

### CONCLUSION

This paper has addressed disabilities associated with aging. Automotive adaptive equipment and vehicle modifications are always customized to an individual's disability.

Two people with the same type of disability, but potentially different abilities, transportation objectives, and financial resources, may need different equipment or equipment modifications. Although elaborate and costly approaches may be required at times, in many cases, simple equipment can make a difference between being homebound and dependent on others for daily transportation or being transportation-independent. In general, the deficits associated with aging exacerbate any pre-existing disabilities and may require further adaptation as time goes on. For example, a paraplegic may become affected by osteoarthritis to the point that transferring out of a wheelchair becomes difficult, necessitating vehicle modifications to allow driving from a wheelchair.

Table 2 reiterates the information in Table 1 in summarizing available adaptive equipment that facilitates or restores the control interface. However, Table 2 adds the factors of ingress and egress, and visual and auditory input. Equipment for severe disabilities and conditions is beyond the scope of this paper.

It is often difficult to find someone capable of obtaining or making, installing, and checking adaptive equipment for fit and function. Once installed, effective training in adaptive equipment use also may be difficult to obtain. Older drivers or their families or friends can seek assistance from vocational rehabilitation agencies, rehabilitation hospitals, and other similar agencies. These agencies can suggest occupational therapists, evaluators, trainers, medical supply dealers, and vehicle modifiers to specify, furnish, install, and train drivers in the use of adaptive equipment. There is also a national association of adaptive equipment and vehicle modification dealers—the National Mobility Equipment Dealers Association.<sup>6</sup>

Some of the equipment described in this chapter can be bought at aftermarket automotive supply houses and dealers. Although some dealers and modifiers can be counted on to be imaginative and innovative in devising solutions to adaptive needs, the threat of liability—the fear of legal action—hangs heavily over the rehabilitation industry and inhibits much that could be done.

One innovation that the adaptive equipment industry should address is assistive devices for easing the effort of fastening seat belts for those with movement and dexterity limitations. Vehicle modifiers for people who are disabled often use homegrown inventions, such as fixed belts and belts installed on wheelchairs, to effect adequate passenger and driver restraint.<sup>7</sup>

<sup>6</sup> The National Mobility Equipment Dealers Association is headquartered in Florida and accessible via the Internet ([www.nmeda.org/](http://www.nmeda.org/)).

<sup>7</sup> To the author's knowledge, there are no commercially available assists for fastening seat belts. Hence an unknown number of older drivers elect to drive and ride unbelted because the belts are difficult to fasten.

<sup>5</sup> The author uses this technique sometimes with a Dragon Naturally Mobile digital recorder.

TABLE 2 Adaptive Equipment Application

<i>Function</i>	<i>Adaptive Equipment</i>	<i>Typical Disabilities/Applications</i>
<i>Mode A Controls—Primary</i>		
Steering	Assist grip (“spinner”) Smaller-diameter wheel Reduced-effort power steering	Arthritis, spinal cord injury, upper limb amputation or paralysis  Same as above, plus muscular dystrophy, multiple sclerosis, post-polio weakness
Throttle/brake	Left accelerator Pedal extensions Hand controls	Use with caution! Primarily for amputees and hemiplegics Short legs, arthritis, post-polio weakness, range-of-motion limits Post-polio weakness, spinal cord injury, bilateral lower amputation, multiple sclerosis
<i>Mode A Controls—Secondary</i>		
Cruise control—SET	Raised button	Arthritis
Headlamp beam selector	Relocated from floor	Only on older vehicles; often provided on hand controls
Horn	Affix label to assist Relocated button	Visual limitations Arthritis
Turn signals	Extension	Amputation/paralysis of left arm
Windshield washer/ wiper momentary	Ring or extension	Arthritis
<i>Mode B Controls</i>		
Transmission	Extension	Arthritis, amputation/paralysis of right arm, multiple sclerosis
Parking brake	Extension	Spinal cord injury, post-polio weakness, left leg amputation or paralysis
Other Mode B controls	Electric Extensions/add-on buttons	More severe disabilities listed than above Any of the above
<i>Mode C Controls</i>		
Ignition/engine start	“Quad” key holder Remote start	Arthritis, multiple sclerosis Any of the above
Other Mode C controls	Extensions/add-on buttons	Any of the above
Ingress/egress	Steps or running boards Assist handles Personal lift [EZ Rizer (R)]  Minivan modification	Arthritis, hemiplegia, multiple sclerosis Same as above For pickups and similar truck-type vehicles. Any severe limitations in strength or movement Lowered floor, power ramp for those using scooters or wheelchairs
Seat adjustment	Power seats	Advisable for any loss of strength or range of movement, especially arthritis
<i>Visibility Enhancements</i>		
Controls	Relabeling	Presbyopia, advanced cataract, mild macular degeneration, epiretinal membrane
Signage	Delineation/outlining	Enhances contrast
	Supplementary floodlighting	Same as above
	Bioptic telescopic lenses	Any of the above, plus those with “low vision”
Surroundings	Large area mirrors Wide-angle rear view mirror	Arthritis, monocular vision, advanced glaucoma Same as above
<i>Auditory Warnings</i>		
	Amplified buzzers, turn signals	Hearing impaired
	Master warning lamp	Hearing impaired

The adaptive equipment and vehicle modification field has much to offer older drivers seeking to retain personal transportation independence as long as possible. This paper has only scratched the surface in describing available adaptation and modification possibilities and those that are appearing daily on the market. Alone or combined with the technology of intelligent vehicle systems, adaptive equipment can and does play a key role in enhancing older driver performance and safety.

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# In-Vehicle Intelligent Transportation Systems

## Safety and Mobility of Older Drivers

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Many older drivers depend on the automobile for shopping for food, visiting the doctor, socializing with friends, and traveling. Older drivers in North America, with lifelong habitual patterns of automobile use, are not likely to give up driving willingly to use public transit or other transportation alternatives. Large cities tend to be designed with limited access to essential needs (e.g., food, clothing, medicine, and social contact), which only can be met by driving. Health and financial problems, general declines in ability, specific driving skill deterioration, and poor visual health in older drivers can lead to reductions in driving or to driving cessation. Many but not all older drivers become aware of their deficiencies and compensate in several ways (1). Restrictions to mobility from policy or age-related declines in driving capability limit the lifestyles of elderly people (2, 3). Maintaining an independent and meaningful lifestyle that is supported by driving requires an array of policy, service, infrastructure, and technical solutions. In-vehicle intelligent transportation systems (ITS) applications are an obvious technical solution.

ITS applications are the fusion of advances in wireless communication technologies, automotive electronics, computing, and the Global Positioning System (GPS). Various ITS applications, such as route guidance, emergency vehicle location and response, vision enhancement systems (VES), and collision warning systems, appear to be applicable to older drivers. In the larger context of interventions, ITS applications represent a small, unproven fraction of available countermeasures. Few in-vehicle ITS applications currently are

used by drivers, and fewer still are used by older drivers. However, this is likely to change dramatically in the new century. Ideally, ITS applications would increase older-driver mobility and safety. Pragmatically, given the available empirical evidence, the impact of in-vehicle ITS on older-driver safety and mobility is uncertain. The use of in-vehicle technologies by older drivers has not been a research priority in North America. For example, of the two recent books on ITS and human factors, only one briefly mentioned older drivers.

Older drivers are most likely to benefit or suffer from the effects of ITS technologies (4–9). Some older people embrace and experiment with new technologies. However, many are less confident in their ability to operate new systems. Initial fear of technology, difficulty in operating a device when driving, display information illegibility, and need for specific training are likely to be recurrent issues for older drivers when using many ITS technologies.

Although the number of ITS applications continues to grow, the value and functional advantage of technological driver information have yet to be determined. To date, the application of technology, instead of driver information needs, has been the predominate focus of the marketplace initiatives of many ITS developers. For example, the number of driver information systems (10), such as advanced driver information systems, advanced traveler information systems, and generic information driver support, has increased steadily.

ITS applications are likely to benefit older travelers, whether older travelers use transit or a personal vehicle. Suen and Sen address transit mobility options for seniors

in an earlier paper (pp. 97–113). For example, when integrated into centralized dispatch and management centers, several ITS-related technologies have been developed to assist with the timely delivery of transit and paratransit to older travelers. These technologies also can help travelers find out when the next bus will arrive at a particular stop. Wallace examined the preference for a range of service options (11). Whether a service option should be delivered in person or through technical support is a critical issue. ITS intermodal solutions, which allow travelers to transfer seamlessly from car to bus or train to airplane, also have been identified as requiring researchers' attention. In North America, most older travelers are likely to travel in a personal vehicle (2) for a variety of reasons (12). Thus, the focus of this paper is on in-vehicle ITS applications.

Ultimately, to the extent that in-vehicle ITS applications are found safe and effective, drivers and the general public will not be put at risk. However, if these systems are applied without the consideration of older people's needs, safety undoubtedly will be compromised. If ITS products are to be beneficial, they must accommodate the capacities of older drivers and the safety needs of all drivers. Older drivers may benefit from the array of ITS technologies being developed if the technologies are designed using human factors principles and practices (13–16). ITS products used by a transportation system should be tested to determine whether driver safety is compromised (17). As the bottom line, ITS applications should increase mobility but

not compromise safety (18). To this end, a brief introduction to in-vehicle ITS technologies precedes a review of the empirical research on the in-vehicle ITS applications that have included older drivers as a user group. Given that many ITS applications are in the early stages of development, issues of design guidelines, standards, and evaluation methods also are discussed.

## IN-VEHICLE ITS TECHNOLOGIES

In the past 10 years of research and development, a variety of new in-vehicle applications has emerged. Route guidance, adaptive cruise control (ACC), collision warning, vision enhancement, and automatic accident notification typically have been the focus. Driver information platforms and services that have been popular include in-vehicle telephony, laptop, and personal digital assistants; on-road hazard warnings; smart signs; congestion and vehicle system monitoring; and e-mail, fax, World Wide Web, tourist, and emergency services. New applications that are hybrids of computing, automotive electronics, communications, and GPS are emerging regularly. At first glance, people are either struck with skepticism or fascinated by these technologies.

The purpose of this section is to detail the general functionality of the systems. How these systems are integrated into the vehicle is useful conceptually. Figure 1 illustrates the basic relationships among system components. The following devices are among the hardware:

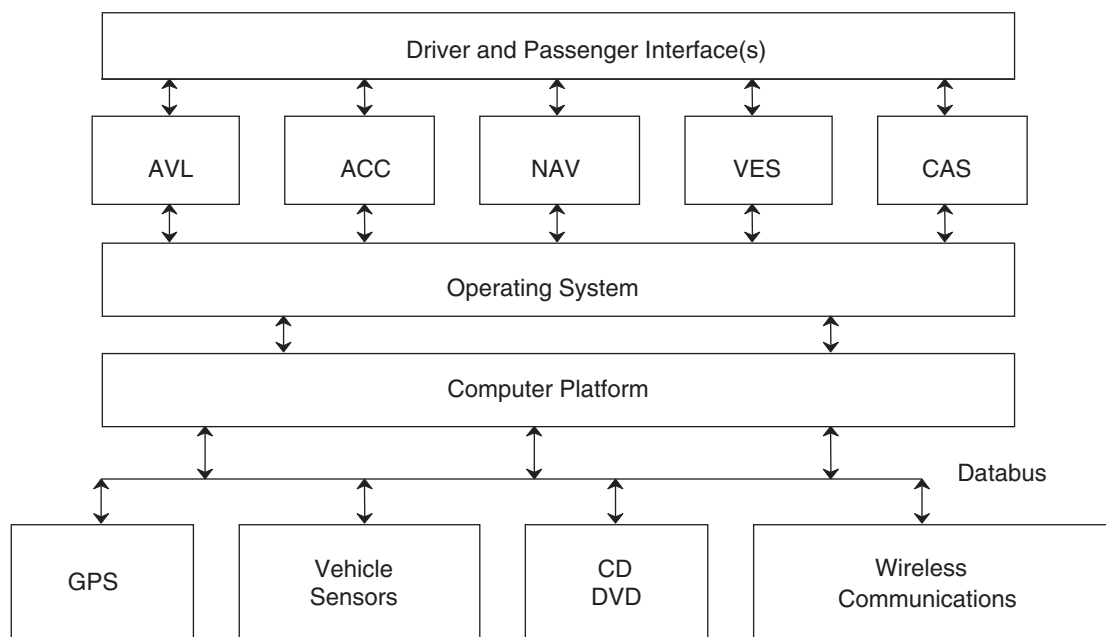


FIGURE 1 Generic model of hardware, software, and user interfaces for in-vehicle ITS applications. (NAV = navigation system; CD = compact disc; DVD = digital videodisc.)



- GPS for vehicle locating;
- Vehicle sensors for locating objects
  - In front (e.g., obstacle and pedestrian detection),
  - To the sides (e.g., blind-spot detection), and
  - Behind (e.g., children, toys, and shopping carts);
- Road conditions (e.g., black ice);
- Wireless communication technologies for voice and data, such as phone calls, travel information, weather, congestion, and safety advisories (e.g., road closures); and
  - Compact disc and digital videodisc players.

A data bus moves packets of information to and from the hardware and software distributed throughout the vehicle.

The computer platform and operating system control and integrate hardware, software, and interfaces. Specific applications, depending on engineering and marketing goals, may be integrated. System reliability suggests separation, but the coordination of display information across applications suggests integration. The integration of multiple system components into a vehicle is important. Within the Intelligent Vehicle Initiative, 26 user services were combined into 7 technology modules, 4 of which are relevant to older drivers (19). These modules are basic collision warning technologies, advanced warning technology, basic traveler information development, and driver convenience services. Consistency of interaction and prioritization of information from multiple applications has been a concern of industry and government. Interaction with a plethora of systems was identified as a critical development issue. For example, a driver receives information from the route guidance system that is in direct conflict with the collision warning system. Which information, if any, should the driver follow?

Figure 1 includes automatic vehicle location (AVL), ACC, navigation or route guidance, VES, and collision avoidance systems (CAS). In addition to these applications, a consortium of vehicle manufacturers, chipmakers, and software corporations has marketed the AutoPC. The AutoPC presents a range of mobile office functions, such as paging, concierge assistance, e-mail, World Wide Web, and traffic reports. Interaction with each application, unless automatic, is dependent on an interface, which consists of various displays and controls. Most driver interfaces are inserted into the dashboard column to the right of the steering wheel. Passenger interfaces are built into the backs of seats and in a location that does not interfere with the deployment of the passenger-side airbag. Information on specific systems follows.

### Emergency Alert or AVL

An emergency alert or AVL system transmits to a dispatch center the status and location of a vehicle that is malfunctioning or that has had an accident (20).

Automatic notification occurs when the airbag deploys. A call service center then attempts to contact the vehicle occupants through a hands-free phone. The nearest 911 center is called if assistance is requested or if the occupants do not respond. In addition to emergency response, roadside services, stolen vehicle tracking, remote unlocking of doors, diagnostics of vehicle breakdown, yellow-pages business locator, and restaurant reservation services also are being developed. Many car manufacturers are selling or intend to market emergency response systems with monthly service plans that allow subscribers to choose from a variety of additional services.

Mayday systems may speed the delivery of emergency medical services in rural areas. The National Highway Traffic Safety Administration (NHTSA) noted that 93% more rural accidents result in deaths than do urban accidents (21). The timely delivery of emergency medical services has been identified as one of the primary reasons that fatal traffic accidents have decreased in industrial nations over the past 40 years (22). If mayday systems can reduce emergency response service time to accidents, especially in rural areas, these systems will become important ITS applications. When in a crash, an older driver is three times more likely to die than is a younger driver (23). Thus, rapid delivery of emergency medicine is likely to benefit older drivers. Fragility of older people suggests a range of other countermeasures in addition to ITS (24–26).

### Navigation Technologies

Navigation or route guidance systems (for traveler information, advisories, trip planning, etc.) provide drivers with directions to a destination. After the driver inputs a destination, the system guides with voiced or displayed turn-by-turn instructions (27). Navigation systems have the potential to optimize routes, ease trip planning, avoid congestion, and solve or avoid getting lost. Route optimization can be requested, and alternative routes can be suggested if congestion or traffic accidents impede. Manufacturers offer many different navigation systems as options in higher-priced vehicle models. Navigation systems in Japan have reached the highest market penetration rates. House numbering conventions make finding particular buildings difficult unless local residents are asked; navigation technology makes finding a specific address easier. In general, older drivers are assumed to have more difficulties finding a route than younger drivers (28). Fear of losing their way in unfamiliar places may limit mobility choices. Older drivers who do not know a particular area or are reticent to venture out may benefit from these technologies as long as the drivers can hear or see the directions.

## Adaptive Cruise Control

ACC or intelligent cruise control is designed to increase driver comfort by adapting conventional cruise control (CCC), through sensor feedback loops and algorithmic tailoring, to forward vehicle changes in velocity (29, 30). Drivers can relax more because they do not have to adjust headway continuously. At a predetermined limit, the system disengages, changes gears, or applies limited braking for the driver, as needed. ACC systems do not necessarily provide a warning after the headway has reached the limit, and ACC systems do not take evasive action. ACC is a consumer product in Japan and Europe and is likely to enter North American markets within the next few years.

## Infrared and Ultraviolet Vision Enhancement Systems

Infrared vision enhancement systems (IVES) use a sensor display to represent thermal differences between an object and its background, such as pedestrians or animals on the road (31). Ultraviolet vision enhancement systems (UVES) are designed to aid drivers in the detection of driving-related environmental features, such as lane markings at night, and in adverse conditions (e.g., rain, fog, and snow). Several manufacturers are developing near and far IVES, but the UVES have been abandoned. The technologies of the VES appear promising for increasing older-driver mobility (13, 14, 20). These systems may assist with older-driver loss of visual capability (32–34). In the IVES, thermal energy differences between objects in the traffic environment are displayed on the windshield, using a head-up display (HUD) or a small display mounted in the dashboard. A pedestrian with a thermal signature that is different from the traffic environment background would be seen at a greater distance because of target contrast differences.

## Collision Avoidance Systems

CAS convey potential collision situations to drivers. The direction and severity of a collision depends on rapid changes in the traffic environment (35–37). Given the overrepresentation of elderly people in vehicle accidents (38–40)—particularly intersection, turning left across traffic, merging, and backing accidents (41–43)—the development of CAS for these crash patterns appears logical. But what, when, and how warning information should be presented for different crash types that rarely occur (22) is challenging (44, 45). Being able to reduce speed quickly after a radar detector goes off is an analogous situation. Many radar detector owners have found

that they are not able to respond fast enough to prevent getting a ticket. If auditory and visual warnings are given, the information should be presented in sufficient time for drivers to initiate avoidance maneuvers.

From the Intelligent Vehicle Highway Initiative Program (19), four crash scenarios were targeted as amenable to the CAS in lightweight vehicles (i.e., cars, vans, and light trucks)—namely, rear-end, lane change, or merge collisions and single-vehicle road departures (46). The rear-end crash CAS, for example, would notify the driver through auditory, visual, or tactile displays when a lead vehicle is decelerating or stopped, which are the two most common accident configurations. Although not ITS applications per se, mirror systems may allow drivers to see into blind spots. Older drivers, who tend to use mirrors more often because of restricted head movements, are likely to benefit (3, 5).

## EVALUATIONS OF IN-VEHICLE ITS APPLICATIONS

In general, the use of technology by younger age groups appears to be an implicit design and evaluation assumption. Ironically, ITS devices in the United States tend to appear in luxury vehicles, which traditionally have been purchased by people over age 55. European experience suggests that older drivers tend to purchase smaller vehicles with options that are likely to assist the driver, such as power windows (personal communication, P. R. Oxley, 1999).

A body of sound empirical research is needed to form a solid foundation for ITS technology development. Open ITS research tends to be performed on a contractual basis, where replication of previous results is the exception, not the rule. Many corporations evaluate ITS devices, but results are proprietary and not published. A patchwork of ITS and ITS-related knowledge has evolved over the past decade. With a few exceptions, a coherent, sequential body of research on ITS human factors is beginning to emerge, but the body of knowledge about older drivers is limited. Research that includes older-driver samples is reviewed below.

## Perceptions of ITS Applications

Several focus groups have been conducted to determine if older drivers are willing to use various ITS applications. Sixsmith (47) examined the expectations of older drivers related to the following in-vehicle systems: route guidance, anticollision devices, radio data systems, awareness monitors, and breakdown detection devices. Six focus groups of older drivers (age 52–79) discussed driving performance and the in-vehicle systems. Among the major driving difficulties experienced by drivers

were navigation problems, night driving, and declining competencies (e.g., reaction time and perception; 48).

The results indicated that women were more reluctant than men to accept new technologies. Some participants believed that new technology would increase safety, and some thought that new technology was the answer to all their problems. Others were wary of the new technology, especially at the driver-machine interface. The five technologies discussed provoked mixed reactions, with no apparent gender differences. When asked whether new technologies would give the participants an increased confidence in situations where the participants had been reluctant to drive (e.g., in central London or at night), the responses were negative generally. The older drivers did not see the new devices as particularly useful and tended to believe that ITS applications would have more benefit for younger drivers and businesspeople. Negative comments were made for any system that would startle the driver, such as warnings, or that would demand more of the driver's attention. As Sixsmith explained, "people felt that driving is dangerous enough today without extra problems imposed by [an ITS] that may be poorly designed, or at least poorly adapted for elderly drivers, especially when such devices are not necessary" (47). On the basis of this limited study, new technologies may not be the solution to many of the difficulties encountered by older drivers. The participants were skeptical of the value of and their ability to cope with systems that present additional warning signals and information.

Radio data systems, which provide up-to-date information on road conditions, weather, and so forth, were met with enthusiasm. Female drivers especially appreciated any device capable of making the vehicle more reliable, such as breakdown detection and emergency alert. In general, older drivers were reluctant to give up control of the vehicle (e.g., by using anticollision devices), and many drivers saw the devices as potentially replacing proper driver attention to roadway hazards.

Although gathering only subjective evaluations of specific new technologies, the study served to increase awareness about some of the potential concerns of the older driver.

### Performance Evaluations of ITS

Within Elderly and Disabled Drivers Information Telematics (EDDIT), a project of the Dedicated Road Infrastructure for Vehicle Safety in Europe (DRIVE II), six ITS applications (route guidance, traffic information, emergency alert, reversing aid, night vision, and collision warning) were tested to determine whether older-driver mobility improved or safety was compromised (17–20). For each system, approximately 30 elderly drivers—10 each within the age ranges of 65–69, 70–79, and 80 or older—were sampled. Males and females were balanced approximately within each age range, had a driver's license for a minimum of 5 years, and still were active drivers. Table 1 shows an overview of the applications and how they were tested.

Navigation systems that diverted the driver's attention for prolonged episodes resulted in drivers reducing speed and steering off course. As the complexity of route guidance increased, basic driving task performance declined—more for older than younger drivers. The authors concluded that collision warning and reversing aids, for a variety of reasons, might have little effect on improving mobility. In contrast, the VES and emergency alert with the AVL (mayday) were likely to improve older-driver mobility and personal safety. Both the UVES and the IVES appeared to improve nighttime visibility of pedestrians and roadway guidance features. In subjective perceptions of the VES, older drivers indicated that the system was easy to use (100% UVES) and that they now may choose to drive at new times (73% UVES, 60% IVES). Emergency alert, which provides vehicle location information to a central dispatch cen-

TABLE 1 Overview of EDDIT ITS Evaluated Devices (20)

<i>ITS Device</i>	<i>Specific Scenario</i>	<i>Evaluation Procedure</i>			<i>n</i>
		<i>Driving Simulation</i>	<i>Test Track</i>	<i>On Road</i>	
Collision warning	Right turn (U.K.) across oncoming traffic from a major to a minor road	X			30, 27
Reversing aid	Eight back-up maneuvers, with and without reversing aid			X	43, 39
Route guidance	Routes in urban and suburban regions			X	27, 35, 30, 9, 7
Traffic information	Highways near Lyon (France)			X	20
Emergency alert	Public road around Cranfield (U.K.)			X	22
Night vision	Prescribed test track route (Sweden and U.K.)		X		31 (UVES), 15 (IVES)

ter, also was viewed favorably. Overall, some systems show promise, and others require further development and evaluation.

### Wireless or Mobile Phones

Wireless communication technologies, such as cell phones, will deliver many ITS voice and data applications in the future. In-vehicle ITS applications are likely to divert the driver's attention, similar to driving with a mobile, wireless, or in-car phone. Driving and using the phone requires the driver to perform several tasks at the same time. It has been shown that using a phone when driving can increase the chances of an accident by up to 4.8 times (49). The primary factor in the relationship between phone use and accidents appears to be the reduction in the driver's attention to events on the roadway. Absorption of attention may focus on the manipulation of a device—for example, dialing a phone number or talking (50, 51). Conversations can vary from talking about the weather to heated arguments. More intense discussions may divert attention away from the task of driving. Hands-free phones do not necessarily prevent drivers from becoming absorbed in a conversation. Furthermore, when talking, the person on the receiving end of the driver's phone does not know the traffic events demanding the driver's attention.

The extent to which drivers might compensate for the increased risk associated with phone use, for example, by reducing speed or increasing headway, should be considered. In a simulator study of the effects of phone use on driver behavior in a car-following situation, Ålm and Nilsson (52) found an increase in choice reaction times and shorter minimum headways when the driver was using a phone. In addition, elderly drivers had greater increases in reaction time when using a phone than younger drivers. Drivers' mental workload, measured with the NASA Task Load Index (TLX; 53), increased with the phoning task. Moreover, drivers did not compensate for the added demands of the phone tasks by increasing headway. The negative impact of current in-vehicle technology and the apparent failure of drivers to compensate for the diversion of attention while using this technology raise the definite possibility that drivers—especially older ones—will have difficulty performing driving tasks safely when new ITS services are introduced through in-vehicle phones.

### Navigation Systems

Navigation systems have received the greatest number of evaluations. McKnight and McKnight observed 150 drivers—equally divided among three categories of

younger than age 25, age 25–50, and older than age 50—interact with five different navigation displays (54). The content of each display type varied. An area map, a strip map, position information, guidance information, and position and guidance information were presented twice in a random order to participants. Dependent measures included total time looking at the display and appropriate traffic responses. Participants were expected to respond appropriately to the traffic situations in the video presentations—for example, by making a turn.

The older drivers failed to anticipate turns more frequently (34%) than did the middle age (28.4%) and younger (28.6%) drivers. The cumulative glance duration to the navigation displays was highest for the older drivers (5.8%) compared with the middle age (5.1%) and younger (3.9%) drivers. Although not significant, the older group responded to traffic situations more accurately (41.5%) than did the middle age (37.5%) or younger (36.2%) groups, which is consistent with a cautious driving style. The guidance display, which produced an audible alarm and a directional arrow before a turn, had the lowest error rate and total looking time but was ranked as least preferred of the displays. The authors noted several benefits of navigation systems. When a driver is wayfinding in an unfamiliar area, correct anticipation of turns may reduce the need to search the traffic environment for signs. Missed turns, last-second maneuvers, and vehicle speed—which can affect other drivers—may be reduced with the use of a navigation aide. The authors argued that the attentional cost of navigation displays is not a cause for concern. As the basis for this conclusion, looking at the display did not seem to interfere with appropriate turn responses to traffic information.

Both Barham et al. (55) and Oxley et al. (56) examined the benefits and safety implications of route guidance systems for 35 elderly drivers (age 65 or older), who were asked to drive a predetermined route once with and once without TravelPilot, a route guidance system. Four separate measures were taken when the drivers were following the prescribed route: (a) the length of time spent looking at the TravelPilot was estimated by a researcher sitting in the back seat of the car, (b) the participant's driving technique was observed by an experienced driver assessor, (c) an assessment of the navigation device was administered in pre- and postexperimental questionnaires, and (d) mental workload was assessed before and after using the NASA-TLX.

The examiners found no differences on assessed ratings of performance, although only overall scores were presented. Assessor subscores for steering, braking, anticipation, positioning, and so forth were not reported. All of the participants were members of the Guild of Experienced Motorists, which may not have



been indicative of the performance of ordinary older drivers. Driver eye glances to the TravelPilot represented 7.5% of all glances, and males made longer glances ( $M = 0.73$  s) than females ( $M = 0.63$  s). A potential relationship between the measures of working memory (WM) and glance frequency—but not of glance length—was suggested. More looks could mean that people with worse memory need to look back at the display to acquire or refresh a piece of information. The TravelPilot was rated as easy to use. No safety-related problems were found, except when drivers were faced with the “dual task of driving and following the route guidance system’s instructions.” Some participants said that they would travel more frequently if they had a route guidance system. Dingus et al. (57) reported similar findings: younger drivers spent 3.5% of the time looking at the navigation system, and older drivers looked 6.3% of the time.

Pohlmann and Traenkel (58) asked 24 younger (age 35–50,  $M =$  age 41) and 24 older (age 61–70,  $M =$  age 67) drivers to use TravelPilot IDS, another navigation system. An equal number of men and women were in each group. Use of the system caused participants to reduce speed more often than for the road-map condition. Slight lateral deviations, which required the driver to make corrective steering actions, significantly were higher in the TravelPilot IDS condition than in either the map or control conditions. A similar pattern of results was found for the severe deviations that required drivers to make strong course corrections. Drivers tended to turn the steering wheel toward the display, which was situated to the right, when looking toward the display. This observation may explain in part the pattern of steering corrections. Overall differences between younger and older drivers were not universal. Both age groups had difficulties using TravelPilot IDS. Observed differences were attributed to age-related changes or differences in technology experience, or both.

In an investigation of navigation systems, Cambell et al. (59) reported that a group of older drivers (age 55–85) found the features of TravTek, a specific navigation system, more difficult to learn to use and less functional than did a group of younger drivers. There was some indication that the initial reticence to use a system such as TravTek diminished as older drivers gained more experience with the system. Thus, initial perceptions of ITS products are likely to be affected by a fear of or a lack of confidence in using the technology. In general, until elderly people have adequate experience, they may be reluctant to use the technology.

Inaccurate navigation information can result from database inaccuracies and the loss of satellites because of line of sight obstacles. In a second study, a group of older drivers (age 55–76) interacted with navigation

information that was either 100% or 77% accurate. They were not able to use the more accurate information as efficiently as a younger group of drivers (age 18–54). A third study that introduced a delay between the presentation of a message and the recall of the message also produced performance decrements in the older group. The second and third studies highlight the WM limitations of older drivers. The WM is related to the number of times that a driver needs to look at or reacquire information, such as from a guidance display (20). Thus, older drivers with more limited WM are likely to need to look at a display more often than drivers with better WM. Independent of WM declines, older drivers made more glances for longer durations than did younger drivers (60, 61).

Dingus et al. (62) examined older-driver performance with the TravTek navigation device, which uses synthetic speech to convey guidance. Several studies with older drivers have been reported. Study 1 consisted of 18 people in Orlando, Florida, in three age groups: 16–18, 35–45, and 65–73. Thirteen different routes were used: one for practice, six for visitors, and six for residents. Each route had a minimum of seven turns and was driven during daylight and off-peak hours. Drivers were instructed to travel from start to finish of a route, using the fastest route possible. Route type, gender, and traffic density were assumed to be relatively constant. The navigation displays used included turn-by-turn with voice guidance, turn-by-turn guidance without voice, a route map with voice guidance, a route map without voice guidance, a directions list on paper, and a conventional paper map. Participants were screened for near and far visual acuity (20/40) and hearing.

Several dependent variables were measured, including percentage of time scanning roadway and navigation aids, lateral acceleration variance, longitudinal acceleration variance, and navigation performance (e.g., wrong turns, verbalizations, time lost, and trip and planning time). Several safety-related errors were identified that had the potential to cause the driver or other vehicle driver to maneuver to avoid a collision. The authors analyzed the following: glance durations in the presence of a hazard that exceeded 2.5 s, inappropriate reactions to roadway hazards, unplanned lane deviations when focused on a display, speed reductions associated with attending to a navigation display, stops in an unsafe location to acquire navigation information, retrieval of navigation information at an intersection after the traffic light had changed from red to green, short headways maintained, and long glance durations to the display.

An age difference for display interaction glance duration was significant. On average, older drivers had longer glance durations to the display when compared with the youngest drivers. Age differences were found for lateral



variance, longitudinal variance, and large steering corrections. Older drivers were less erratic or more cautious than were younger drivers. Older drivers also had lower longitudinal variance than the younger and middle age drivers. Steering wheel reversals ( $>6^\circ$ ) were significantly more frequent for the older drivers than for the other two age groups. Increased attention to the navigation display may have caused greater difficulty in maintaining lane position. Older drivers took longer to plan a trip and to travel to a destination. No differences between groups were found for navigation errors. Older drivers had more inappropriate glances (i.e.,  $>2.5$  s) to the route map, both with and without voice and paper direction conditions. Older drivers also had the highest frequency of errors in speed reductions when interacting with the display, as well as the highest rates of intersection safety errors and unplanned lane deviations.

A naturalistic field study also was performed with visitors to the Orlando area who had used TravTek. Data for 1,150 participants automatically were logged and categorized into five age groups: 25–34 ( $n = 220$ ), 35–44 ( $n = 431$ ), 45–54 ( $n = 319$ ), 55–64 ( $n = 130$ ), and 65 or older ( $n = 50$ ). When given the choice to use a particular type of display, older drivers overwhelmingly chose the turn-by-turn with voice display, which was the system default. Older drivers requested the help function more frequently than did other age groups. No differences between age groups were found for the repeat voice function.

Kostyniuk et al. (63) surveyed older drivers who had used the TetraStar navigation system to receive voice and visual turn directions. In a previous study (64), TetraStar, on a variety of measures, was evaluated as a well-designed system and was preferred over another navigation system, the Ali-Scout (65). TetraStar indicated turn-by-turn maneuver directions, the distance to the next turn, and the name of the street where the next turn was required, all on a 4-in. color display (LCD). Sixty participants—divided equally between the age groups of 19–29, 30–54, and 65–80—were recruited from a previous study (64). Participants were asked to drive a Mercury Sable equipped with TetraStar for 28 days. Participants filled out daily trip logs and an extensive usability survey, which included questions on patterns of use, relative utility, and perceived ease of use.

The results indicated that the older drivers were less likely to use the system for commuting than the other age groups. Younger drivers were less likely to use the system for personal trips than were drivers in the other age groups. Older drivers took more of their trips during the morning than drivers in the middle and younger age groups. A significant difference between age groups for ease of use and learnability was found. The older age group reported more difficulty with learning and using the destination selection interface than the younger age

group. On turn-by-turn instructions provided by the system, age differences were found for the preferred amount of advanced warning. Drivers in the older group said that the information was perhaps too far in advance. Once an arrival display was shown with a destination address, participants in the younger age group reported more difficulty than the older age group in finding the destination. Ratings of the level of distraction produced by the TetraStar during daylight differed by age. Drivers in the older age group reported significantly more distraction than did drivers in the middle age group. Understanding the directions provided by the voice guidance feature also differed by age. Drivers in the older age group had less difficulty understanding directions than did drivers in the younger age group. A similar pattern of results was found for judged level of distraction of the voice guidance. Younger participants reported more distraction than older drivers did. Older drivers had higher overall impressions of the sound of the voice than did the younger drivers. The lowest line of the display was difficult to read for some of the drivers in the older age group. In a direct comparison between Ali-Scout and TetraStar, TetraStar overwhelmingly was preferred by 90.2% of participants who had used both systems.

Kostyniuk et al. (65) addressed several issues that arose when older participants used the Ali-Scout and TetraStar navigation systems. The observational basis of the study was that older drivers tend to use navigation systems with the assistance of their spouse or traveling companion—a fact not previously reported in the literature. Two focus group sessions were conducted with a total of 18 older participants (age 64–82,  $M =$  age 72.2). Ten had participated in a previous study (63), and eight were the spouse of a participant. Discussion items included copilotting and training. The copilots typically accomplished several tasks, such as navigating, monitoring driver alertness, serving as an extra set of eyes, and reading road signs. In some situations, the navigation system may function like a copilot. Display glare, bifocals, and ease-of-use issues also were mentioned. A copilot or companion may overcome some of these issues, but additional research on team navigating is needed (66).

### Adaptive Cruise Control

The ACC system reduces the driver's need to interact continuously with the accelerator, especially during highway driving. In a large-scale field trial (67), participants used a test vehicle for 2 weeks ( $n = 84$ ) or 5 weeks ( $n = 24$ ) with an ACC system and data-logging equipment. During the first week, each group used a 1996 Chrysler Concorde in the manual or CCC mode.

The rest of the time both test groups used the ACC. Three age groups participated in the 2- and 5-week studies. The categories of the sample were younger (age 20–30,  $M = \text{age } 24.4$ ), middle age (age 40–50,  $M = \text{age } 44.2$ ), and older (age 60–70,  $M = \text{age } 64.8$ ) drivers. In the 2-week group, half the participants reported as non-CCC users, and half reported as frequent CCC users. In the 5-week study, all were frequent CCC users.

Each participant was familiarized with the the system during an orientation session. Drivers could choose when and how to use the system; however, the vehicle had to be at least in third gear and traveling 35 mph before the ACC system could be engaged. A “sweep” infrared sensor detected distance and rate of closure to vehicles ahead, even when the driver turned. A “cut in” sensor could detect when other vehicles cut in front of the driver. A warning indicated when the ACC system could not function because of system failure or reduced visibility conditions (e.g., salt spray, snow, and fog).

A total of 534 h or 35,033 mi of operational ACC use was analyzed, and 30.7% of driving time was spent with the ACC on. Overall, older drivers drove less than other age groups, which is a common finding (2, 22). Learning how to use the system required several hours, and the integration of the ACC into driver behaviors took approximately 1 week. When conditions were favorable, individuals used the system from 20% to 100% of the time. Older drivers tended to use the system more frequently than did the younger drivers. Older drivers used the ACC to a greater degree (distance engaged/total distance) for the 35–55 mph and the 55–85 mph speed bands. At velocities between 35 mph and 55 mph, older drivers used the ACC system more often (33 h) than did the middle age (17 h) and younger (14 h) drivers. Distributions of driver headway in manual condition (i.e., without ACC or CCC systems) and with the ACC indicated a shift toward a greater headway margin with ACC for both older and younger drivers. The ACC use by all age groups was greatest for speeds above 55 mph. As a function of time, the ACC usage declined for older drivers from Week 2 to Week 5 in both speed bands (35–55 mph and 55–85 mph).

When using the manual or CCC system, drivers exhibited a range of following or headway regulation styles. Strategies varied from a nonconflict orientation to tailgating. Ultraconservative drivers or drivers who prefer longer headways and lower speeds were more likely to be older women. Fewer older drivers were “hunters”—drivers who prefer closer following distances and faster speeds—than were drivers in the other age groups. The driver could set a headway distance/time of 2.0, 1.6, or 1.0 s. Not surprisingly, younger drivers set the system for smaller headways and older drivers preferred longer headways. Tailgating was

not supported by the ACC—that is, longer headways were a functional constraint. Age differences were attributed to a closer fit to driving style. Younger drivers were less likely to engage the ACC if a closer headway was desired.

Overall, older drivers favored the ACC. Only 5% of the drivers did not feel comfortable with the ACC and likely would not use the system in the future. The participants cited a variety of system design issues: (a) a desire for greater passing acceleration, (b) fewer false decelerations, (c) a lack of ACC response to stopped objects, and (d) poor performance in bad weather. Although use of the ACC increased safe following and decreased “accelerator stress” or throttle modulation, the system may increase complacency, that is, not responding to hazards because of a belief that the system will take care of the conflict. Patterns of high deceleration may indicate an expectation that the ACC would resolve conflicts with other vehicles automatically. Analyses of specific instances of this scenario in the data were equivocal. Additional research focusing on many of the design limitations, such as supervisory function and driver mental models of system functionality, was suggested.

### Infrared Vision Enhancement Systems

The purpose of the VES is to aid the driver’s ability to see hazardous objects, such as guardrails, other vehicles, and the roadway (e.g., edge lines, especially during low-visibility conditions; 31, 68–70). Caird et al. (71) conducted a VES study with 24 younger ( $M = \text{age } 23.5$ ) and 24 older ( $M = \text{age } 71.9$ ) drivers using a driving simulator system. Conformal and nonconformal displays were tested in a variety of traffic scenarios. A conformal display directly highlights aspects of the traffic environment for the driver; a nonconformal display is connected to environmental events but not necessarily superimposed on the events. For example, the conformal display placed blue bars on the front and rear bumpers of parked and approaching vehicles. The bars expanded in correspondence with size changes of a vehicle. The nonconformal display was centered on the roadway and indicated the approach of vehicles by changing size.

After training, participants drove through city streets, crossed intersections, followed other vehicles, and reacted to the sudden appearance of a pedestrian in daylight and foggy conditions. Lateral separation between oncoming vehicles was significantly greater with the conformal display than with baseline separation distances. For the intersection scenario, the light changed from green to yellow to red on 50% of the approaches. Older drivers ran the stoplight more often than did younger drivers, and drivers with the conformal

mal display ran fewer lights than did drivers who used the nonconformal display. When a pedestrian suddenly appeared between two parked vehicles, drivers using the conformal display had faster perception–response times (PRT) than did drivers using the nonconformal display. Subjective impressions of conformal and nonconformal systems indicated potential advantages and disadvantages. The VES was favored when visibility was limited by weather (e.g., fog, snow, rain), time of day (e.g., nighttime, dusk), or roadway geometry (e.g., curves, railway crossings). Heavy traffic and cluttered environments were considered poor situations for the application of the VES.

Overall, conformal displays appeared to have a performance advantage over nonconformal displays. Nonconformal displays require drivers to scan the environment and recognize the salience of a target before control actions can be taken. In some scenarios, the time cost of scanning the environment may increase the PRT. Conformal displays may obscure or hide information in the traffic environment that is behind an HUD overlay. Furthermore, the technical and economic feasibility of conformal display types is not trivial.

The VES allows drivers to see objects and hazards sooner. However, several obstacles limit the development of these products (71):

- The field of view of the imaging system (HUD) restricts the visibility of hazards and of pedestrians in the periphery. Peripheral vision or useful field of view, which declines with age, is a logical candidate for support by a system that is able to enhance the detection of peripheral targets. However, projection of thermal image differences across the full windscreen is, at this time, cost-prohibitive because of glass quality and projection system constraints (72). When projected in an HUD, the image may cover up other important visual information in the traffic environment, such as moving vehicles (73, 74).

- Images (of a color) formed by a pedestrian resemble undifferentiated blobs. These are difficult to recognize as pedestrians and require perceptual learning and experience. Recognition difficulties increase identification difficulties and therefore PRTs, which is contrary to the improvement of hazard PRTs. Low-contrast objects may become more detectable, but the problem of recognition remains. For example, a child's heat image, once seen, must be recognized as being a child and then as being in the roadway and thus to be avoided.

- The alignment of the thermal image with the traffic environment may be imperfect because the eye location of the driver may vary intra- and interindividually. Improper alignment of displayed imagery and the traffic environment, for example, may position the pedes-

trian or elk in the wrong place. Transformations of visual–motor space to these nonaligned positions would be required of the driver.

- The display of infrared images in a nonconformal display (the images appear in a separate display) in the dashboard requires the driver to monitor the display for infrequent targets (75, 76). A pattern of looking with the VES display may reduce the sampling of important environmental information (77).

- An accommodation to the display and then a shift in attention back to the traffic environment is likely to increase PRTs.

- For devices that require division of attention, an interaction of age and task complexity generally is predicted; that is, increases in age produce greater decrements in performance on one or both tasks (78–80). For example, the allocation of attention to information in the VES HUD image may cause older drivers to miss other important traffic events (81).

## Collision Avoidance Systems

The CAS warn the driver in advance of an impending emergency event. Despite a high level of research activity on the CAS, few studies have included a sample of older drivers. Dingus et al. (82) had 108 participants—in age groups of 18–25, 30–45, and 65 or older—use a CAS display when driving a 1990 Oldsmobile Trofeo. Three types of displays were tested. The car icon display showed a perspective representation of headway distance; for example, a red-flashing icon meant that a dangerous headway had been entered. The bar perspective display represented critical headways with red bars and safe headways with green bars. The indicator light display flashed either red when the headway was dangerous or an orange–amber when the headway was appropriate.

Participants followed a confederate lead vehicle for 40.3 km on a two-lane state highway and residential streets. The lead vehicle engaged in several maneuvers that were intended to elicit responses from participants. For example, the lead vehicle tapped the brake lights without braking, signaled and braked for a turn without turning, and engaged in moderate and normal braking. The drivers also had several distraction tasks to perform, such as interacting with a touch screen, a cellular phone, the radio, and climate controls. The researchers collected baseline following distances on the outbound portion of the route and the display measures on the inbound route. For coupled (undefined) headway events, the car icon display produced headways that were, on average, 0.2 s longer than the bar or indicator light displays. A similar main effect was found for braking events. Age effects,

secondary task performance, and interactions were not mentioned.

In another study by the same authors (82), the effects of false alarms (FA) were examined. Forty participants—half were age 18–24 and half were age 65 or older—drove the same route as the previous study with a modified bar display. The bar display was used in combination with an auditory warning, which reported “look ahead” when the headway was 1.1 s or shorter. At 0.9 s, the oral message “Brake” was presented and the red bars flashed at 4 Hz. An FA was presented by the experimenter in circumstances that may produce an FA, such as in a curve or driving up or down hills. When the experimenter generated an FA, the display cycled from green to red and the “Brake” auditory warning was presented. The participants were then assigned post hoc to one of three FA percentage groups: 0%–30%, 31%–60%, or 60%–100%.

Younger drivers had shorter mean headways (2.01 s) than did older drivers (2.58 s). A significant interaction of age by FA category was found. Younger drivers tended to increase the following headway when more FAs were experienced; older drivers were more insensitive to FAs. Overall, an increase in headways with CAS display use was a promising result. But with extended use, this effect may fade. Additional research is required to determine if this fading will occur.

Tan and Lerner (83) evaluated 26 warning sounds for the CAS in three phases. Auditory warnings were passed through many evaluation steps, including definition of weighting and evaluation attributes. Thirty-two participants, equally divided between two age groups (20–40 and 65 or older), judged 28 auditory warnings on 11 attributes while hearing two levels of vehicle noise (truck and sedan). Auditory warnings were presented at 6 dB (A) above the vehicle noise level. Each sound was judged on a 1–7 Likert scale for each attribute. On the basis of attribute weightings, four warnings were preferred: a low fuel warning (a rapid siren), a continuous low-pitch ambulance siren, 2,500- and 7,500-Hz broad pulse of 110-ms repeated at 8-ms intervals (with a pause of 110 ms), and a similar pattern with narrow 2,600- and 7,800-Hz peaks. An interaction of age and sound was found. Overall, older listeners rated stimuli higher than younger participants did. Four sounds, in particular, were rated lower. The perception of these sounds by older listeners may have been affected by age-induced hearing loss.

## DESIGN GUIDELINES, STANDARDS, AND EVALUATION ISSUES

Many issues clearly are important to the successful delivery of ITS applications for older drivers.

## ITS Guidelines

Human factors guidelines typically specify ways that designs should consider the user. For many reasons, the user often is forgotten in the process of designing. Guidelines serve several functions, including a means to summarize human engineering data, to make general recommendations about design, and to specify design principles (84, 85). A guideline may be derived from the design constraints of a class of problems, the available empirical information in a particular domain, specifications for user requirements, and expert judgment. Guidelines are checked so that applications do not omit important user requirements. A guideline is useful if the guideline solves a design problem.

Guidelines have many properties that increase usability. To be useful, human factors guidelines must be well organized, readable, and applicable to design problems. A guideline that includes domain context, is accessible, and provides a foundation on which to extend a new design is likely to be more useful and usable (86, 87). Pragmatically, guidelines are intended to help the designer or engineer find a solution quickly. The remainder of the path is left to the designer and design team. Expert judgment, if acquired, tends to take over when guidelines and user requirements are limited or unclear. Human factors design decisions are likely to include the expertise of the individual, the literature, and immediate colleagues to make real system decisions (88). The role of design is to prove or confirm options that may make a product viable. Guidelines can serve to constrain a solution space and eliminate nonviable design path (89).

The Federal Highway Administration (FHWA) has had many research groups produce design guidelines for advanced traveler information systems (27, 90–93). Products developed in FHWA’s human factors program include (a) human factors guidelines and handbooks, (b) human factors databases for computer searches to identify data relevant to particular research and design questions, and (c) human factors performance models to allow users to predict driver performance. These information products are being developed to aid in the design of ITS applications to meet drivers’ needs and requirements (94). Similarly, NHTSA has supported the development of guidelines for the CAS (95).

The current ITS design guidelines do not necessarily accommodate older drivers’ performance restrictions and preferences (7). Guidelines collected by NHTSA, FHWA, DRIVE II, and others require careful analysis and, in many cases, modifications to individual guidelines to achieve an appropriate fit of older drivers’ capabilities. To create a set of design guidelines, authors have tended to review a variety of source materials, such as handbooks, technical



reports, conference proceedings, book chapters, and journal papers. A set of guidelines is then derived and appropriately organized and formatted. Several authors have considered older drivers in the development of guidelines (24, 32, 96–101). For example, Nicolle and Peters (98) organized guidelines for older and disabled drivers into sections for general principles, control of the system, display of information, training, and documentation. This approach assumes that before the creation of a specific application, it is possible to specify a comprehensive amount of knowledge that designers will find useful. In contrast, Green et al. (92) advocated documenting the critical issues that designers resolve so that others who traverse similar design paths can resolve the same difficulties quickly. Understanding the design issue and how the issue was resolved are fundamental to creating better design guidelines. Given several guideline development approaches and the known nonuse of guidelines (86, 102), the relative utility of extensive design compendia for ITS remains to be seen.

Although the guidelines listed below from Caird et al. (24) appear to provide some important direction, the guidelines are merely a starting point. For example, although the division of attention commonly is recognized as a critical problem—and even more for older drivers—how do designers make interfaces less “sticky” (i.e., attention absorbing) and more “transparent” (i.e., requiring little attention to acquire the important information)? The design principles serve as a negative end goal (what not to do). Almost no help is given to designers so that they can create the artifact (103). A set of guidelines that outlines how to achieve legibility, apprehension, minimal attention, ease of use, and so forth for older drivers, with illustrated case examples, is needed (104).

- Fundamentally, human factors contributions to in-vehicle ITS applications must advocate designs that accommodate a large distribution of users—especially older drivers—and a range of ambient lighting conditions and that minimize workload.
- Higher levels of task difficulty that affect the division of attention, the WM, or manual control are more likely to affect older drivers than younger drivers.
- ITS applications that produce divided attention between tasks, redirect attention for prolonged periods (multiple looks and looking), or create extreme oscillations in mental workload (overload and underload) are likely to endanger drivers using these applications.
- The fit of ITS applications, such as the VES, to older drivers must consider the behavioral adaptations that have been made by drivers (e.g., not driving at night). Congruence among driver capabilities, ITS applications, and adaptive behaviors should be investigated.

## Standards Activities and ITS

Standards, in contrast to guidelines, are much harder design constraints; that is, manufacturers tend to follow standards closely. No standards have been developed for in-vehicle ITS applications yet (105), but this omission will change soon. The International Organization for Standardization, the Enhanced Safety of Motor Vehicles of International Harmonized Research Activities, the Society of Automotive Engineering, and the American Association of State Highway and Transportation Officials are engaged in standards activities associated with in-vehicle ITS. Various subcommittees within each organization are addressing different systems and general design principles (7, 106, 107).

Duplication of efforts, dissemination of activities information, lack of an empirical body of research on which to make comparisons, difficulties in achieving consensus between countries and disparate interests, and the time required to reach a resolution of interests are common barriers to standards development. For example, draft design standards for navigation systems are in committee (108), but many navigation system products are already in the marketplace. Although older drivers are given some consideration, the language used in the formation of draft standards has not identified older drivers explicitly as an important user group.

## System Evaluation

From a human factors perspective, ITS considerations often are about safety. Ideally, an evaluation method should have the potential to determine whether a particular ITS product will improve safety, have a negligible effect on safety, or—in the worst case—reduce safety (109–111). As a difficulty for determining the safety benefits or liabilities for a given ITS application, human factors methods tend to concentrate on performance measures that do not translate into system-level safety measures (112). The acceptable performance in a given situation often is open to the interpretation of the driver or experimenter. Performance measures, such as lane variability or glance duration and frequency, represent safety proxies, where poorer performance is viewed as less desirable and more likely to increase the probability of an accident (105, 113). Without adequate data, there are no means to link accidents to ITS applications. Acceptable levels of safety are specified in terms of accidents, and relative safety is open to the subjective interpretation of the likelihood that particular ITS application interactions will dispose the driver to greater or lesser risk. Basic knowledge of driver behavior and system-specific design experience is lacking (87). Therefore, specifying absolute threshold levels



of safe and unsafe driving performance generally is not possible at this time (87). In addition, ITS technologies are changing rapidly and, as a result, are difficult to evaluate (114, 115).

Safety is affected by how the technology is developed and tested. The relative importance of a variety of measures is not agreed on (107, 114, 116). The selection, collection, and interpretation of key performance and system safety measures is likely to vary, depending on the researchers, their organization, the ITS application, and the available resources. Despite these difficulties, an in-vehicle ITS application, once it is designed and prototyped, needs to be put through an evaluation process to determine what difficulties users will have with the application under various circumstances (e.g., on the road, in emergencies) and how users will integrate the application into the task of driving (117).

Several good reviews of measures and methods specific to in-vehicle ITS technology have been published, namely by Green (87) and Zaidel (113). Various measures have been used to estimate the relative safety of ITS applications. Zaidel listed the following measures: "Steering control, lane position, variability, speed or headway maintenance, and eye glance duration and frequency were used as proxies of safety measures." When worse values result for these performance measures, the measures are interpreted as being less safe. Reductions in safety also can result from negative changes in driver behavior, such as speeding and other violations. Safety can be compromised by conflicts between interaction requirements with an ITS application and the demands of the traffic environment, information in the ITS application and traffic controls and signage, and ITS information and the goals of the driver. Positive safety effects of ITS applications may include appropriate speed choices, appropriate headway adjustments, optimal alertness, improved overtaking and gap-acceptance decisions, and reduced extended exposure (118).

### Behavioral Adaptation

Behavioral adaptation, whether conscious or not, plays an important but poorly understood role in buffering age-related declines. Driver adaptation is construed broadly to mean positive and negative changes in behavior that result from in-vehicle components such as ITS displays (e.g., navigation, the VES), roadway contexts (e.g., freeways, rural intersections), the environment (e.g., night, inclement weather), and certain other behaviors that were not present before the change. A summary of the literature by the Organisation for Economic Co-operation and Development (119) concluded that behavioral adaptation occurs for certain vehicle improvements (e.g., antilock braking systems,

studded tires) but not necessarily for others (e.g., daytime running lights, seat belts). Alternate evidence for seat belt adaptation (120) and daytime running light effects (121) have been published. Unfortunately, the literature review does not include age differences in behavioral adaptation for vehicle modifications.

A range of adaptive behaviors has been identified by researchers, including (a) reductions in speed, exposure, highway driving, number of passengers, and attentional workload and (b) avoidance of peak hours, limited-access highways, driving at night and in bad weather, unfamiliar cities, complex intersections, and quick maneuvers (12, 78, 122, 123). Adaptive behaviors can be grouped broadly into behaviors that allow the driver more time (e.g., speed reduction); that avoid complex, busy, or uncertain driving contexts (e.g., intersections, peak hours, unfamiliar routes); and that avoid particular conditions (e.g., nighttime, ice, snow). Given incremental and differential losses of capability (124), older drivers should be informed of their age-related declines in abilities. Adopting effective adaptive behaviors is likely to follow (1). Presumably, older drivers make strategic decisions to compensate for the loss of maneuvering and response capabilities (12, 125). Systematic analysis of how, when, and why these adaptations are adopted by older drivers has not received adequate research attention.

ITS products should complement or add to older-driver adaptive strategies. Adaptations to in-vehicle technologies may include not using the devices at all or not when in transit, using the technologies in predictable ways to increase the efficiency of travel (e.g., optimize routes, increase speed), and using the applications to achieve driver goals that were not intended by the designers (e.g., to violate signs, signals, and others' right-of-way). Many researchers who have advocated the potential of ITS technology for age-related declines in capabilities such as vision have assumed that the fit between driver and technology was straightforward. The solution to visual decline is not so simple. For example, if older drivers do not drive at night, then the VES will help them drive at night. In latitudes where there is limited daylight in winter, the VES appears to be a reasonable means to expand the mobility of drivers.

### CONCLUSION

Society tends to look to technology for solutions. Issues that arise from an aging demographic shift will require technology solutions as well as infrastructure, policy, and service answers. As Hancock et al. explained, "what works for older drivers will work for the rest of the driving public," but conversely, ITS applications that fail to serve older drivers will leave a large and increasing seg-

ment of the driving public at risk (44). Older drivers may be the beneficiaries of well-designed ITS products. But there is a chance that older drivers, if not considered in the development of ITS products, may experience more difficulties than before. Currently, given available empirical evidence, the impact of ITS technology on older-driver safety and mobility is not completely understood and not necessarily predictable. For example, the introduction of new technologies is likely to produce unexpected interaction effects, such as conflicts between drivers with and without these systems, between in-vehicle information and traffic environment information, and between drivers who use ITS technologies in unexpected ways. The emphasis of ITS development programs has been on the delivery of certain categories of information, with minimal regard to the fit of the information into the goal-directed behaviors of drivers. What information should be available and why have not been addressed substantively. Designers and engineers who produce ITS applications most likely will overwhelm the older driver with the proliferation and non-integration of in-vehicle system information.

Various in-vehicle ITS applications will affect older-driver performance. Fear of using technology, difficulty in seeing displayed information, unease with use, the need for quick responses to warnings, and long auditory or visual messages are significant barriers to the large-scale acceptance of ITS applications by older drivers. In-vehicle displays must be seen across a range of lighting conditions and, more important, across age-related changes in the visual system. Dividing the attention of older drivers between ITS applications and the demands of traffic, roadway geometry, signs, and signals should be minimized. Older drivers will have to look more often at a display and for longer durations to obtain the information. Devices that require extensive manipulation (e.g., dialing a number on a mobile phone or negotiating the options in a street database) or divert attention (e.g., entering a travel destination into a route guidance system when driving) are likely to affect older drivers adversely. Driving requires that memory and control tasks be performed concurrently. Driver navigation and information systems, depending on design, may cause older drivers to forget information. Many older drivers trade varying degrees of response speed for accuracy. Choosing to respond more slowly and being absolutely sure about certain maneuvers before deciding to proceed are manifestations of overall reductions in the speed of processing and execution (126). Interaction with in-vehicle technology that requires fast responses or diverts attention away from the roadway to an interface is incompatible with the declines associated with aging. Each of these interaction difficulties is more likely to be exacerbated when

the complexity of the traffic environment is high (e.g., at intersections), in high-traffic volume, on unfamiliar routes, and in bad weather conditions.

A lack of training for older drivers is a potential barrier to effective ITS use. Older drivers are less likely to have used a variety of new technologies. Unfortunately, training solutions often are sought after the older person has found an application difficult to use. If drivers find an ITS application potentially valuable, ease of use and ability to learn the system become critical. Clearly, system defaults should reflect settings preferred by the majority of users. Systematized training and support at the time a system is purchased may help older drivers to accept and use ITS applications effectively. The availability of technical support for older drivers also should be considered.

At many points within the development cycle, human factors guidelines and evaluation methods are critical. Human factors design guidelines allow designers and engineers to add their expertise to current knowledge when approaching new designs. Guidelines also can serve as a checklist to determine whether a prototype has met accepted design and evaluation practices. But catalogs of guidelines often fail to specify when, where, and how to apply a guideline. Illustrated case examples that have served to guide previous design decisions may be helpful. Guideline collections should include references to the original empirical research on which a guideline is based, so that the generality, validity, and reliability of a guideline can be checked.

Many evaluations have emphasized older-driver mobility as the important dimension of the evaluation. Older drivers typically are asked if a device would increase the likelihood that they would drive more in particular situations after having some experience with the device. Older drivers perceive the VES and systems that increase the perception of safety and security, such as emergency response, as having the potential to increase mobility. Asking drivers their preference for and impression of a device may or may not be congruent with the drivers' performance with the device. An in-vehicle application, for example, may be perceived as adding safety, but the device actually may not (115, 127). Therefore, the principle of convergent empirical evidence from objective and subjective sources is important. Long-term measurement of use and performance of drivers with a system over a 3- to 12-month period appears to be an essential but costly study.

The evaluation of ITS devices requires consideration of the following:

- Addressing the problems of people who have difficulty using in-vehicle displays (e.g., older drivers);
- Fitting a presentation modality to drivers' sensory capabilities (e.g., auditory, visual, multimodal);

- Limiting tasks that divert attention (e.g., braking, object recognition);
- Optimizing the form that display images take (e.g., size, color, location); and
- Determining whether the system can be operated safely in a range of traffic contexts (e.g., emergencies).

In addition, the use of ITS applications may produce new kinds of behaviors. For example, it is unknown whether drivers will use higher speeds at night because they can see farther ahead (a negative behavior adaptation) or whether older drivers will choose to travel at night when they did not before and perhaps should not. Appropriate and inappropriate behavioral adaptation in older drivers has had minimal research attention. Designers of prospective evaluation methods, despite due diligence, have difficulty anticipating the new types of driver errors, multiple system interactions, behavior adaptations, and driver-to-driver interactions within the transportation system.

The development of ITS applications appears to be advancing faster than transportation human factors can provide empirical results and theoretical insight (106). The following are needed:

- Basic empirical knowledge of driver behavior (88) and adaptive strategies;
- Convergent and replicated performance and preference data on the spectrum of in-vehicle ITS products being developed;
- The determination of an acceptable level of safety once an ITS product enters the transportation system (109);
- Data about increases or decreases in the frequency and severity of accidents over levels set before the introduction of an ITS technology; and
- The expert estimation of the likelihood that drivers will fail to detect hazards when using ITS devices (111).

The risks associated with the use of ITS applications unfortunately are distributed throughout the transportation system. As a result, understanding the daily context in which older drivers travel is critical. Assumptions about hazard exposure and interaction frequency should be made explicit.

ITS applications also offer the potential to increase the mobility and safety of future older drivers. However, these systems are not the only countermeasures available (22, 128). Although many ITS applications have the potential to increase older-driver mobility, many countermeasures have been developed. A systematic review of the effect of these many countermeasures on safety and mobility has not been performed (109). What may increase the mobility of the majority of transportation users could impinge on the mobility of older drivers. The

effects of an ITS application on a population of drivers is not uniform. Some may enjoy the benefits of traveling to destinations faster, but others may find the increased speed and information complexity of driving inhibits the desire to travel. It is simple enough to impose difficult task demands and driving conditions on a sample of elderly drivers (age 75 or older), so that age differences are significant. However, research still is needed to determine the degree to which in-vehicle ITS applications can offset declines because of the aging process and whether this objective is realistic. Demand for helpful products that provide mobility advantages for the older driver is a stronger force than the demand for new technology. Finally, the relationship between driving performance with these systems and safety has yet to be determined. ITS applications must at least keep current levels of safety constant.

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- This paper reflects the views of the author and not necessarily the views of the Transportation Development Centre of Transport Canada.*



# Public Education and Information

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# Impact of Public Information on Safe Transportation of Older People

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In April 1994, the television newscaster Hugh Downs, age 73, described the already flourishing opinion that older drivers as a group are unfit for the road as “manifestly unfair,” noting that unqualified drivers “come from all age groups, genders, and economic levels.” His comments appeared in the widely distributed Sunday magazine *Parade* and reached millions of Americans. His supportive observations probably resonated favorably among older drivers, but the generalized public characterization persists that older drivers are out of sync with today’s driving demands. Information and statistics that furnish a realistic description of older-driver behavior so far have contributed only blips on the broad radar screen of public opinion, which tends to draw primary perceptions from the occasional tragic crash involving an older driver and apparently caused by driver error. Disparaging anecdotal recollections exchanged in personal conversations kindle negative views as well.

Research clearly has dispelled these exaggerations, but research also has identified the physical and cognitive problems that older drivers must face sooner or later. The pace of age-related debilitating change cannot be predicted for the individual, but for older drivers as a group many characteristics can be anticipated and responses developed. Disseminating this growing body of knowledge to a poorly informed public is one function of an information and education program. Second, this program would distribute the specialized information and corrective strategies that can help older people stay safely on the road longer. Third, the program would

alert older people to the possibility that one day they may have to move out of the driver’s seat and into an alternative form of transportation. This difficult transition point can be reconciled more easily with advance thought and planning. Fourth, the program would address the interest groups that have a particular stake in the safety and mobility of seniors, such as families, friends, doctors, therapists, other caregivers, traffic police, automobile manufacturers, highway engineers, social service agents, and lawmakers.

## INFORMATION AND EDUCATION IN THE 1990s

The behind-the-wheel performance of older people became an issue a little earlier than a decade ago when lengthening life spans began to show evidence that the older-driver population was about to expand markedly. The initial vista was the driving task—that is, how older drivers perform, what improved measures could be developed to gauge the performance, and what steps an older person could take to extend the driving years. The broader contemplation of lifetime transportation needs, which for many would include a period when driving no longer was possible, is infrequent, probably because the American concept of mobility is bound up firmly with the personal passenger vehicle. Only when older people are forced by circumstances to stop driving do they and their family members consider other options.

## Catalogs and Mature Driver Improvement Courses

A mid-1990s survey conducted by the American Association of Motor Vehicle Administrators (AAMVA)—an affiliation of state and provincial motor vehicle departments in the United States and Canada—illustrated the point above (1). AAMVA member jurisdictions were asked to catalog the areas of expressed public interest or concern about older drivers. The responses fell into seven general categories:

- Graduated licenses,
- Older-driver crash rates,
- Age-based testing requirements,
- Availability of retraining for older drivers,
- Specific medical and vision problems,
- Roles of police and medical professionals in identifying problem drivers, and
- Dealing with an older person perceived to be no longer capable of safe driving.

Most of these categories suggest a primary interest in protecting the driving privilege, a yardstick that typically measures mobility.

Subsequently, AAMVA compiled a catalog of older-driver-related informational material, consisting primarily of literature with a smattering of audiovisual items, distributed by member jurisdictions (2). The list proved extensive and was dominated by materials addressed to older drivers, furnishing reminders, tips, advice, and precautions. Few brochures covered the provision of counseling to families and others coping with an older person who is exhibiting erratic driving behavior.<sup>1</sup> The catalog also enumerated materials that discuss graduated licenses, physician involvement, older-driver self-assessment, and transportation options (rare).

Two pamphlets produced by the American Automobile Association Foundation for Traffic Safety (AAAFS) and the American Association of Retired Persons (AARP) took assessment beyond description to simple performance tests that older drivers can self-administer. At least one state offers an older-driver awareness course, and three private organizations—AAA, AARP, and the National Safety Council (NSC)—have created training and educational sessions for older drivers called mature driver improvement (MDI) courses,

which cover the spectrum of problems and response situations that older people experience when driving. In some states, a percentage reduction in the person's vehicle insurance premium serves as an incentive to complete one of these courses.

The program 55 Alive by AARP—the largest of the three organizations—started in 1979 and in the subsequent two decades processed 6 million seniors, 1.8 million in 1997–1999 alone. AARP commissioned a survey of the graduates: 86% reported changing their driving habits, 66% said that they now regularly check blind spots, and 58% claimed to maintain a safe following distance.

AARP's *55 Alive Fact Sheet* included several independent evaluations (3). The New York Department of Motor Vehicles (DMV) compared pre- and postcourse accident and conviction rates. The DMV found that the “overall accident rates were 15 percent lower and overall conviction rates were 56 percent lower in the 18 months following the course than in the 18 months preceding it” (3).

In 1989 the California DMV reported that “the comparison of pre- and postcourse records of 40,399 MDI graduates with those of a 75,064 control sample show that MDI graduates had 16 percent fewer fatal and injury accidents and 15.7 percent fewer convictions than the control group” (4). The California DMV continued the assessment over a 5-year period (1988–1992). In 1994 the California DMV published the findings, stating that “at a minimum the conclusion to be drawn from this series of studies must be that course completion is not associated with a reduction in crashes,” although the findings also showed that “the picture was not as negative for fatal and injury crashes, where the results might properly be described as mixed” (4). California MDI graduates showed a consistently lower citation rate than the control group.

Lifespan Associates, in cooperation with the Beverly Foundation and the National Mobility Institute, produced a catalog (5) similar to AAMVA's. Lifespan Associates appended the content analysis, showing that 62% of the materials were aimed at older drivers, 17% at families and friends, and the remainder was scattered. Very little information was directed to the general public. Often-mentioned subjects included aging and health, provider referrals, driver improvement and rehabilitation, behavioral changes, and driving cessation. Transportation options, vehicle design adaptations, licensing issues, and vehicle maintenance were mentioned less frequently. Lifespan concluded that

these findings suggest that new information materials should begin to take a comprehensive approach, so that information for older drivers, family and friends, professionals, the general public and other targeted groups communicates messages clearly and

<sup>1</sup> This situation is changing. Recently issued publications directed to families and others seeking ways to help an older driver include *When You Are Concerned—A Guide for Families Concerned About the Safety of an Older Driver* (New York State Office for the Aging, 2001–2002) and *How to Help an Older Driver—A Guide for Planning Safe Transportation* (American Automotive Association Foundation for Traffic Safety, 2000).

consistently. Messages should also involve not only information for safe driving now but driving modifications and driving cessation as conditions warrant. Issues of alternate transportation and how to bring up the subject of driving limitations and cessation with relatives and friends, whether one is the older driver or the family member or friend, should be discussed in a framework of transportation planning for current and future mobility needs. (5)

In the *Safe Mobility for Older People Notebook*, Scientex Corporation added its overview of the available literature (6). Scientex echoed the two previous studies and reinforced the Lifespan Associates observation that the broad nature of the material, although useful in describing the typical degenerative effects of aging and the applicable generic responses when driving, only sporadically addressed the more specific trouble situations when people genuinely need help. One such application, for example, could be a definitive formula for steering a person with Alzheimer's disease through the various steps of gradually reducing mileage, driving cessation, and formulating an ensuing alternative transportation plan.

Implicit in the information programs of the future must be messages that go beyond the descriptive to the helpfully prescriptive. The next 25 years will bring a steadily expanding population of older people, with increasing proportions of this population staying behind the wheel for additional years. Therefore, the performance of older drivers will receive increasing scrutiny. Devising information programs that both accurately characterize older-driver behavior to the critical eye of the general public and help older people and their families prepare for the necessary changes in driving behavior appears to be a desirable, even requisite, objective. Communications directed to older drivers and their families should encourage the recognition of transportation options, even during the years when driving difficulties may seem a distant possibility. For older people, future mobility most often has been defined in terms of the personal passenger vehicle. Reconstructing mobility scenarios to illustrate the availability and eventual acceptability of other potentially useful transportation options constitutes a sharp challenge for the creators of the information and education materials.

The growing accumulation of research data on older drivers should facilitate the process of developing practical information programs. Translating the language of research into the quickly read and easily grasped messages that a fast-moving society demands is one desirable goal of an older-driver public information and education strategy. Other suggestions have begun to percolate, as carefully structured information programs are viewed not only as a helpful coun-

seling agent but also as a possible way to motivate behavioral change.

## Marketing Campaign Fundamentals

In *Special Report 218: Transportation in an Aging Society*, Kanouse of the RAND Corporation listed information campaign fundamentals (7, pp. 143–144) that are worth restating:<sup>2</sup>

1. "Information will have the greatest influence when it specifically addresses the audience's needs." Most of the older-driver population need to comprehend how to prolong the driving years. Many families concerned with the driving performance of an older relative need to be informed about options for dealing with the situation.

2. "Audiences seldom change their behavior in response to information they already have." Much of the available literature describes characteristics of aging that are familiar to many older people. Research consistently reveals that most older people make their own safety-related adjustments to problems, such as poor night vision and uneasiness in peak-time traffic. Unprompted self-regulation suggests that telling older drivers that their reactions have slowed and that they react poorly to glare probably elicits no behavioral change because the older drivers have already made appropriate adjustments.

3. "Information campaigns work best if they take advantage of the audience's existing motivation (that is, giving people information that helps them do what they already want to do)." Even though families and friends strongly may desire to change the driving behavior of an older person or help the older person quit driving, families and friends may not know how. Specific information that opens this doorway is more likely to spur action.

4. "People are likely to respond more favorably to information that empowers them than to information that makes them feel powerless." An older person facing driving difficulties may be helped more by information that explains how to cope with problems than by information that dwells on the increased danger the driver now faces.

5. "Communications will have more influence on behavior if they contain information that is relevant to decisions." Descriptive information improves the understanding of a problem, but defining the available responses to the problem may be more useful to motivate constructive action.

<sup>2</sup> Kanouse's statements appear in quotation marks.

6. "People are more likely to use information if it is provided to them in a way that takes into account how and when they will use it." Radio has been a heavily used medium for general highway safety communications because messages reach people in vehicles, where presumably the messages can be applied immediately. Similarly effective media should be used to deliver messages to older people and their families.

7. "Information can have an especially strong effect on behavior when it induces a change in mind set or leads people to reframe the way they think about alternatives." Older people generally do not address the possibility that they may some day be unable to drive. Changing that mind-set—that is, overturning what Kanouse cited as a "routinized response"—begins the process of helping the older person plan for a future that will require alternative forms of transportation.

8. "Large-scale educational efforts are most likely to reach people when they are presented on a sustained basis through multiple channels and are reinforced at the community level." This basic campaign strategy, validated in countless information and education efforts, asserts that repetitive messages that target carefully identified audiences and deliver through appropriate channels will produce desired results over time.

Kanouse added that long-term effects

can be far greater than measurable short-term effects. Although initially a media campaign promoting safety may change the behavior of only a few people, social modeling can greatly multiply this effect. Moreover, a sustained campaign of educational messages can eventually change many of those who were resistant during the early stages. (7, p. 144)

He concluded that the common theme to draw from these eight principles was that

designing an effective strategy for informing consumers—one that stands a good chance of facilitating appropriate changes in their behavior—requires careful thought and planning and often formal or informal research. It requires careful analysis of why consumers now behave the way they do, what they know, and what they want. It requires analysis of the context surrounding the behavior one is trying to affect. Finally, it requires considering these issues separately for different behaviors... and for different types of consumers, because the answers will often be quite different from one type of product to another and one type of consumer to another. (7, p. 145)

This statement probably means that driving is viewed in contrasting ways by different socioeconomic

groups, ethnic groups, and genders, and even perhaps by 70-year-olds in comparison with 85-year-olds. Certainly the baby boomers, whose older representatives are only a decade from retirement, may have a considerably different outlook than current seniors do. Research that measures the attitudes and expectations of the varied subgroups will need to precede the formulation of information strategies and to incorporate the findings unique to each group.

Kanouse did not dismiss straightforward media campaigns as without value; he added that these campaigns could be effective in raising general awareness levels. He observed that these efforts "may be quite important when it comes to the special needs of older drivers, because unlike many problems involving public safety, the facts have not been widely aired and debated in public forums. Thus, there is ample room for awareness to grow" (7, p. 153).

### The General Public's Mental Image of Older Drivers

Kanouse's words are 12 years old, but they still carry an unfortunate ring of truth. Although the understanding of how age affects driving has advanced greatly in research circles, the message has been poorly transmitted to the general public, which still sustains an underlying suspicion that older drivers as a group are less than fully competent and the cause of many crashes. Although there may be little incentive for the general public to alter that perception, there should be considerable motivation on the part of older drivers and the formal safety community to make the public aware that safe driving behavior is not a function of age. Aging only predicts that declining physical and mental capabilities will influence driving behavior but at rates unpredictable for individuals.

The desired consequence of information campaigns would be a public readiness to identify the safety gaps in individual driving behavior, without assigning broadcast censure to older people as a group. The importance of that distinction may depend on how laws and licensing procedures are framed to deal with aging drivers. In California, for example, two fatal crashes in 1999 involving older drivers brought swift legislative response in the form of a bill requiring more stringent and frequent testing of drivers based on age (8). The original bill would have shortened progressively the time between vision, written, and on-road tests as age increased; the bill was modified to eliminate any reference to age and then subsequently withdrawn. Later, the bill was reintroduced and passed without specific reference to age.

Although consideration of age-based testing is an issue for others to debate, the general public's mental picture



of older drivers poses a specific challenge to people who develop messages about older drivers. Presently held by many people, a skewed image ultimately influences public policy.

AAMVA, operating through the Public Affairs and Consumer Education Committee's Older-Driver Working Group, developed an information package intended to portray the older driver realistically in terms of both crash history and the functional effects of physical and mental change (9). The historic reliance on per-mile crash data as the benchmark measure of driver ability is softened by the equally descriptive calculation of crashes per capita, which reveals older people to be among the safest of all age groups. The AAMVA kit summarized many of the characteristics exhibited by older drivers, including the significant tendency toward self-assessment and driving behavior modification.

### Social Marketing

More recently, AAMVA adopted a broad policy statement on older-driver licensing (10). The statement called for closer relationships with transportation providers, social service agents, medical service providers, and safety organizations. The following objectives were listed:

- Expand older-driver referrals to nonregulatory mental, physical, and driving skill assessment sites;
- Increase placement of older drivers in educational classes, such as classes administered by AAA, NSC, and AARP;
- Make counseling more available to people who are losing the privilege to drive; and
- Expand information about the availability of transportation options.

AAMVA also set the ambitious task of initiating a long-term social marketing campaign that would "target aging drivers and their families. The campaign would inform drivers and their families about the need to prepare for transportation and other needs before license restrictions or revocation become necessary" (10). This campaign suggests an awareness of the value in helping older people consider transportation as a real need, whether a personally operated vehicle is involved or not.

It is believed that this outreach would be the first time a major national outreach has been attempted that speaks both to and about older drivers. AAMVA will seek to form liaisons with the National Highway Traffic Safety Administration (NHTSA), the National Association for Area Agencies on Aging, AAA, AARP, and other social

service agencies to broaden affirmation of the message and to solidify the distribution network. AAMVA also will strengthen the relationship with the National Council of State Legislatures to work toward model legislation that "adequately addresses the concerns of driver licensing, traffic safety, and law enforcement agencies regarding aging drivers" (10).

Social marketing as a discipline is summarized in the Lifespan literature review, which was prepared in conjunction with the project Family and Friends Concerned About an Older Driver (5). This project, in turn, draws from the work of Kotler, Zaltman, Andreason, and others (5). Social marketing attempts to influence the general public to accept and act on an idea instead of acquiring a product. The distinguishing feature lies in the goal of influencing behavior, either changing behavior or keeping behavior unchanged despite other pressures.<sup>3</sup>

Success in a social marketing effort will be achieved by the organization that best assesses the perceptions, needs, and wants of the target markets and satisfies the target markets through the design, communication, pricing, and delivery of appropriate and competitively practical offerings (5).

Kotler defined social marketing as the design, conduct, and management of programs seeking to increase the acceptability of a social idea or practice (5). Social marketing relies on traditional retail marketing tools, such as exchange theory, which refers to the target audience's perception of the relationship between costs and benefits of the sought-for behavioral change. When the personal benefit of the proposed behavioral change exceeds the cost of making the change, then actual change may occur. As Kotler explained,

social marketing is distinguished from education, propaganda, and social advertising by the motivational element. Propaganda and education impart information and perhaps change values; social advertising is simply mass distribution of a message. None necessarily contemplates changing behavior, although changes in perceptions and values initiated by education or propaganda may in time result in behavior modification. (5)

The report *Marketing of Traffic Safety* (11), prepared by a group of scientific experts and commissioned by the Organisation for Economic Co-operation and Development (OECD), presented a step-by-step outline for developing a social marketing

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<sup>3</sup>NHTSA recently announced the commissioning of a national social marketing campaign to deal with older-driver issues.

plan that could be useful to address older-driver safety issues.<sup>4</sup> Table 1 describes the OECD outline. Table 2 is a simulated marketing campaign based on the OECD outline.

Clearly, the OECD outline illustrates—as Lifespan also pointed out in the description of social marketing—that the process often may include more than communication strategies. Elements of the social and policy environment may be addressed in the formula for proposed change if the target audience finds the benefits of change particularly difficult to perceive and the costs to society of noncompliance are extremely high. Then interventions at the policy or regulatory level (e.g., legislation) may be justified. Interventions also may include the enlisting of support from the organizations and networks with an interest in and ability to influence older drivers (social service agents, doctors, etc.). For example, research has suggested that the willingness of older drivers to plan ahead for the time when they no longer can drive does not interest the target

audience. Motivating a change of outlook undoubtedly will require the intervening efforts of various agencies.

A Lifespan survey of doctors, nurses, therapists, psychologists, and representatives from other fields (police, AAA, insurance agencies) revealed information about the dynamics of informational exchanges (16). When seeking information about older drivers, these professionals most often turned to motor vehicle departments, professional journals, professional societies, continuing education, and information gathered at conferences. They infrequently relied on the media, experience, research, or state health departments.

The professionals most often inquired about subjects on regulations and procedures to report unsafe drivers, aids or strategies to correct or mitigate health conditions that impair driving, personal liability when reporting a problem driver, and potential referral sites. Less frequently asked about subjects included older-driver crash experience and prevention of crash-related injuries.

When obtaining information, the professionals generally preferred to receive it in fact sheets, conferences, continuing education, and reference manuals. They were less enthusiastic about brochures, journal articles, and videotapes. When working with older drivers, the professionals thought that the most important information to dispense concerned aging and safety, laws and regulations, involvement of family and friends, medical conditions, transportation alternatives, and referral programs.

<sup>4</sup> Jarvinen (12) of the Central Organisation for Traffic Safety in Finland, cited the OECD report as an “excellent set of guidelines for the comprehensive assessment of measures promoting mobility and safety.” Jarvinen also recognized the importance of information and education when he observed that a major issue in dealing with the transportation and safety needs of an aging society falls to the “general lack of recognition, awareness and knowledge that surrounds problems associated with the mobility and safety of the elderly community.”

TABLE 1 Social Marketing Outline (11) for Road Safety (OECD)

<i>Situation Analysis (Getting to Know the Market)</i>	Define the problem, analyze both the environment and the consumer, and develop a list of possible safety initiatives. Extensive problem identification research is critical in accomplishing this first step. <sup>a</sup>
<i>Market Segmentation and Targeting</i>	Analyze and divide the market into homogenous key target groups. Determine which groups are large enough to be worthwhile targets, are reachable, and are not impervious to a marketing program.
<i>Setting Objectives</i>	Objectives should be clear, realistic, within reach of the administering organization, and subject to periodic progress monitoring.
<i>Formulating Marketing Strategy</i>	OECD says four variables make up the marketing strategy: <i>product</i> (goal to be achieved), <i>price</i> (what the intended consumer must give up in exchange for achieving the goal), <i>place</i> (distribution methods or locations to be used), and <i>promotion</i> (channels of communication). OECD views communications strategies as particularly important.
<i>Implementing Program</i>	Stick to program objectives and be flexible in adapting every available means to achieve the objectives.
<i>Monitoring and Evaluation</i>	Determine program response (were targets aware?) and program effectiveness (did behaviors change?). The latter may require extended tracking studies because change often occurs slowly, over long periods.

<sup>a</sup> OECD lists three types of research as essential to an overall campaign: problem definition, development to guide content, and execution of material and evaluation to assess effectiveness.

TABLE 2 Social Marketing: Possible Planning Guide Based on OECD Outline

<b>Objective</b>	Stimulate families to help older drivers extend their driving years and take the necessary steps that smooth the transition to alternate transportation when that becomes necessary. Possible campaign slogan: <i>Get Involved with Your Older Driver</i>
<b>Situation Analysis: Families of Older Drivers (13–15)</b>	<ul style="list-style-type: none"> <li>• Families feel definite responsibility for the well-being of an older person but don't know where to get help and are generally unaware of available resources, such as the DMV, or other transportation options. They wish that there were a universal number to call and a web site to access. They often meet with resistance from DMVs, the medical community, and other potential resources when help is sought.</li> <li>• They usually recognize early problem symptoms but don't necessarily relate them to driving, and they may become unnecessarily concerned when older persons are still capable of driving.</li> <li>• They don't know how or where to begin, so they wish that someone else would initiate the discussion about driving with their parents, such as the medical profession.</li> </ul>
<b>Problem Identification: Family Assistance</b>	Problem identification research has been extensive, and message content research is partially defined, (e.g. families express a need for a greater range of information about functional impairments, coping, intervening, and where to get help). Research is needed to perfect the language of messages and materials aimed at families.
<b>Market Segmentation and Targeting</b>	Will urban and rural families respond to the same stimuli? Do urban families feel a different responsibility because transportation options are more varied? Do ethnic differences imply a need for selective approaches? Will strategies useful for families dealing with 75-year-olds be equally effective for 85-year-olds? Will people who become older drivers in the next century respond to the family entreaties useful today? Are special messages required for the support disciplines: doctors, caregivers, highway engineers, police, and legislatures?
<b>Setting Objectives</b>	Objectives can be defined in terms of people reached or in terms of impact, which is far harder to measure. Evaluation research should provide some measure of family involvement outcomes.
<b>Formulating Marketing Strategy</b>	The <i>product</i> is increased family participation in assisting older drivers. The <i>price</i> is greater involvement. The <i>places</i> will be varied and should include every location where families might expect to get help and generalized information from broadcast distribution sources. <i>Promotional</i> channels will be equally diverse. Promotional messages that help families approach the very difficult moment when an older driver must be convinced to cease driving and accept an alternate will require extensive care in development: first to secure family acceptance of its responsibility and then to illuminate the available sources of support, such as doctors and therapists.
<b>Program Implementation</b>	Although materials may be developed at a national or state level, assuring that appropriate information reaches the families of older drivers may be the responsibility of local resources with specific knowledge of community needs and services.
<b>Monitoring and Evaluation</b>	Tracking studies will be necessary to measure the impact on families. Did the families do a better job? Did the families find the informational materials and agency resources helpful? When driving cessation became imperative, were families able to identify and arrange for suitable transportation options that satisfied the needs of the older person?

When presenting the information to older people, the group preferred to use pamphlets, brochures, fact sheets, and videotapes instead of personal or group communications, reference materials, the media, audiotapes, and the Internet. When the professionals sought assistance to work with impaired older drivers, they most often relied on driver evaluators, professional agencies and organizations, health providers, and professional societies.

The Subcommittee on Public Information of the Transportation Research Board (TRB) Committee on the Safe Mobility of Older Persons asked a sample group of practitioners and researchers attending a 1999 TRB conference to prioritize audiences and messages for a potential social marketing campaign (17). For the ranking of target audiences, the respondents placed older drivers first, followed in order by families, friends, the general driving public, caregivers (e.g., therapists,

nurses, home health care personnel), doctors, law enforcement, and elected officials.

The two reasons that the respondents cited older drivers as the top-priority target were to provide a reminder message to older drivers that compensations are available for age-related impairments and to prepare drivers to accept limitations and prepare for alternatives. Two respondents ranked families and friends as the top-priority target because families and friends most likely will be the first to notice the types of behavior that may interfere with driving safety. Table 3 lists the ranked message priorities.

When asked to list the compelling near-term objective of a social marketing campaign, the respondents gave a variety of answers, and no central theme emerged. Two similar observations appeared particularly relevant, however:

- Emphasize the kinds of help available to people experiencing driving problems and the alternatives

available to people who have lost or are about to lose the privilege to drive, and

- Help seniors and their support networks plan now for the time when driving is restricted and when driving ceases.

### Nationwide Initiative

In 1997 the U.S. Department of Transportation published the report *Improving Transportation for a Maturing Society* (18). The report established the motivating premise of safe mobility for life, intending to convey the following idea: lifelong transportation availability is essential, but the expectation that a person always will be the driver, as the mobility cornerstone, is not essential. The 1997 report set three goals:

1. Keep a person driving as long as is safely possible, particularly in areas with limited transportation alternatives.

TABLE 3 Potential Subjects for Various Target Audiences by Rank Order

<i>Older Drivers</i>	<ul style="list-style-type: none"> <li>• Recognizing and compensating for the degradation of aging</li> <li>• Retraining that may let them drive longer safely</li> <li>• Preparing for the time when they will no longer be able to drive</li> </ul> <p>Other less frequently mentioned topics were preparing for driving restrictions based on physical or mental problems; emphasizing the need to stay socially active; and driving is a means, not an end.</p>
<i>Families and Friends</i>	<ul style="list-style-type: none"> <li>• Helping older drivers obtain counseling or training that will extend their driving years</li> <li>• Arranging for older drivers to receive medical review and counseling</li> <li>• Setting up alternative transportation for an older person who can no longer drive</li> <li>• Devising a strategy to help (or require) that an older person decrease driving</li> <li>• Encouraging or arranging a test to determine driving fitness</li> </ul>
<i>Caregivers</i>	<ul style="list-style-type: none"> <li>• Taking responsibility for discerning physical or mental limitations that might affect driving</li> <li>• Following through on observations by advising patient and family</li> <li>• Following through on observations by advising medical authorities</li> <li>• Setting up driver retraining regimens, as appropriate</li> </ul>
<i>Doctors</i>	<ul style="list-style-type: none"> <li>• Including decisions about potential driving problems in diagnoses of older persons</li> <li>• Clarifying the need to stop driving to those who no longer should drive</li> <li>• Counseling older drivers on self-help techniques that may extend driving years</li> <li>• Reporting findings as required or permitted by law to appropriate government authority</li> </ul> <p>Other less frequently mentioned topics were learning referral services available for driver assessment and transportation support and emphasizing interventions available to doctors.</p>
<i>Law-Enforcement Personnel</i>	<ul style="list-style-type: none"> <li>• Reinforcing the importance of recognizing problem drivers</li> <li>• Advising officers on ways available to initiate retesting of drivers with apparent problems.</li> </ul>
<i>General Public and Elected Officials</i>	<p>Both of these target groups elicited highly individualized comments so rankings could not be established. Among the opinions cited were</p> <ul style="list-style-type: none"> <li>• The public should be informed that compensating behaviors, retraining, vehicle adaptations, and alternative transportation options are available for older persons beginning to experience driving difficulties</li> <li>• Elected officials should be encouraged to support and pursue the development of driving alternatives</li> </ul>

2. Improve public and private screening and evaluation systems that provide the means to determine when older people no longer can drive safely.

3. Educate the general public on what can be done to maintain operational safety as each person ages and on how to prepare for older age without driving.

After the 1997 publication, a 1999 NHTSA initiative involved a series of national forums and focus groups and was reinforced by an extensive telephone survey. The collection and assembly of this new information will be designed to assess the transportation needs of older Americans, will bring a useful set of fresh data into the research mix, and will provide social marketers with a richer perspective on how to cast the messages that are intended to influence older people and the people who have an interest in the safe transportation of older people.

The nationwide initiative brought together forums of professionals, policy makers, and practitioners and included both national and local perspectives on older-people safe mobility issues, highway design, driver programs, and transportation options. Subsequent to the forums, older people and their caregivers were assembled into focus groups to discuss transportation issues. These discussions and subsequent telephone surveys will be used to draft a national agenda and strategic plan to provide safe transportation for a maturing society. This document will be a potentially valuable tool for people contemplating social marketing efforts. The observations by caregivers (usually adult children) will have special interest for the shapers of social marketing strategies, particularly on how the caregivers help older people stop driving and how the caregivers solve the ensuing dilemma of providing transportation for older people who no longer can drive. These caregivers also were asked an even more important question: What systemic changes would they recommend to ease their transition (20 years from now) into the status through which they are now guiding their parents?

In November 1999, a TRB conference was convened to begin the process of following up *Special Report 218*. The participants heard initial results from the forums and generated an outline agenda of research, development, and implementation needs. In the social marketing arena, the participants suggested the following:

- Develop strategies to communicate transportation options,
- Emphasize community-level development of mobility materials,
- Educate the media to frame the issues properly,
- Educate policy makers and professionals about older-driver issues,

- Pilot-test informational programs that would alert an older person to transportation options ahead of when an older person must stop driving,

- Encourage the use of the Internet by older people for shopping needs and information about transportation options, and

- Encourage states and communities to develop and promote transportation options.

### SOLVING TRANSPORTATION PROBLEMS: A SOCIAL MARKETING CHALLENGE

The first task of the social marketer is to set priorities. Among the possible audiences, older drivers and their caregiving network rank as primary targets.<sup>5</sup> Among the subject areas, methods that can help older drivers maintain or refurbish driving skills and strategies that are designed to smooth the difficult and often highly resisted transition from driver to passenger deserve principal attention.

Among the marketing groups, state motor vehicle departments and health and social service agencies probably can reach most older drivers the quickest, but a host of localized distribution channels may have the most dramatic effect. Such potential outlets include churches, senior centers, libraries, neighborhood newspapers, market checkout counters, post offices, community college adult classes, and bulletin boards.

Marketing tools range from the general (e.g., mass media) to the personal (e.g., church bulletin insert). The choice of marketing tools hinges on the research that defines where and how seniors gather and what types of information seniors find trustworthy. Most campaigns require multiple marketing tools because the target population is diverse.

Behind this first tier of opportunity lies a secondary group of targets and subjects that must be woven into the mosaic, as resources and time permit. The secondary group includes the general public, police, and law makers as targets and a more accurate definition of older people's driving capabilities, needs, behaviors, and crash records as subject matter.

In summary, the objectives of a social marketing campaign are to

- Help older people capitalize on techniques and behaviors that allow more years as drivers;
- Assist older people and the community of interest surrounding them to prepare for and move through the

<sup>5</sup> The networks include families and friends foremost but also doctors, therapists, and others in associated disciplines.



difficult period when driving must be restricted or stopped; and

- Construct a frame of reference that allows the general public to see older drivers in a realistic context, influenced more by the validity of older-driver behavior than by the occasional, emotionally charged tragedy that often is featured on television and in newspapers.

Encompassed within these objectives are subsidiary goals:

- Encourage older people to plan well in advance for the time when they may be required to stop driving.
- Help families and friends to take appropriate action when they recognize that an older person's driving ability should be reassessed.
- Stimulate the greater participation of doctors and others in the broader health care community to help older people to sustain driving skills when appropriate and to seek alternative transportation when driving should cease.
- Encourage an active role in problem solving by people in disciplines that can have a marked effect, such as highway engineers, law enforcement, automobile manufacturers, law makers, and senior citizen organizations.
- Publicize the availability of transportation alternatives.

The objectives above tend to be general because marketing directed at large groups requires broad initiatives. Research then isolates definitive eccentricities within the larger groups and allows marketers to narrow the target, to refine the messages, and to select the best communications channels.

Many older drivers self-adjust for reductions in their physical and mental capabilities. This process may be instinctive, instead of overt, because some older people queried in focus groups reported that they sensed no driving problems and generally were unaware of the effects that aging or medications have on driving ability (13). Older people are surprised when they learn that their per-mile crash rate is high. However, objective observers (professionals and the children of older drivers) reported that older drivers exhibited problems in perception and judgment (13). Thus, self-regulation, even though already demonstrably effective, could be perfected more by social marketing efforts that clearly define age-related changes and offer specific compensating strategies applicable to driving.

The availability of objective assessments for seniors also should be explored. The value these assessments often can have in extending the driving years should be emphasized. This subject area poses a severe social marketing challenge because seniors tend to regard any form

of skill evaluation suspiciously, even though numerous focus group findings indicate that older people have no objection to more frequent testing based on age. One focus group offered the surprising suggestion that driving evaluations should begin at younger ages so that seniors will have an idea of where they are headed (13).

Some European nations have provided assessments and educational opportunities for older drivers. In Great Britain, the Forum of Mobility Centres—a network of sites dedicated to helping elderly and disabled people retain their mobility—provides a range of services, including assessment of driving ability, selection and use of wheelchairs, driving instructions, fitting of adaptive devices in vehicles, advice, and information. The centers strive to help clients achieve independent mobility. Currently, there are 13 accredited centers—10 in England and 1 each in Ireland, Northern Ireland, and Scotland—plus 3 associate member centers.

Since 1983 Britain also has conducted biennial mobility road shows, where older people and people with disabilities can drive cars outfitted with special controls and equipment that ease the driving task. The British Institute of Traffic Safety offers “advisory drives” for seniors, and the Automotive Association's Foundation for Road Safety Research published the handbook *Helping the Older Driver*. The German Traffic Safety Organisation offers four 2-h seminars and, in conjunction with the German Auto Club, provides driving assessments. The Netherlands has produced a handbook and conducts driving assessments.

From the OECD study, the focus of a successful marketing program must be on the targeted consumers because the messages explain how the consumers can accomplish their objectives. The subtleties of this strategy largely are unexplored. For example, practitioners who daily deal with older people have noted that older people with a particular condition voraciously seek information concerning that condition (19). The literature dealing with conditions such as arthritis, changes in vision, subtle onset of dementia, and so forth could incorporate references to the condition's effects on driving and include instructive commentary on coping with these effects when driving. The material also could recommend that transportation options be weighed early on, before the options become needed, to prepare the user for the eventual transition. Acceptance of buses or light rail, for example, could be developed gradually through early recognition of eventual need, augmented by training for actual use. The range of general health-related informational material addressed to seniors could include similar references to the effect of aging on driving and the utility of early thought about alternative transportation options.

The importance of good health maintenance has been a staple of the medical profession's message to

America, but the relationship of good health and driving longevity has been an infrequent topic. Clearly, healthier older people usually are able to drive longer; thus, promoting personal health may help seniors extend the driving years. For example, the Partnership for a Walkable America prepared a pamphlet on the physical and mental benefits of walking, including decreased risk of developing colon cancer, dying of heart disease, developing diabetes, and others (20). The pamphlet also could have included that more walking could equal more driving. Market initiatives that encourage increased walking can make a dual point: driving years may be extended because of personal health benefits from walking, and walking can become a comfortable, convenient, always available, optional form of transportation.

Unfortunately, walking too often is an uncomfortable venture for older people, particularly in urban settings. Pedestrian "Walk" signals (when available) may allow insufficient time for slower-moving seniors to cross safely. When sidewalks are unavailable, seniors may have to walk on the shoulder or the road. Vision or hearing problems may put seniors at even higher risk.

Marketing initiatives that encourage increased walking need to be accompanied by significant engineering adaptations that make walking comfortable for older people. Even then, acceptance of the pedestrian lifestyle may vary by age. Some research has suggested that people born before World War II were accustomed to walking and that they have less trouble readapting to that mode as a senior. People who reached driving age after World War II were caught up in America's romance with the automobile and strongly may resist giving up their personal transportation. Baby boomers may be the least receptive to dissolve the partnership with the automobile.

The concept of including low-key, even casual, references to older people's driving capabilities within materials (articles, films, television shows, soap operas, etc.) that deal with otherwise unrelated subjects could encourage a more optimistic societal view of older drivers. Moving safety belt use from the marginally acceptable to the culturally approved offers an example. When newspaper crash reports routinely began to include information on safety belt use or nonuse and when TV actors riding in cars began reaching for safety belts, a new criterion was established. Safety belt use became the rule rather than the exception. Today, older drivers generally are viewed with cautious suspicion. Shifting the public perspective to one of optimistic encouragement of the older person could be a way to define the goal of a social marketing campaign. This example also suggests the importance of continuing to evaluate older people's viewpoints on transportation in accordance with the social marketing imperative to study and assess issues from the consumer's perspective.

Research opens the window on emerging issues and changing opinion bases.

Population projections alone make the growth of the older-driver segment obvious, but longer life spans also mean added years as drivers. An increasing proportion of women will be entering the older-driver stratum as well, perhaps reversing the recently discovered tendency of some women to quit driving too early (21).<sup>6</sup> Some women born in the first half of the century never learned to drive, some deferred to their husbands, and some reluctantly became drivers after being widowed (16). Younger women, particularly baby boomers, have built lifestyles that rely heavily on the personal convenience and flexibility of a passenger vehicle. As these women age, their transportation needs and desires more nearly may match the needs and desires of men. Social marketing programs must stay abreast of and devise new approaches that weigh these shifting demographic trends.

## OLDER DRIVERS: ANOTHER VIEW

Older drivers who age normally can be grouped into three general phases. Suggested communication techniques and channels can be developed for each category.

### Phase 1

The older person experiences initial problems of aging that begin to affect driving and trigger self-compensation. This person needs to know that gradual physical and mental changes are normal, continuing adjustment of driving behavior often can extend safe driving for many years, and acceptance of the need for change is the key to safe operation.

### Marketing Challenge

The marketing challenge is to provide informative materials for older people and their families that reinforce effective driving responses, motivate older people to stay focused on driving behavior, and make older people aware of the potential value in health and wellness programs, retraining, rehabilitation, and adaptive devices. Materials could include information on how to buy a car, tips on staying healthy with the driving advantages that accrue as a result, and guidelines on the

<sup>6</sup> As Wilkins et al. (21) reported, 10 of the 15 focus group participants indicated interest in driving assessment, 8 actually completed the assessment, and 4 drove so well that they could immediately return to or increase their driving. The other 4 needed various amounts of further training. One woman who resumed driving said, "I need a boost."

practicality of planning for other transportation options long before such options become necessary.

### *Research Needs*

The research needs probably are minimal because the information already is available.

### *Marketing Materials*

Good materials are available, but the materials need to be reinforced by the inclusion of useful information in printed matter that older people are most likely to read or see. Motor vehicle departments could adopt a standardized program to contact every driver at age 70 and offer counseling and assistance on how to extend driving years, including information on obtaining evaluations through social service and medical sources. Literature prepared for or by the medical community could offer similar avenues of assistance. Health maintenance organizations could set up and publicize driving assessment programs. Insurance company magazines could provide both older drivers and their families with guidance on assessment of driving skills, preparation for limitations on driving, and counseling on adjusting to transportation alternatives when the time comes.

### *Marketing Agents*

The most appropriate marketing agents probably include motor vehicle departments; area agencies on aging; health, social service, and safety organizations; insurance companies; AARP; AAA; and AAMVA.

### **Phase 2**

The older person experiences additional symptoms of aging, possibly making driving unsafe. The person may not be fully aware of this status or may be in denial. This person needs to know about evaluation and rehabilitation possibilities and available vehicular adaptive devices.

### *Required Corollary Assistance*

This phase requires the active presence and involvement of an “early warning” network, including family, friends, police, doctors, and others in the health care

community. All segments should be aware of the aging symptoms that may require intervention.

### *Marketing Challenge*

The marketing challenge is to reach the families of older drivers and other members of this early warning network with materials that encourage participation in the observation and intervention processes and makes members aware of the options available to assist the older driver. As an adjunct, informational material should be developed that doctors and others in the health care network can give older patients and their family and friends of influence.

### *Research Needs*

1. Determine what incentives and messages will trigger the interest and action of families and friends to help an older person make wise choices about driving.
2. Determine the comfort level at which doctors actively will deal with a patient’s driving capabilities and what informational materials the doctors seek as a supplement to their recommendations about driving. Also determine if informational materials concerning rehabilitation and evaluation services would encourage doctors to incorporate these services more frequently into their treatment regimens.
3. Determine what incentives and training will encourage the people in the broader health care network to assess driving capabilities as a regular facet of examinations and to identify the kinds of informational materials that these people would find useful to assist older people.

### *Marketing Materials*

Marketing materials currently are limited. Some available materials address aspects of this phase, but much development is needed, subsequent to research that identifies effective messages and communications channels.

### *Marketing Agents*

Reaching seniors requires a combination of delivery systems: motor vehicle departments, health and social service agencies, the medical community (e.g., doctors, therapists), the media, and perhaps churches. The initiative also requires a variety of delivery methods: printed materials, word of mouth, informational videotapes, radio and television talk shows, the Internet, toll-

free telephone numbers, and so forth. Reaching families and friends requires similar delivery agents, most likely through the health care network: doctors, therapists, home health providers, and possibly employees at motor vehicle departments.

### Phase 3

The older person no longer is capable of safe driving and may be unaware of or unwilling to recognize this status. This person needs a complete change of outlook. The support system must be geared to help the older person shift to an alternative form of transportation, which may include a change in lifestyle. People of any age who experience catastrophic illness, such as severe stroke, or advanced dementia, may become Phase 3 candidates without progressing through Phases 1 and 2.

### Marketing Challenge

The marketing challenge is to develop materials that present the transition in constructive terms through the motivation of the support network to facilitate change and to create materials that define the avenues of assistance available to the older person who no longer can drive. The description of transportation options and the active participation of the support network in helping the older person negotiate and become comfortable with the idea of alternatives has particular importance. For older people whose recuperation eventually may allow for the resumption of driving, perhaps with specially adapted vehicles, the marketing campaign also should address these possibilities.

### Research Needs

There are multiple research needs, particularly in relation to how older people view alternative transportation options and in what way the support system views the responsibility to help the older person cease driving and convert to these options. Because research already has shown that older people express little interest in planning for the time when they no longer can drive, further investigation would be useful in the development of marketing strategies that begin to shift the social dynamic toward the acceptance of life-long transportation as the desirable objective instead of life-long driving.

Research should be stratified demographically to assure that all socioeconomic groups are represented and

that age, sex, and ethnic differentials can be sorted out. For example, older men tend to be more reluctant to stop driving than women are. On occasion, older men may voice the determination to keep driving even after their license has been terminated. Focus groups consisting of men with the determination to remain drivers at any cost could be helpful in determining what motivations could alter the perspective. Conversely, as mentioned earlier, older women in relatively good health may stop driving because of low self-confidence or lack of experience. With proper encouragement and retraining, some of these women can remain safe drivers.

### Marketing Materials

Much development is needed because availability sharply is limited. After preparatory research delineates consumer desires and the useful approaches to reshape these desires gradually, extensive testing of messages will be needed.

### Marketing Agents

When licensing decisions are involved, motor vehicle departments necessarily form part of the delivery system, although decisions to stop driving occur more often apart from licensing considerations. The gradually evolving improvement in vehicle driver testing procedures should enhance assurance among all drivers, not just seniors, that licensing decisions are valid. The assurance may not be enough to overcome some older people's general fear of motor vehicle department testing, however. The growth of third-party competency evaluations by occupational therapists or trained volunteers is a welcome development. As marketing agencies, motor vehicle departments should assume responsibility for the information programs that clarify testing and licensing procedures and options.

Other delivery agents will include social service and health agents, doctors, care providers, and operators of alternative forms of transportation (e.g., buses, light rail, taxis, dial-a-ride). Another promising delivery agent may be other older people, exchanging opinions about options and choices that proved comfortable. One of the most helpful marketing strategies is to tap into the peer transmission process (19).

### CONCLUSION

The Year 2001 brought the hopes for renewal that new centuries and new millennia typically foster. The surg-

ing increase in the aging population suggests that in this case, old will be new because many new solutions will be required to deal with the problems associated with this growing number of older people. Not the least of these problems is the transportation equation. For many people, just as  $2 + 2 = 4$ , transportation needs = an automobile. Shifting that viewpoint, even marginally, poses a formidable assignment. Social marketing campaigns need to convince older people that when the time comes for driving cessation, the alternatives can be palatable and perhaps even desirable.

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# Policy

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# Transportation Policy for an Aging Society

## Keeping Older Americans on the Move

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Whether by foot, wheel, or rail, transportation is the glue that holds all of life's activities together. Mobility is, and will continue to be, an important element of healthy aging, enabling older people to visit friends and family, volunteer, work, learn, go out to dinner, see a movie, window shop, travel to the grocery store, and access health care.

The new vision is of an active old age, in which retirement does not signify a cessation of full participation in life. Wachs (1) argued that income, education, and health could have a positive relationship with travel demands among old people. Today's older people and tomorrow's mature baby boomers with greater incomes, increased education, and improved health are relatively better off than their parents and grandparents. These factors suggest that tomorrow's older people are more likely to pursue a range of activities requiring transportation that is responsive to this active, albeit older, lifestyle.

Research and anecdotal evidence have shown that people routinely view the ability to travel as synonymous with personal freedom and independence. For example, many older people see mobility as inextricably linked to personal image, dignity, and well-being (2–4). Other research has suggested that the ability to stay connected to friends and community is an important element to physical and mental health (5). Most adults equate mobility with the ability to drive; the loss of driving is seen as a handicap, which results in, at best, a change in lifestyle and, at worst, the end of life as they know it. One survey of older people at a health maintenance organization in Southern California identified

losing the ability to drive as more frightening than even the loss of a spouse or the poor health of a child (6).

Despite the importance of transportation to personal lives and society's capacity to ensure the productivity of one of its fastest-growing populations, over the last decade there has been little policy movement that would suggest serious progress in keeping an older America on the move. In this analysis, although transportation is critical to individuals and the community, there are many institutional and system barriers to policy innovation. This paper examines policy evolution and developments between 1988 and 2000, characterizes the political dynamics governing transportation policy for an aging society, and concludes with policy research recommendations that may provide new impetus and urgency to the issue.

### POLICY CONTEXT: OLDER PEOPLE AND TRANSPORTATION NEEDS

Like their children, older people overwhelmingly choose the automobile as the primary mode of transportation. As the 1995 Nationwide Personal Transportation Survey of the U.S. Department of Transportation (DOT) revealed, more than 80% of people age 65 or older chose to drive or ride as a passenger in a car to make a variety of trips: shopping, medical appointments, family and personal business, religion, recreation, and so forth. Table 1 displays the percentage of trips made by older people by automobile, public transit, walking or biking, or other modes in urban, suburban, and rural areas.

**TABLE 1** Percentage of Older-People Trips by Mode and Region (7)

<i>Mode</i>	<i>Urban</i>	<i>Suburban</i>	<i>Rural</i>
Automobile	77.3	93.7	94.8
As driver	54.9	71.7	68.1
As passenger	22.4	22.0	26.7
Public transportation	8.5	0.9	0.3
Walking/biking	13.3	4.6	4.6
Other	0.9	0.9	0.3

Rosenbloom (7), Burkhardt (8), and other researchers have noted that the increase in licensing patterns among older people and increased trip making by automobile indicate a continued and growing reliance on the automobile. This behavior is reinforced by travel preferences developed at younger ages and the spatial reality that more than two-thirds of older people live in suburban and rural areas, where transportation alternatives are not readily available.

## A DECADE OF TRANSPORTATION POLICY

Public policy is the authoritative allocation of costs and benefits on society. Transportation policy is a mosaic of action and inaction by federal, state, and local policy makers and institutions that determine winners and losers:

- Who will enjoy optimal mobility?
- When will some have their choices limited?
- Where will investments in transportation improvements be made?
  - How will all these decisions be implemented?
  - How will the related costs and benefits be distributed?

Transportation policy for an aging society results from a complex set of relationships among transportation, public safety and human services providers, interest groups, and people who seek to define and promote their transportation priorities in the midst of a long list of competing problems and solutions that are vying for public visibility and resources.

The competing issues include combinations of problems and solutions, such as

- Improved older-driver licensing and testing methods,
  - Research and development (R&D) investment for safer vehicles,
  - Usable and accessible transit systems and public transportation,

- Increased funding for current services and innovative paratransit services, and
- Livable communities that support aging in place.

Each of these problems—solutions and many others involve at least one level of government. However, few receive serious attention and sustained support because of the dynamic conflict between transportation policy issues and other issues, such as education and health, that compete for the same public support and resources (9).

Table 2 summarizes the relative roles, responsibilities, and actions of the federal and state governments, the private sector, and the individual, who is often overlooked. The actions of these institutions and actors over the last decade characterize the current state of U.S. transportation policy for an aging society and the trajectory for the future.

## Federal Action and Incremental Leadership

Despite its primacy in many policy areas, the federal role has been limited in transportation policy for older people. With few exceptions, there has been little investment in resources that would establish a coherent policy to address the mobility needs of an aging nation. Although the U.S. Congress has not provided adequate resources, U.S. DOT and the U.S. Department of Health and Human Services (HHS) have made incremental contributions. The greatest achievement of these modest initiatives has been to raise the visibility of the issue at opportune policy junctures, such as the reauthorization of transportation and human services program legislation and useful guidelines and the research to assist state and local authorities.

Table 3 provides a summary of prominent federal action over the last decade to support the mobility needs of older people. The items listed in the time line consist of three types of activities: legislation that has provided funding or policy definition, events that have given visibility to the issue, and selected studies and guidance that have helped to define the problem and optimize limited public funding. Many research projects, studies, and guidelines have been issued in the past 10 years; the identified projects, studies, and guidelines have garnered significant attention and have helped shape the continuing debate over problem definition, priorities, and solutions.

## Legislation

Legislative activity in support of older people's mobility always has occurred in the context of other issues. Four key pieces of legislation have been enacted in the past

**TABLE 2** Modal Roles and Responsibilities in Transportation for an Aging Society

	<i>Driving</i>	<i>Alternative Transportation</i>	<i>Walking</i>
Federal government	<ul style="list-style-type: none"> <li>• Funding of infrastructure</li> <li>• Vehicle, highway, &amp; driver safety R&amp;D (e.g., ITS), crashworthiness, standards</li> <li>• Data collection &amp; dissemination</li> <li>• Agenda setting</li> </ul>	<ul style="list-style-type: none"> <li>• Funding of transit infrastructure</li> <li>• Funding of service provision, public transportation, &amp; human services transport</li> <li>• Accessibility rights (ADA)</li> <li>• Vehicle &amp; service R&amp;D</li> <li>• Coordination &amp; agenda setting</li> </ul>	<ul style="list-style-type: none"> <li>• Agenda setting</li> <li>• Develop &amp; provide guidelines</li> <li>• Funding (limited)</li> </ul>
State & local government	<ul style="list-style-type: none"> <li>• Funding &amp; construction of infrastructure</li> <li>• Licensing/relicensing</li> <li>• Insurance standards</li> <li>• Traffic safety rule making &amp; enforcement</li> <li>• Funding of local roads &amp; infrastructure</li> <li>• Traffic safety enforcement</li> </ul>	<ul style="list-style-type: none"> <li>• Funding of transit infrastructure</li> <li>• Funding &amp; operations of transit and human services transportation</li> <li>• Implementation of federal mandates</li> <li>• Local funding of systems &amp; services (e.g., senior shuttle services)</li> <li>• Limited operations</li> <li>• Coordination of volunteers</li> </ul>	<ul style="list-style-type: none"> <li>• Funding &amp; construction</li> <li>• Traffic safety regulation &amp; guidelines</li> <li>• Implementation of state guidelines</li> <li>• Zoning &amp; placement</li> </ul>
Private sector & individual behavior	<ul style="list-style-type: none"> <li>• Vehicle design &amp; manufacture</li> <li>• Insurance</li> <li>• Consumer &amp; vehicle operator</li> <li>• Self-regulation</li> </ul>	<ul style="list-style-type: none"> <li>• Private providers (e.g., contract services, taxis)</li> <li>• Employers of caregivers/ consumers</li> <li>• Consumer &amp; primary provider of transportation to nondrivers</li> </ul>	<ul style="list-style-type: none"> <li>• Design &amp; development</li> <li>• Lifestyle choice (e.g., housing near transit)</li> </ul>

**TABLE 3** Federal Policy Supporting Transportation for an Aging Society, 1988–2000

1988	<i>Special Report 218</i>
1989	“Moving America” Policy Outreach (DOT)
1990	Americans with Disabilities Act National Transportation Policy: “Moving America” Nationwide Personal Transportation Survey
1991	Intermodal Surface Transportation Efficiency Act of 1991
1992	Older Americans Act (OAA) Reauthorization
1995	White House Conference on Aging: <i>Choices for Our Future Report</i> Nationwide Personal Transportation Survey
1997	<i>Improving Transportation for a Maturing Society</i> White House National Science and Technology Council: <i>Transportation Science and Technology Strategy</i>
1998	Transportation Equity Act for the 21st Century <i>Mobility and Independence: Changes and Challenges for Older Drivers</i>
1999	National Agenda for the Transportation Needs of an Aging Society TRB conference: Transportation in an Aging Society: A Decade of Experience
2000	Planning Guidelines for Coordinated State and Local Specialized Transportation Services Pending Reauthorization of the OAA Draft National Agenda: Strategic Plan for the Transportation Needs of Aging Society
2001	<i>Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians</i>



decade. These laws have redefined access as a right, funded services and infrastructure, and promoted R&D. Transportation typically is funded as part of a larger public transportation program or as a critical element of a human services program, such as nutrition.

The Americans with Disabilities Act of 1990 (ADA) did not provide funding per se; however, the legislation did redefine access. The ADA established access to transportation as a civil right. Public transportation service providers must guarantee access to key bus and rail facilities for people with disabilities. Historically, transit services for older people have been linked to transportation for people with disabilities. Given the relative growth in disability as a person ages, the ADA has contributed to the U.S. commitment to access and to the development of paratransit services for people unable to use fixed-route systems.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the 1998 Transportation Equity Act for the 21st Century—ISTEA's successor—fund the nation's surface transportation needs. Each has provided considerable funding for R&D to support driver safety, intelligent transportation systems (ITS), and infrastructure and resources to operate transit systems.<sup>1</sup> ISTEA made a significant contribution by providing new flexibility for Federal Transit Act Section 5310 funds to be used by private, nonprofit organizations or public agencies that coordinate transportation services for older people. In addition, Sections 5310 and 5311 funds may be used for the delivery of home meals as long as the services do not result in diminished services to transit riders. Beyond additional program flexibility, specific funding is limited. Much of U.S. DOT's work for the elderly is conducted within the department's relatively small discretionary resources budget.

The Older Americans Act (OAA) reauthorization of 1992 identified transportation as a priority service, critical to the independence and well-being of older people. Most of the transportation funding, however, is dedicated to program-related transportation services, such as nutrition and health. Title III of OAA requires that states spend an adequate proportion of support services funding on access services. In 1996 nearly \$60 million, or approximately 8%, of Title III funding was spent on transportation (10). This sum did not include state and local transportation funds nor the far greater investment in transportation by the Social Services Block Grant Program, the Community Services Grant Program, or Medicaid for medical-related transportation. Although each of these programs makes significant investments in transportation, the funds support

basic mobility needs, not necessarily the services that respond to the needs of healthy aging (e.g., social trips).

Unfortunately, specific age-related research that may have been conducted by the Administration on Aging of HHS has been severely curtailed because of dramatic cuts in the agency's research programs. Consequently, the federal agency with the greatest institutional knowledge of the older consumer has been unable to implement programs that could make a meaningful contribution to meeting the mobility needs of older people. Although significant human services program funds are spent on transportation, the role of HHS has been limited by Congress to coordinating with U.S. DOT to improve the program efficiency of current services within current resources—instead of seizing a proactive role to anticipate the transportation needs of a dynamic, growing, increasingly suburban, and diverse aging population.

These pieces of legislation and the supporting activities have forged a de facto policy of linkage, developed over the last 40 years. Older-people mobility continues to be linked to poverty programs, programs for people with disabilities, or rural programs. Rarely, if ever, has the issue of mobility for an aging society received specific legislative attention or identity outside one of these three issues.

For example, statutory linkage can be seen in the Federal Mass Transit Act, which makes funding available "to improve access for the elderly and people with disabilities."<sup>2</sup> A linkage also can be seen in national strategic planning. Recent transportation reforms to support welfare-to-work and related poverty programs frequently have been identified with the larger federal goal of accessibility and mobility. In 1997 the White House's National Science and Technology Council issued the *Transportation Science and Technology Strategy*, the national strategic goal of accessibility and mobility that combines the mobility needs of welfare recipients and older people who no longer drive (11). These may be nondrivers and may need responsive transportation; however, each group has unique travel needs and resources. Although many older people are poor, live in rural areas, and may be disabled, a policy that always links these groups into one problem set may preclude a focus on the transportation needs of a growing number of older people who are not poor, do not live in rural areas, or are not disabled. Current policies do not support and are not prepared to anticipate the demands and needs of the largest segment of older people aging in place in the suburbs. Consequently, as this segment of the population grows, current policy will continue to promote solutions

<sup>1</sup> See Sections 9, 18, and 16 (B)(2) of the Urban Mass Transportation Act.

<sup>2</sup> See Section 5310.

designed to address different populations and will not reflect changes in needs.

### *Agenda-Setting Events*

Continuous outreach events are critical for maintaining the focus of the general public and of elected officials. When conferences, summits, and listening sessions are successful, they achieve media attention and focus the attention of decision makers on providing resources to a problem. However, conferences, summits, and listening sessions often result in symbolic victories that coalesce continued support from people who already are interested in the topic and who are preparing for the next opportunity to influence policy meaningfully (e.g., reauthorization hearings). There has been considerable federal outreach from the executive branch. The success of these outreach events has been modest, briefly gaining the attention of elected officials or serving to galvanize support from interested groups, researchers, agencies, and the general public. Incremental progress characterizes policy over the past 10 to 12 years.

In addition to research events sponsored by the University Transportation Centers Program of U.S. DOT and by the Transportation Research Board (TRB), a series of highly visible events has gained attention and helped define the issues around transportation and aging. The 1989 National Transportation Policy Outreach, Moving America, of U.S. DOT included the needs of older people in a survey of special populations. The outreach resulted in the issue's inclusion in the national transportation policy of U.S. DOT, which served as a context for the reauthorization that later became ISTEA.

Under the goal of social well-being, the 1995 White House Conference on Aging adopted Resolution 30: Maximizing Transportation Choices, which sought more resources, research, and liability protection. The purpose of this resolution was "to ensure accessible, low-cost transportation for older people and persons with disabilities ... as well as cost sharing by individuals" (12).

The White House conference laid the foundation for five other events that produced a series of recommendations in services, R&D, and funding (13). The United Nations International Year of the Older Person (IYOP) 1999 provided a backdrop for other outreach events that engaged policy makers. These events included a nationwide outreach by U.S. DOT to craft a national agenda for the needs of an aging society and the TRB conference, Transportation in an Aging Society, to follow up *Special Report 218*. Both activities provided valuable opportunities to broaden the coalition of support for addressing the needs of older people and to engage the participation of senior policy officials from

the private sector, U.S. DOT, HHS, the Department of Veterans Affairs, and the National Institutes of Health in joint events and projects. Federal coordination of aging issues during the IYOP also resulted in the publication of an interagency report—*Coming of Age: Federal Agencies and the Longevity Revolution*—that highlighted the importance of transportation.

### *Studies and Guidelines*

Although studies and guidelines have been developed over the last decade, few have succeeded in informing policy making and gaining national attention. For example, *Special Report 218* provided a compendium of knowledge and set in motion a rich research agenda, which would continue to develop for more than a decade (14). But 2 years later, the *National Transportation Strategic Planning Study* of U.S. DOT was relatively silent on the importance of aging and transportation (15). Responding to Congress's request to "conduct a long-range, multimodal study to the year 2015 for transportation facilities and services to carry persons and goods," the U.S. DOT planning study stood in sharp contrast to TRB's contributions to understanding the mobility needs of older people (15). Despite the aging of the baby boom generation by 2015, the U.S. DOT planning study only briefly focused on how the health, economic well-being, and average age of retirement could influence leisure travel and work-related trips. This brief focus demonstrates the relatively weak traction that the issue of aging and transportation has had in policy making.

The 1990 and 1995 Nationwide Personal Transportation Surveys provided statistical information on older people's travel and the opportunity to highlight the importance of older people as a consumer group. The inclusion of older people in the 1990 Demographic Special Reports series reflected the continued interest by many policy makers in transportation (16). Reports based on the 1995 survey data provided additional insight and information for policy makers interested in the issue (17, 18).

In 1995 U.S. DOT Secretary Federico Peña requested a study on aging and transportation, representing significant attention within the department. The results of the study, *Improving Transportation for a Maturing Society*, reported a multimodal review of the effects of aging on transportation, including older operators of commercial vehicles, ships, rail, and general aviation aircraft (19). Although modestly funded, the report represented an attempt by the department to scope the issue and develop momentum. However, a change in department priorities, combined with the demands of anticipating reauthorizing legislation, limited the attention.

U.S. DOT and HHS cofunded Burkhardt et al.'s study *Mobility and Independence: Changes and Challenges for Older Drivers* (8). Although the title would suggest that the report addressed only the needs of older drivers, the report is the first major document to articulate successfully the preferences of older people as consumers of transportation and to discuss the limited alternative options to driving. The report contributed to research in the area and to national attention. For example, the authors projected that the future fatality rates of older drivers would approach the number of drunk drivers killed throughout the United States in 1995. These findings brought research debate, media urgency, and the attention of the public and policy makers to the issue.

Recent U.S. DOT outreach and planning may provide additional attention. This volume, as a follow-up to *Special Report 218*, should provide another opportunity for focusing attention on the issue and may mobilize researchers and policy makers. In addition to broad policy movement in the area, the federal government has contributed ongoing research guideline development in three specific areas that correspond to older people's mode choices.

## Driving

U.S. DOT—particularly the National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Administration (FHWA)—is the principal actor in the area of older drivers' safety. The overall framework has focused limited resources on research to examine driver and safety issues, road infrastructure, and vehicle safety.

Driver and other related safety issues are reflected in NHTSA's investment in studies of state driver testing procedures and processes, specifically the use and efficacy of state driver licensing Medical Advisory Boards. Human factors research also has played a prominent role in NHTSA's agenda. The research has leveraged industry research and other U.S. DOT investment in university-based studies of occupant safety, attention, warnings, and vehicle design.

FHWA has conducted considerable work to improve highway infrastructure. For example, a series of reports and related guidelines have been provided at the Turner-Fairbank Highway Research Center: *Pavement Markings and Delineation for Older Drivers* (20), *Intersection Geometric Design and Operational Guidelines for Older Drivers and Pedestrians* (21), and recently the *Older Driver Highway Design Handbook* (22).

The investment of DOT in ITS has highlighted research and encouraged the automobile industry to examine the application of in-vehicle telematics to improve the automobile. For example, many of these technologies may

provide emergency services or may help compensate for diminished function (e.g., night vision).

## Public and Alternative Transportation

The federal role in public and alternative transportation for older people primarily has been to fund new infrastructure and operations. However, U.S. DOT has sponsored studies and demonstrations that attempt to address the needs of older people. Because of the ADA, public transportation systems are more sensitive and proactive in meeting the physical accessibility of many older people; others are examining the role of security, better lighting, and other characteristics that may encourage older people to use transit.

Research in the areas of access and innovative demand response and related paratransit systems has been ongoing for more than 30 years. Now increased computer power and reduced cost of computation are stimulating a renewed interest in computer-aided dispatch and vehicle location systems, which may improve service for older people and reduce the cost of operations. Leveraging ITS funds, the Federal Transit Administration (FTA) is conducting research on how the availability and affordability of information technology could improve paratransit and dial-a-ride systems.

In addition to the research on technology innovation, FTA funded a research and evaluation project to examine the efficacy of Maine's Independent Transportation Network (ITN). ITN offers a new approach to meeting the mobility needs of older people by using a network of volunteers, automobiles, and innovative marketing appeals (e.g., frequent rider benefits). ITN has shown promising results and is being assessed for successful replication elsewhere (23).

Both FTA and HHS have worked to improve the coordination of transportation and human services transportation resources to provide optimal mobility within current resources. Although older people are not the sole focus, research and the resulting guidelines for the states could improve the availability, cost, and responsiveness of alternative transportation systems. The joint DOT and HHS Coordination Council for Access and Mobility recently issued *Planning Guidelines for Coordinated State and Local Specialized Transportation Services* to encourage state and local governments to coordinate transportation and human services transportation investments (24).

## Walking and Community Design

Although not typically within the federal role, improving older pedestrians' access and safety has gained some

attention. Most efforts in this area support research to inform state and local authorities on age-sensitive planning and operations (e.g., traffic signal timing). For example, FHWA has developed pedestrian design guidelines that benefit older people.

In addition, the debate over the costs of urban sprawl and the livability of communities has provided an opportunity for a dialogue on how the design of non-car-dependent communities could benefit older people. Although not well funded, continuing research and discussion on this topic and the link to environmental–energy benefits could yield an innovative lifestyle alternative for pre-older people (age 50–54), who might consider moving to new transit- and pedestrian-oriented developments to age in place.

### **State and Local Policy Making: The Politics of Implementation**

Although federal transportation policy for older people can be characterized by bureaucratic incrementalism, transportation and aging in the states can be explained best by an issue attention cycle, which is driven by news events that define the older-driver problem instead of discussing older people’s mobility.

Policy discussion typically is initiated by an accident involving an older driver. If another person is injured or killed, the family or interested parties may mobilize and define the accident as part of a larger problem of older drivers. The media coverage of the accident combined with the actions of the victim group bring attention to the problem and use the opportunity to demand better testing of older people or age-based license restrictions. However, as the issue is displaced from public view by other events, the media and public’s interest in the topic wanes and then disappears until the next accident (25).

Although beyond the public eye, the victim group mobilizes to pass legislation to mitigate the perception of an older-driver problem. They confront a political process that stifles new issues from attaining action by policy makers. Interested legislators may become involved and submit draft legislation to change the state’s driver licensing rules governing older drivers (e.g., requiring vision or road testing at a certain age). If hearings are conducted, the inherent complexity of what is an older or impaired driver, combined with the lack of a clear solution, such as a cost-effective test or a viable alternative to the automobile, makes the sponsoring legislator less passionate and limits the support from others in the legislature. In addition, opponents mobilize to counter that age-based testing inherently is unfair and inappropriate. They define the attempts of the people seeking the regulation as misguided or blinded by ageism (26). The ensuing conflict in most states leads to legislation that is lost in committee, or to

symbolic legislation that often resembles what already may be possible under current law (e.g., driver review by a driver licensing Medical Advisory Board). When action is taken, the most frequent outcome is legislation that reduces the time between renewals for older drivers and requires a vision test. In some cases, such as Connecticut, vision testing for older people symbolically is passed, only to have implementation stalled because of a lack of funding.

Driven by events, this dynamic conflict plays out annually in nearly every state. Unfortunately, real policy initiatives to support the mobility needs of older people are not nearly as ubiquitous. The cycle is often short lived and does not gain sufficient momentum to address the larger question of lifelong mobility, including licensing and alternatives to driving. Policy in the states and local communities can be defined as driver licensing and regulation, alternative transportation, and community initiatives around walking and zoning.

Driver relicensing in the states reflects a range of options, and pluralism characterizes policies nationwide. The policy changes in license renewal practices were identified from three information sources: the American Automobile Association’s (AAA) compilation of rules for state driver licenses for 1989 and 1999 (27, 28), the relevant websites for state government agencies dealing with licenses,<sup>3</sup> and phone calls to the state agencies when the data from AAA and the websites were incomplete.

These data provided a baseline and a means to identify policy innovation over the last decade. An effort was made to determine if states had become more or less strict with drivers in general and with older drivers in particular. If only one state changed a practice in the past decade, no change was indicated. However, if more than one state dropped or added a regulation, the change was noted as a trend.

### **Standards for All Drivers (1989–1999)**

Standards governing all drivers refer to drivers without violations or other incidents or issues to warrant closer scrutiny by licensing officials. Five categories of practices were examined: length of license or time between renewals, renewal by mail, in-person testing, review of past driving record, and restricted licenses.

#### *Length of License*

There was a definite trend toward a longer fixed-length license. The number of states with the 4-year renewal

<sup>3</sup>The agencies usually are the departments of motor vehicles.



dropped from 39 in 1989 to 24 in 1999; the number of states with the 5-year renewal increased from 4 in 1989 to 16 in 1999. In addition, no state had longer than a 5-year license in 1989, but 10 years later, 5 states had 6- to 8-year licenses.

### *Renewal by Mail*

The number of states permitting mail-in renewal increased from 22 in 1989—including the District of Columbia—to 28 in 1999.

### *In-Person Testing*

- Vision test. There were no basic changes in a decade in terms of reliance on the visual acuity test (using the 20/40 measurement), which was the most widely used. In 1989, 35 states and the District of Columbia required a vision test for all ages. Ten years later, 34 states and the district required a vision test.

- Knowledge test. There was no change in the number of states administering a written test as part of the renewal process.

- Road test. No state required a road test for all drivers in either 1989 or 1999.

### *Review of Past Driving Record*

Several states used the criterion of past driving record to administer additional tests in 1989.

### *Restricted Licenses*

This option included restrictions on drivers by time of day, distance from home, and trip purpose. The *AAA Digest* did not record information on restricted licenses in 1989. However, U.S. DOT conducted an examination of restricted license use by all states (29). A comparison was not possible, given the missing data for a few states, but the overall pattern showed no change.

### **Requirements for Older Drivers (1989–1999)**

The pattern was mixed on more rigorous state testing and assessment of older-driver abilities at the time of renewal. Generally, the states that changed regulations governing older drivers opted to reduce the period between renewals, which enabled examiners to determine whether the discretionary use of a vision or road test was warranted.

### *Who Is an Older Driver?*

There was no standard agreement among the states about the definition of an older driver, with the range varying from age 60 (Arizona) to age 75 (Illinois). The most frequent criterion was age 70 or 75, but diversity in interpretation prevailed.

### *Length of License*

There was a definite movement toward shortening the license length for older drivers. Within 10 years, 11 states had adopted this strategy, increasing from 4 in 1989. The shorter intervals varied in length from 1 to 4 years, with the most common practice being 2 years. There was an increase from 2 states to 15 states in the adoption of the same strategy for younger drivers.

### *In-Person Testing*

Overall road and knowledge tests appeared to be less attractive options; however, regulatory change resulted in an increase in the use of the vision test for older people.

- Vision test. In 1989, 4 states administered a vision test specifically to older people; 10 years later, 11 states required a vision test for older drivers.

- Knowledge test. Only two states and the District of Columbia required a written test for older drivers in 1989. In 1999, only one state and the District of Columbia maintained this requirement.

- Road test. Road testing was less popular with the passage of time. In 1989, four states—Hawaii, Indiana, Illinois, and New Hampshire, plus the District of Columbia—required a road test at a particular age, most frequently age 75. In 1999 that requirement was found in only two states—Illinois and New Hampshire, plus the District of Columbia.

### *Denial of Mail-In Renewal Privileges*

The mail-in renewal option was not pursued in 1989, but some states had explored it. In 1999, four states did not permit mail-in renewals after a driver reached a certain age; three states—California, Louisiana, and New York—used age 70 as a marker, and one state—Iowa—used age 65 as a marker.

### *Review of Past Driving Record*

There was no evidence that state agencies had perused past records of violations any more closely for older drivers than for other age groups.



### *Restricted Licenses*

All but three U.S. states had a restricted license option, although not age related. Cobb and Coughlin (30) found that many state licensing examiners viewed graduated or restricted licensing as a useful alternative for older drivers with capacity problems, thus facilitating limited mobility for daily activities but reducing the risk of accident. Three types of restricted licenses were common, particularly in rural states: time of day, radius or function, and road access. The most frequent limitation was time of day, with fewer states regulating road or radius driving.

### **DRIVER LICENSING POLICY TRENDS IN THE PAST DECADE**

When any driver, regardless of age, comes up for license renewal, a series of meetings or information exchanges can serve as an evaluation or testing venue: frequency of appearance (length of license), ability to avoid the meeting (mail-in renewal), and three types of testing (vision, knowledge, and road). For all drivers, the renewal process is not restrictive. Most states have increased the license length, permitted mail-in renewals, and dropped all tests except the vision test. For older drivers, the picture is slightly more complicated. Testing for driver knowledge was used neither more nor less frequently. Vision testing of older drivers increased, but road testing dropped in use.

States appear to regulate seniors by shortening license length and forcing an in-person appearance. The emphasis is on a visual inspection by the examiner instead of the administration of a test. As Cobb and Coughlin (30) found in their earlier study of driver examiners, the most important criterion was described as “what they looked like coming through the door.” The testing procedure that most closely approximates driving is the road test. Never popular to begin with and given limited state resources and public patience at licensing bureaus, this test is on the way out. The renewal process basically affirms a person’s right to drive instead of thoroughly and regularly evaluating the person’s skills.

Most of the regulations focus on identifying the unsafe driver through a knowledge, vision, or road test. However, evaluative research has produced mixed results at best for the use of any of these strategies for identifying the hazardous driver (31–35). Even attempts to limit unsafe driving through a restricted license have not been able to eliminate problematic driving (36, 37). Driving involves a combination of vision, cognitive, and motor skills, combined with experience. These situations are difficult to replicate in a renewal process that often is characterized by

severely limited technical, personnel, and physical resources. A better test frequently is called for as a policy solution, but the political support to invest additional public funds in state licensing bureaus is doubtful. In the absence of a clear solution that is technically, financially, and operationally effective and politically acceptable, a licensing policy consensus remains elusive.

Maryland is developing a pilot program that is both multiagency and multiservice and that promises to respond to the mobility and personal needs of the older driver. The Maryland Motor Vehicle Administration, the state’s Departments of Health and Aging, and other participants from federal and county agencies are working together to identify an impaired driver from medical, enforcement, and other data. The agencies also are implementing a strategy to promote optimal mobility. For some drivers, this strategy could mean the imposition of graduated restrictions, rehabilitation and education, or transitioning to the use of alternative transportation. This model program may serve as an instructive, easily replicated, and politically feasible policy alternative for other locations in the United States.

### **Public and Alternative Transportation**

Although the discussion of transportation and aging at the state level generally centers on relicensing issues, an increasing number of jurisdictions are more aware that the policy issue must center on mobility—for both drivers and nondrivers.

New Hampshire, for example, is considering a policy of graduated delicensing for older people. But at least one member of the New Hampshire State Transportation Safety Task Force admitted that this delicensing will be “a really tough issue,” because like many states, “New Hampshire has almost no public transportation. There is no way for these people to get around, other than driving. It’s important. It’s their link to the world” (38).

For older people who no longer may choose to drive or who no longer can drive, providing a transportation choice becomes a critical component of a transportation policy for an aging society. However, as the New Hampshire official observed, many regions of the country have few, if any, transportation options. Many rural and many suburban areas do not offer transportation alternatives. FTA’s Nonurbanized Area Formula Program has stimulated some state and county transportation services. However, like their urban paratransit counterparts, these services typically are underfunded and overwhelmed by demand and high operating costs.

In metropolitan regions, state and local transportation services reflect federal program priorities to support the mobility needs of specific populations, such as poor

people and people in need of health-related trips, nutrition support, and so forth. Incremental improvements to large transit systems in urban areas have made fixed-route services more accessible, but paratransit operators—often as part of a regional public transportation authority—have found the demand “exploding.”

The provision of alternative transportation—particularly door-to-door services—for older people is complicated by the cost of operations, service quality, and availability. Burkhardt et al. (8), Cervero (39), and others have cited the high cost of providing quality paratransit services to older people or any other population. Operating van or car services that typically run below capacity does not optimize driver time and vehicle productivity. Providing trips for the range of demands of older people often is beyond the technological and personnel resources of most services. Although not entirely dedicated to the mobility needs of older people, HHS estimated that the department funds more than \$6 billion in transportation services annually to support human services programs in aging, education, welfare-to-work, and so forth. The combination of HHS and DOT subsidies, combined with state and local funds, represents a significant investment in transportation beyond fixed bus and rail systems.

Despite this investment, quality of service often fails to meet the needs and expectations of older transportation consumers. Operators are forced to prioritize the trip needs of older riders by implementing a policy of mobility triage: travel demands for health and food services receive priority, and the remaining trips—for example, for social, entertainment, religious, and volunteer purposes—which also are crucial to healthy aging, are secondary or not supported at all (40). In some instances, riders are faced with inordinately long delays or lack of service. Local providers, such as town senior centers, must operate on particularly stringent budgets, because the centers compete with a range of community demands from roads to schools. Consequently, the transportation policy of local governments often supports only the most basic mobility needs with shared vehicles (e.g., school district vans and buses) or with vouchers for taxis when available.

Alternative transportation services are equally frustrating for providers. Poor service quality often results in negative publicity and criticism from public officials for what may be an otherwise efficient provider. Demand-response services provided by a larger public transportation paratransit authority may fall outside the normal operations and skills of a transit facility. Often small and medium transit providers are more familiar and more effective with fixed-route bus or rail services. Paratransit lacks operational predictability and does not fit readily into the same management or logistics paradigm of directing a bus or rail system.

Although demand-response services represent one of the fastest-growing portions of transit ridership, many providers have started to manage their high costs and public criticism of service quality by pursuing a policy of demand diversion. Demand diversion is an attempt to curtail older and disabled passenger demand for paratransit services by directing these passengers to use fixed-route bus and rail services.

For example, the Los Angeles Metropolitan Transportation Authority Board recently approved a plan proposed by its paratransit provider to manage the surging demand for paratransit rides, which has grown 20% to 30% annually. The strategy includes training riders to use fixed-route buses and trains and improving use of agency databases to ensure that people who are eligible for paratransit on a trip-by-trip basis only use the system when necessary (41). Clearly, the increase in demand for these services indicates a pressing mobility need and preference that the current services are unable to provide. But a policy of demand diversion does not appear to offer adequate transportation choices to the aging. Despite the results in Los Angeles, demand diversion is being pursued in other regions to reduce paratransit costs for transportation and human services providers.

### Walking and Community Design

Policy and guidance supporting pedestrian access is the most difficult to characterize because of the peculiarities and preferences of individual communities. Local zoning, permits, and history most often dictate the construction of walkways and the connectivity of services within a community.

Some localities have developed strategies to make pedestrian movement for all ages safer. For example, the Boston Indicators Project selected transportation as one of the key elements of a livable community and sought to develop performance measures that would enhance the walking experience of Boston residents. Other communities have used geographical information systems to identify high-pedestrian use areas around senior centers, hospitals, and similar facilities as a target for improvements and safety problem resolutions. These analyses have helped planners to place benches for sitting, traffic engineers to slow traffic signals near senior centers, and school personnel to accommodate slower-moving older people and children.

Despite these incremental improvements, rapid growth and bucolic aesthetics weigh heavily on many communities. Rapid growth in many towns has caused sidewalks to be absorbed by widening highways for the accommodation of increases in vehicle traffic. Ironically, the desire for a more peaceful, rural flavor in many suburban communities has caused some local

authorities to see sidewalks as unattractive. Similarly, the desire to preserve open space in the face of rapid growth has convinced many towns to require 1- and 2-acre parcels for building new homes and to place new senior housing on public land that is far from community services. In both cases, this distance by design prohibits walking as a viable choice and increases the challenge for transit alternatives (42).

## Individual Responsibility and Private-Sector Participation

### *Driving*

Although considerable confidence is placed in the efficacy of wisely crafted public policy, individual behavior and responsibility are the strongest foundation for older people's mobility. The information and instruction from programs such as the American Association of Retired Persons' 55 Alive or AAA's older-driver information videotapes provide valuable tools for older people to self-evaluate and assess their driving skills.

Self-regulation remains the mainstay of older-driver safety policy in the United States. Most older people choose to restrict their mobility at night if night vision is a problem, stay off Interstates if speed and large trucks are problematic, or only make trips in the neighborhood for food and the activities of daily living if highways are a problem.

Heralding self-regulation, however, as a great success or as a reason not to declare a growing mobility gap for older people may be misguided. Although self-regulation may contribute to traffic safety, often the fact is forgotten that reduced trip making also may mean reductions in quality of life. Not driving at night means that seeing a movie with a friend is less likely. Not traveling on an Interstate may mean one less visit to a grandchild. Not going beyond the immediate community may mean one less worker or volunteer. In taking measure of the traffic-safety benefits of self-regulation in discussions of the transportation needs of older people, policy makers also should consider that there could be commensurate reductions in full participation.

Until recently, the auto industry has been relatively quiet on the issue of older drivers. However, as the number of older drivers increases, several manufacturers and their suppliers are focusing on the needs of older drivers. Ford Motor Company's Third Age Driver Program seeks to develop improved ergonomic designs for drivers age 50 or older. General Motors has invested in integrating new technologies to compensate for some of the declines that result from the natural aging process (e.g., night vision). Some manufacturers are examining specific older-driver and older-passenger biomechanics,

which someday may reduce the fatality rate of older drivers—so that older drivers do not die from injuries that younger people would survive. The auto industry and suppliers should be encouraged to continue developing designs and technologies that will have universal appeal and safety.

### *Public and Alternative Transportation*

The first alternative transportation mode of choice remains riding in a car with friends and family. This choice reflects the personal preferences of passengers who wish to share the company, security, and convenience of riding with a friend. Clearly, these attributes must be studied further and replicated in any transportation option that is likely to serve as a true transportation alternative to driving. The use of volunteer car drivers in Maine's ITN comes the closest to matching these market characteristics. ITN approaches the transportation needs of older people as a consumer demand instead of as a social service supporting a basic need.

Religious institutions and volunteer organizations often provide the backbone of support in many regions, particularly rural areas. For example, religious groups provide phone chains of people that can take older people to the store, church or temple, medical appointments, and so forth. Friends in Service Helping and other community volunteer groups provide lists of people who can provide health care and other selected trips. In many instances, these services provide the additional functions of increasing social contact and engaging older people in the community.

Taxis are perhaps the greatest underused resource (40). Suffering in part from poor image and the perception—or reality—of high costs, taxi services, when available, do not attract the demand that they should. The perception of cost is a barrier to taxi use and to the development of other market solutions for the alternative transportation problem. The true cost of owning and operating an automobile remains underappreciated by most consumers, both young and old. Additional research needs to be conducted on the true cost of owning an automobile and how these costs can be reallocated to fund transportation alternatives. However, this work will be productive only if conducted with an understanding on how middle-age and older people make resource decisions about the future (e.g., savings for retirement and transportation).

### *Walking and Community Design*

The private sector could make a greater contribution than government to the walking safety and livability of

communities. Planners and developers are considering transit-oriented development and reengineered town centers. Encouragement from all levels of government should be forthcoming to see if the various experiments in design are attractive to all ages. This support could take the form of tax breaks, zoning relief, coinvestment in public transportation facilities to connect developments, and so forth. In contrast, for builders who choose to develop far from public transportation, commercial centers, and community services, land use extractions to support transportation for older people should be demanded to finance sidewalks as well as to provide community transportation and other services.

### CRAFTING POLICY FOR AN AGING SOCIETY: MUDDLING THROUGH

Lindblom (43) has described policy making as the process of muddling through. Transportation policy making for an aging society over the past 10 years, and for the foreseeable future, appears likely to continue the struggle for serious attention from the general public and policy makers. Given the lack of attention and investment, the policy area of transportation has done remarkably well to obtain the passionate support of researchers, service providers, and officials at various levels of government.

The basic characteristics of the policy process and of the issue frustrate any real movement of transportation for an aging society to the top of the policy-making agenda. First, the policy agendas at all levels of government are crowded, and only so many issues are considered at one time. Transportation must compete with other issues that demand the attention of the general public and decision makers on a regular basis, including health care, social security, and crime.

A second hurdle of policy making is the process required to get on the public and government agendas. Typically, issues that do not command much attention must be compelled onto an agenda through a natural or manmade event. Transportation rarely occupies high-agenda status, except when an accident occurs such as a plane crash or other large disaster. For example, the state of the U.S. Interstate infrastructure was a nonissue until a section of I-95 collapsed in Connecticut, killing people who traveled on that busy corridor. Transportation for a specific segment of the population is even more difficult to get onto a policy agenda, because no trigger event occurred to grab the public's attention. Road fatalities occur locally and even then maintain only a short period of public scrutiny. Finally, assuming that a national policy is developed or the elements are crafted, the U.S. federal system does not implement policy easily through the national, state, and

local levels of governance. Differences in resources, regional perceptions of the problem, and institutional capacity often confound the best-made policy.

In addition to system barriers, the issue of the transportation needs of an aging society suffers from certain attributes that make support difficult to gain. First, most issues that move forward without the benefit of an event to focus the public's attention have an issue entrepreneur who can gain visibility and define the problem as urgent and worthy of government action. For example, auto safety remained a dormant issue until Ralph Nader's book *Unsafe at Any Speed* placed the issue before the media and the general public. A similarly skilled policy entrepreneur has yet to emerge for older people's mobility.

Second, in the absence of a single-issue leader, there is no natural coalition to mobilize and generate national interest in older people's mobility. Transportation is important to all but is owned by none. Gusfield (44) has observed that issues become the property of particular groups and their interest sustains and promotes the issues. Because the drunk driver issue had not been championed, Mothers Against Drunk Driving took up the issue and mobilized support. Transportation for older people is largely the interest of several researchers and a few government officials. A large organization or group has not mobilized to move the issue further in the policy process.

Finally, the issue does not elicit natural passion from people. Most people consider driving a lifelong option and do not consider transportation a problem until transportation fails. Unfortunately, the issue does not attract individual attention or investment as a public issue or a personal problem.

### FUTURE POLICY RESEARCH STRATEGIES AND DIRECTIONS

Future policy research should not seek individual benefits but should reflect an overall strategy to gain the general public's attention, spur innovation, and introduce new players to the discussion. For example, continued efforts to place the issue on the national, state, and local policy agenda should continue; however, there should be similar efforts to focus individuals on their transportation needs as they age. A series of specific recommendations and initiatives follows.

#### Agenda Setting and Education

- Educate state policy makers about aging.
- Promote alternative transportation as a mode, not as a social policy tool only.



- Reinvent licensing bureaus as mobility resource centers.
- Earmark funding and fees to build organizational capacity.
- Encourage automakers to provide education on new technologies.
- Implement the highway design guidelines recommended by FHWA (45).

Public and private investment in transportation innovation must continue. These investments should not only increase auto safety for drivers and passengers but also stimulate new ways of providing alternative transportation or entirely new service concepts, which may fall outside the current institutional capacity of providers. Only when these solutions are available will decision makers choose to address the mobility needs of older people. Policy making usually is about linking problems and solutions, not about identifying problems without readily acceptable and affordable solutions.

### Technological Innovation

- Invest in R&D for new auto technologies to address unique safety and operational issues associated with older drivers and passengers (e.g., driver workload, older women's safety, and passenger ingress and egress).
- Define an effective, cost-effective test regime to sample all drivers for fitness.
- Demonstrate and evaluate the White House National Science and Technology Council's 1997 recommendations to develop a regional mobility management system that would provide a basis for the next generation of paratransit systems for all ages.

Finally, significant research has been conducted on travel behaviors, technological innovations, and service provisions, but the true strategic challenge may be to understand personal lifestyle and transportation decision making as people age. That is, make transportation for an aging society an issue for personal attention, like the issues of retirement saving and health insurance. Where people choose to age, how they allocate their resources, and what their range of mobility choices are when they are older ultimately will be most affected by personal decisions and lifestyles.

### Leverage and Stimulation of Markets

- Promote industry R&D and the affordability of new technologies through federal tax incentives.

- Urge the insurance industry to provide technology discounts for the use of safety technologies.
- Amend state liability statutes to extend protection to volunteer driver networks, and educate volunteers about these protections.
- Conduct research on the assessment of the efficacy and market potential of transit-oriented development and livable communities for middle-age and young-old people who may be looking for a new home to age in place.
- Encourage individuals to plan and save for future mobility needs, thereby creating new markets for both private and public services.

### CONCLUSION

More than a decade ago, *Special Report 218* opened with a discussion of how the older population will differ from generations past. The report observed that older people's improved health, education, and income status, combined with their expectations to continue driving, demanded that attention be given to the anticipation of future transportation needs for an aging society. The argument remains valid. Modest, incremental policy progress has been made. The auto industry and others are focusing more on the needs of older drivers, there is now greater flexibility in funding for driving alternatives, and a broader discussion of community design and sustainability for an aging population has begun. However, the speed with which the United States is aging compared with the glacial pace of the policy making and implementation process does not draw a trajectory that predicts adequately meeting the transportation needs of tomorrow's older Americans.

No single group, government agency, or individual has emerged to build and lead a coalition that would ensure that adequate investments in institutions and infrastructures are made to meet the impending mobility gap for aging baby boomers. Until a single, articulate, and resourceful leader emerges, transportation for older people will continue to languish between government agencies, will be only one of a series of services within multiple programs, and will be defined as a private problem—but one that is sure to become a passionate political issue in years to come.

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# Conference and Postconference Reports

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# Focus Group Participants Reflect on Transportation

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This project extends the national dialog on improving the transportation system, including input from seniors and lay caregivers. Policy makers and planners tend to develop plans and strategies, which they think are best for people. But there is a growing recognition that it is important to listen to seniors and involve them in determining the strategies and policies that affect their—and ultimately everyone’s—future.

A series of focus groups was conducted to obtain first-hand accounts from seniors and lay caregivers about their experiences, concerns, and hopes. The project was a partnership effort among a group of national organizations and a variety of community and grassroots organizations that embraced the project and drew on local networks to recruit participants for the focus groups. The partners are listed in Table 1.

## PURPOSE

The focus groups had a threefold purpose:

- To gather opinion data on driving and transportation issues,
- To identify solutions and improvements beneficial to seniors, and
- To send a message to seniors that their opinions and concerns are important and will be reflected in a national agenda and strategic plan for improving transportation.

The reasons for the focus groups were to

- Find out the current, short-term, and long-term perspectives of seniors and lay caregivers;
- Know the extent to which the participants support the recommended actions from community forums with local professionals and practitioners; and
- Obtain additional suggestions for the transportation needs of seniors.

## METHOD

The focus groups followed a series of community forums with local professionals in California, Florida, and Michigan. Twenty-two focus groups were conducted, each lasting about 2 hours and involving 7 to 10 participants. Three audiences were targeted for participation:

- Transportation-rich seniors—people age 65 or older who live in areas with transportation services available at least 6 days a week within a mile of home (9 groups, 84 participants).
- Transportation-deprived seniors—people at least age 65 and living in areas that do not have transportation available within a mile of home (7 groups, 70 participants).
- Family and friends concerned about an older person’s driving ability and mobility; most were also caregivers (6 groups, 49 participants).

Focus group methodology allowed for the collection of both qualitative and quantitative data. Each session began with about 15 open-ended statements

**TABLE 1 Partnership for Recruiting Focus Groups**

<i>National Organizations</i>
American Automobile Association Foundation for Traffic Safety
Beverly Foundation
Eno Foundation
U.S. Department of Transportation
<i>Community and Grass-Roots Organizations</i>
Brighton Senior Citizens Center (Brighton, Mich.)
Dundee Senior Center (Dundee, Mich.)
Florida Atlantic University (Boca Raton)
Focus Hope (Detroit, Mich.)
Huntington Memorial Hospital (Pasadena, Calif.)
Hudson Senior Center (Hudson, Mich.)
Interfaith Action Project (Pasadena, Calif.)
Lenawee County Department on Aging (Adrian, Mich.)
Michigan Department on Aging, Detroit Area on Aging
Morton Plant Mease Health Care, Florida Geriatric Research Program (Clearwater and Dunedin)
Pasadena Senior Center (Pasadena, Calif.)
Shepherd Center (Kalamazoo, Mich.)
Tampa Bay Area Agency on Aging (Petersburg, Fla.)
TRIP Program (Riverside, Calif.)
University of Southern California, Andrus Gerontology Center (Los Angeles)

or questions that all participants could answer, followed by a 25-question written survey. The survey included close-ended questions primarily and, for comparison, several items from a national telephone survey being conducted for the U.S. Department of Transportation. During the final phase of the focus groups, participants voted for specific, priority transportation improvements and actions.

## FOCUS GROUP RESULTS: PARTICIPANTS SPEAK OUT

The results are presented in the passionate voices of the participants themselves. “We have contributed our opinions to this effort because we are concerned about transportation for seniors, and we hope that our contribution will help improve the transportation options for seniors in our community. We speak to you with a collective voice in the hope that you will hear what we have to say as you make policies and plans for the future—our future and yours.”

### Opinions and Concerns of the Transportation Rich

#### *Who Are We?*

“We are 84 seniors who are ‘transportation rich’ because we either drive our cars or live within a mile of transportation. The following characteristics describe us.” Table 2 lists this group’s demographics.

#### *What Are Our Priorities?*

“Being able to drive is very important to us and for us. The automobile is our most ‘user-friendly’ mode of transportation. We lament the fact that driving can be so difficult. However, when we limit our driving, we see our lives becoming limited because we cannot do the things we want to do, when we want to do them. While life can be difficult if we have to limit driving, stopping will have a terrible impact on our ability to get around and perhaps on our lives in general. We are concerned that, even when public transportation is good, we may not be able to use it. The priority for those of us who

**TABLE 2 Demographics of the Transportation Rich**

<i>Demographics</i>	<i>Percent</i>	<i>Income, Health, and Driving</i>	<i>Percent</i>
Female	67	Household income <\$15,000	23
Male	31	Household income = \$15,001–30,000	36
Age 75 and over	59	Household income = \$30,001–45,000	13
Age 65–74	35	Household income = \$45,000+	18
Under age 65	7	Excellent health	16
Unmarried	71	Good health	46
Married	29	Fair health	32
		Poor health	5
		Not driving	36
		Driving with license restrictions	33
		Driving without license restriction	29

can no longer drive is for transportation that is available and adequate. However, it also is important for it to be accessible, acceptable, affordable and adaptable.”

### *What Kinds of Problems Do We Face Getting Around?*

“Many who drive are faced with problems driving at night, in unfamiliar places, and in heavy traffic and on freeways—in general, organizing our driving schedules to compensate for our limitations. We also have difficulties because we are fearful, because we lack self-confidence, especially on highways, and because we are not always able to find our way. It is not easy. Sometimes it is impossible for us to use public transit or paratransit because of our physical inability to access it, the treatment we receive from drivers, and [transit services] limited availability, especially at nights and on weekends. Some of us even think transit is beneath us. We face many hazards as pedestrians and deal with that by being ‘defensive walkers.’ All we really want from transportation is to get where we want to go, easily and on time.”

### *Are We Pedestrians?*

“Actually, very few of us identify ourselves as pedestrians except for recreation. We don’t walk because we can drive. Our ability to walk places for anything more than exercise is limited by health problems, but more than that, by traffic volume, safety concerns, traffic signals and timing, and cars turning right on red. Since very few of us are pedestrians, most of our comments relate to pedestrian problems others face.”

### *What Kind of Drivers Are We?*

“We face a variety of problems as drivers related to our driving ability, vision, reflexes, and forgetfulness. These might even be considered age-specific. But we think that many of our problems are the fault of other drivers (e.g., fast driving, not obeying the speed limit). It’s as if there is a ‘get out of the way, the world belongs to me’ mentality.”

### *Is Limiting or Stopping Driving an Alternative?*

“We know when it is necessary to stop driving at night or in heavy traffic, even though we also know we might experience difficulties because of that decision. Why? We realize that limiting or stopping driving altogether

might interfere with our ability to get to the places we want to go. It can make it difficult for us to maintain the fullness of life, to do fun things, to have an independent lifestyle. The greatest tragedy of all is that it may force us to be dependent on others. These things put fear in our hearts and may be part of the reason we do so little planning for the time we will have to stop driving.”

### *What Can Be Done to Help Us Drive Longer?*

“What do we think are the solutions to many of the problems that we face as senior drivers? One of us had a good solution: ‘It’s not what you see, it’s what you do after you see it.’ We agree with him, so it’s important for us to consider limiting our driving, driving in familiar places, driving safer cars, taking driving courses, and practicing defensive driving. We are willing to consider these and other solutions because we want to drive as long as we possibly can.”

### *What Do We Think About Senior-Driver Assessment?*

“‘Assessment’ is not a concept or term many of us understand. However, when it is explained, we often say that age-based testing, including behind-the-wheel assessment, may be a good idea, especially for other people. At the same time, we have difficulty identifying what should be tested, who should be involved, and where [the testing] should take place. We also worry about having to take tests at our age. Even though many of us think [that] it is a good idea, a lot of us worry that the real purpose of assessment is to get seniors off the road. Actually, what we really believe is that seniors should be self-motivated to stop driving.”

### *What Do We Know About Our Transportation Options?*

“Although we believe that the most user-friendly transportation option is the car, we know of many others, including family and friends, church volunteer drivers, sharing rides with neighbors, taxis, shuttle services, and buses. The primary motivations for those of us who use public transit are to save money and time and to be able to get where we need to go. However, even when public transportation is good, it can be frustrating and time consuming. It also can be difficult to move from one community to another. If we no longer drive, we would be especially enthusiastic about informal transportation systems, such as church volunteer groups and sharing rides with neighbors. We also

would view transportation that is ‘just for seniors’ very positively. We are generally dissatisfied with most of our [nondriving] options because although they may enable us to take care of the necessities, most of them don’t allow us to do fun things.”

### Opinions and Concerns of the Transportation-Deprived

#### *Who Are We?*

“We are 70 seniors who are ‘transportation-deprived’ because we have limited our driving or no longer drive at all, and we live more than 1 mile from public transportation.” Table 3 lists this group’s demographics.

#### *What Are Our Priorities?*

“As seniors who are considered transportation-deprived, we try to drive as long as possible and stop driving mainly because we experience health or physical problems. These problems not only make it difficult or impossible for us to drive but also [make it] difficult or impossible for us to use public transportation. What we need goes beyond having transportation available. We also need transportation that

- We can access regardless of our health conditions,
- We can afford even if we have financial problems,
- Is accessible regardless of whether we live within a block or a mile of it, and
- Can be adapted to our needs in a way that will allow us to do the essentials as well as some fun things in life.

“Rather than try to use public transportation, we often try to mix formal (social and aging services) and informal (family, friends, and volunteer) options to

meet our basic transportation needs. In all honesty, when we are able to drive, we do not consider ourselves to be transportation-deprived, regardless of whether public or paratransit services are available.”

### *What Kinds of Problems Do We Face Getting Around?*

“We have special problems when we drive at night, in heavy traffic, or in unfamiliar places. Those of us who drive need to be defensive drivers. We associate many senior-driver problems with other road users, busy roads, poor road design, and personal difficulties arising from health limitations. When we can no longer drive, we have special problems because public transportation is time consuming and inflexible, and informal transportation programs require us to depend on the kindness of others. Actually, we don’t believe that our real transportation problems are related to driving but begin when we stop driving.”

#### *Are We Pedestrians?*

“Very few of us are pedestrians beyond walking for exercise or pleasure. We do not walk places for many personal reasons, including our physical conditions. We have to contend with several barriers that we think are the fault of others, including traffic, poor drivers, infrastructure problems, and other road hazards. That so few of us walk may not be difficult to understand; however, we don’t seem to care if we walk, and that may be somewhat surprising.”

#### *Is Limiting or Stopping Driving an Alternative?*

“Limiting or stopping driving can be traumatic; therefore, most of us do not limit or stop driving on our own

TABLE 3 Demographics of the Transportation-Deprived

<i>Demographics</i>	<i>Percent</i>	<i>Income, Health, and Driving</i>	<i>Percent</i>
Female	67	Household income <\$15,000	44
Male	27	Household income = \$15,001–30,000	20
Age 75 and over	73	Household income = \$30,001–45,000	10
Age 65–74	21	Household income = \$45,000+	7
Under age 65	1	Excellent health	10
Unmarried	71	Good health	37
Married	23	Fair health	36
		Not driving	36
		Driving with license restrictions	37
		Driving without license restrictions	20

accord. For this reason, it is important for us to dispose of our vehicle when we stop driving. We are not optimistic about being able to get others to stop driving by talking to them or by mandatory age-based testing. We are not sure about how effective self-regulation is as a way for us to stop driving. Many of us believe that if somebody is going to get us to stop, it should be the state’s Division of Motor Vehicles.”

***What Do We Think About Senior-Driver Assessment?***

“We are not familiar with assessment and associate it with the senior-driver improvement programs of the American Association of Retired Persons or the American Automobile Association. In all honesty, we think that assessment may be intended to take away our driver’s license. The way to get us to go for an assessment is to threaten to take away our license or to tie assessment to an incentive, such as a reduction in our insurance premiums. We are not sure about the role that doctors and other professionals, such as the DMV and insurance companies, should play in senior-driver assessment. We are not enthusiastic about promoting assessment with friends or family, nor are we interested in going in for an assessment ourselves. For many of us, our greatest fear is failure.”

***What Do We Know About Our Transportation Options?***

“Those of us who still drive a personal vehicle have the most ‘user friendly’ transportation option. Availability of the car is the key to transportation. Families, friends, and volunteers are user friendly transportation options for those who do not drive, although we know that it can be difficult to get rides from them. For those of us who do not drive, the availability of public transit or paratransit also is important, but accessibility, acceptability, adaptability, and affordability of these transportation programs are equally important.”

**Opinions and Concerns of Caregivers**

***Who Are We?***

“We are 49 people who provide transportation to a senior or are concerned about a senior who needs transportation. The following characteristics describe us.” Table 4 lists this group’s demographics.

***Does Transportation Affect Independence?***

“When they don’t drive, seniors have major problems because they may be unable to use public transportation services and are unwilling to ask for help. We are sad for them because they are often faced with the choice of staying in their homes or moving to a place that provides transportation. Driving is the key to independence for seniors. Those who drive are independent. Those who don’t are dependent.”

***Are Those We Care for Pedestrians?***

“The seniors we care for are not active pedestrians, although some may walk for exercise. Their health problems, vision impairments, and other physical disabilities prevent most of them from walking for any distance or purpose. We also know that they encounter major problems because of traffic, traffic lights, and signals. As one man among us said, ‘they [seniors] have to run like jack rabbits to cross the street before the signal changes.’”

***How Do We Feel About Senior Drivers?***

“Seniors can experience failing mental capabilities, vision problems, frailty, hearing loss, and erratic driving. Many of their problems can be age related, such as diminished depth perception, slow reaction time, diminished physical ability, getting lost, and loss of night vision. However, we have little hope that we can

**TABLE 4 Demographics of Caregivers**

<i>Demographics</i>	<i>Percent</i>	<i>Employment</i>	<i>Percent</i>
Female	76	Unemployed	43
Male	29	Employed full-time	31
Age 75 and over	20	Employed part-time	18
Age 65–74	25		
Under age 65	53		



get the seniors in our care—especially our parents—to stop driving.”

### *What Do We Know About Seniors' Problems with Public Transit?*

“The seniors we care for are not public transit users for a variety of reasons, including health and mobility problems, heat, long waits, walking distance, the need to make appointments, the amount of time that it takes to use public transit, logistics, and lack of information of available options. If seniors are able to use it, public transportation really only appears to meet their basic transportation needs. Many of those we care for believe that public transportation is beneath them.”

### *As Caregivers, What Transportation Concerns Do We Have?*

“We are concerned about family members and friends. The primary reason we are concerned is that a parent or relative of ours has become ill, disabled, or has stopped driving. Transportation is easy for those who drive but not for those who don't drive.”

### *What Are Our Feelings About License Renewal?*

“The seniors we know have a strong desire to drive their cars for as long as possible. We are appalled that in some states, no matter what their age, seniors can get a license through the mail, but at the same time, we are concerned about age-based testing. We do not know what to do about license renewal—although many of us would not hesitate to take the keys away from a parent, most of us would not want our children to take the keys away from us when we get older.”

### *What Do We Know About Senior-Driver Assessment?*

“The few of us who are familiar with driver assessment don't think it is a bad idea. We are not sure that we like the word ‘senior’ in front of driver assessment and think that perhaps everybody should be assessed, but it should be voluntary.”

### *Who Should Be Involved?*

“We think professionals, especially physicians and eye doctors, should make the assessments. Although we

believe that the DMV is the most important location for assessment, community service agencies, educational institutions, and insurance companies are alternatives. One last thing we want to say is that most of us cannot imagine taking or getting a parent, or any senior, to go for an assessment.”

### *How Do We, as Caregivers, Help with Transportation?*

“Some provide transportation to only one person; others to more than one. Some have provided transportation to one person and later to another. Others could not imagine providing it to another senior after a loved one dies. Some began assisting an older person by providing transportation to them. Others began by providing another kind of care and progressed to transportation. Some function as an ‘individual transportation service.’ Others work with informal transportation programs organized through senior centers and churches. And finally, some enjoy the experience and are fulfilled by it, but others find it a burden.”

### *Is Providing Transportation Difficult for Us?*

“Yes, we have to deal with many issues, such as scheduling, coordination, and safety. Many also have our own personal difficulties, particularly health problems. Some have found that teaming with a spouse or friend can ease the physical and logistical burden, but most would benefit by finding ways to improve scheduling, making the logistics easier, and having more hours in the day. And although we often try to facilitate other means of transportation, the absence of information about other options makes it difficult.”

### *Has Being Transportation Caregivers Affected Our Feelings About Our Own Future?*

“Many wonder how we will get around when we get old. Our experience leaves us with the general feeling that you either have to drive or have help when you are an older person. We are concerned about whether we will have to change our lifestyle, eliminate most of the fun things, become isolated, or find a caregiver to help us. We think the things that will make transportation easier for us when we get older are to stay independent, teach others to help, be willing to ask for help, and live where there is access. Most of all, we think it will be important to cultivate family and friends, especially younger friends.”

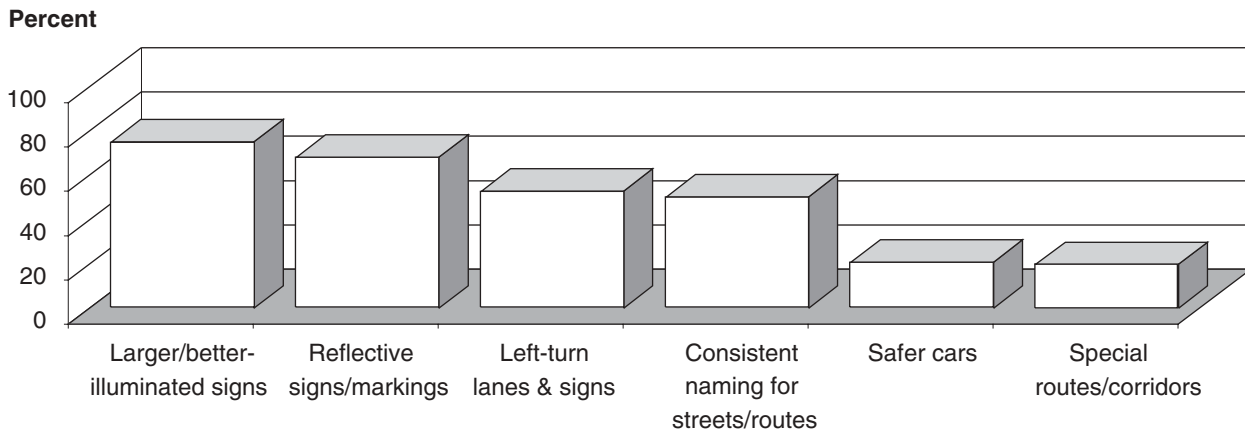


FIGURE 1 Automobile and highway priorities.

SUGGESTED TRANSPORTATION SOLUTIONS

At the conclusion of the focus groups, participants completed a written survey including a series of items asking about priority transportation actions that they believed would most benefit seniors. The choices were recommendations developed by transportation, aging, and health care authorities and practitioners who attended community forums. The actions fell within four areas: automobile and highway, driver assessment, pedestrian safety, and alternative transportation. Participants selected the top three preferences within each category. They also were given an opportunity to add new ideas and suggestions.

After recording preferences on the survey instrument, participants were asked to vote during a postsurvey discussion. Although there was some variation in responses across the three target groups, surprising consistency emerged across groups and across states. Overall results are presented below.

Automobile and Highway Priorities

Improved signage was identified as the leading priority among focus group participants (Figure 1). Particularly important were enhancements that would facilitate nighttime driving, specifically larger and better-

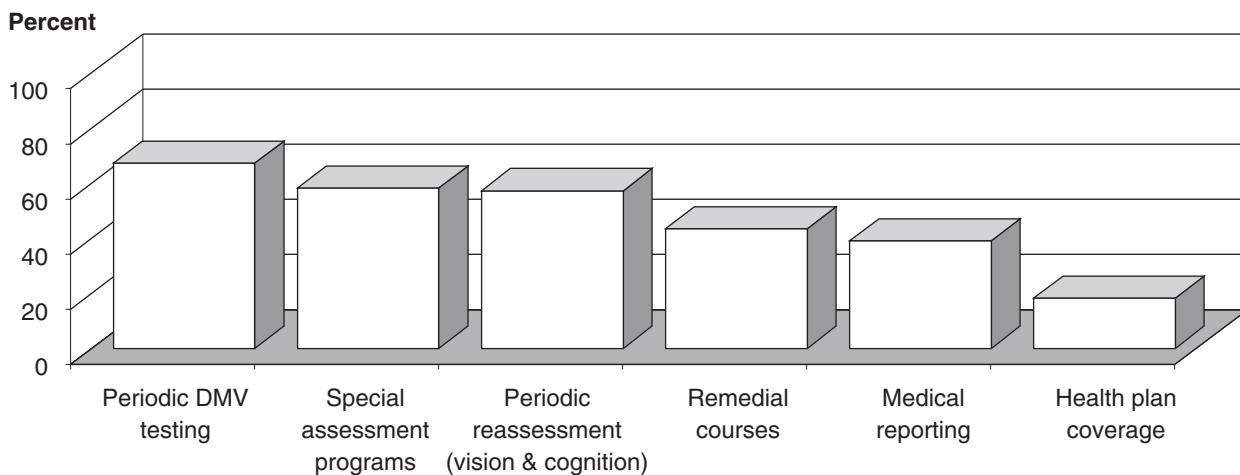


FIGURE 2 Driver assessment priorities.

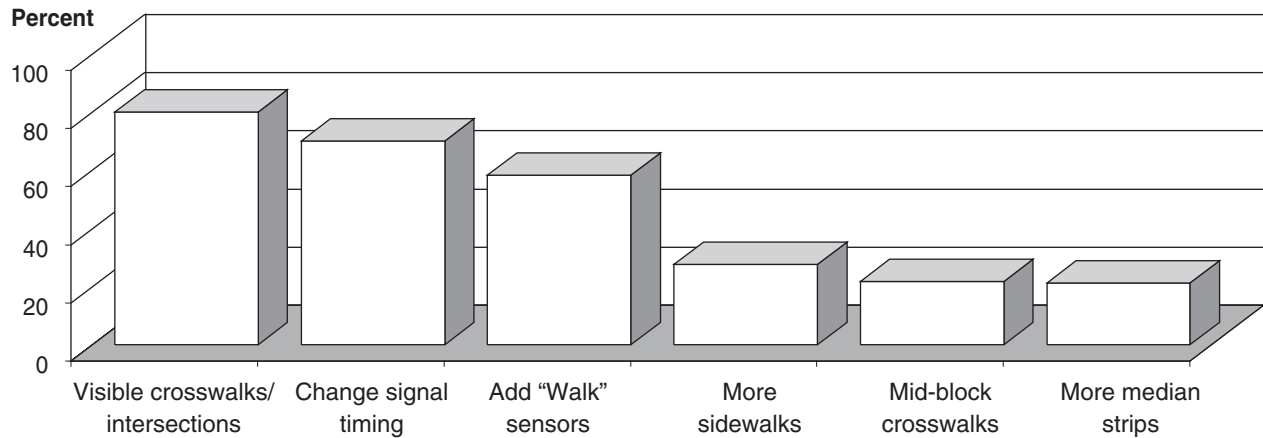


FIGURE 3 Pedestrian safety priorities.

illuminated traffic signs (75%) and reflective signs and road-edge markings (68%). Not surprisingly, dedicated lanes and signal cycles for left turns also were identified as a priority, given the difficulties that seniors often face making left turns at intersections.

#### Driver-Assessment Priorities

The three priorities were periodic reexamination of driving by a driver licensing agency (67%), special senior-driver assessment programs (58%), and periodic reassessment for vision and cognitive ability (57%; Figure 2). These results were consistent with comments that were shared during the focus group sessions. Participants associated driver assessments with license renewal and identified the DMV as having an important role in evaluating driver eligibility.

#### Pedestrian Safety Priorities

Participants identified three priorities for pedestrian safety (Figure 3): visible sidewalks and safer intersections (80%), timing of traffic signals to allow more time for the "Walk" cycle (70%), and sensors to extend the "Walk" cycle when pedestrians are present (58%). During the focus groups, problems with street crossings and inadequate signal timings were identified repeatedly as major safety problems.

#### Alternative Transportation Priorities

Priorities for alternative transportation included specialists who provide "one call does it all" information (64%); personalized subscription transportation services using vans (54%); and special kits on how to use

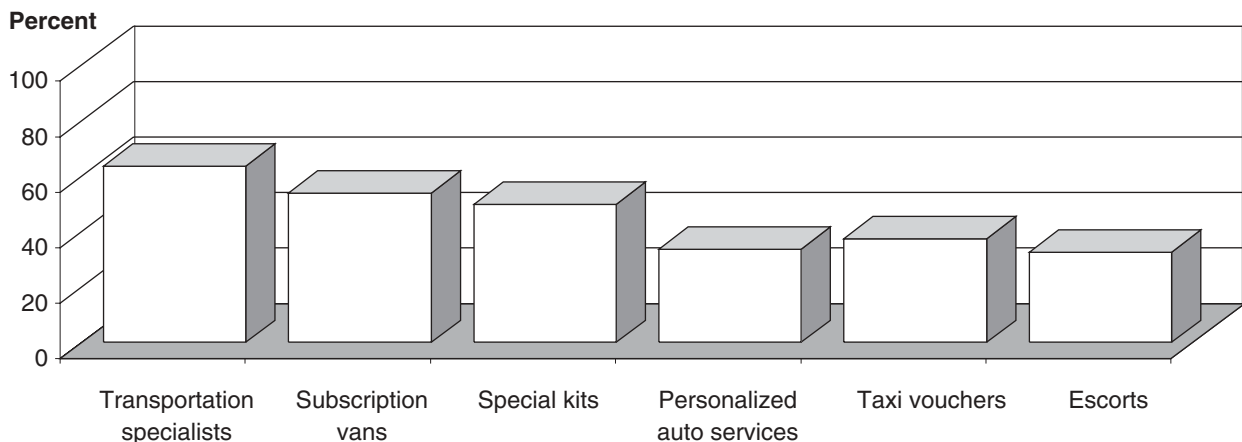


FIGURE 4 Alternative transportation priorities.

TABLE 5 Summary of Focus Group Responses

<i>Theme</i>	<i>Representative Response</i>
Private automobile	“I can’t see, can’t hear, can’t walk, but I have my car.”
Driving limitations	“I can’t read the signs very well.”
Transportation-deprived	“If you don’t drive, you’re out of luck.”
Transportation alternatives	“It’s not just availability.”
Senior pedestrians	“I can’t even walk to the john.”
Senior-driver assessment	“What is it?”
Public transportation	“Public transportation is sick.”
Informal options	“Thank goodness for volunteers.”
Transportation planning	“Being a caregiver has made me think.”
Quality of life	“It’s difficult to do the fun things.”

public transportation, map routes, and free passes (50%; Figure 4). The need for a mobility manager and public transportation kits reflects the interest of participants in more information and a single, easy-to-access point of contact. Perhaps the big surprise was the priority of personalized service with vans; however, there appeared to be much greater interest in taxis and personalized services with automobiles.

## RESPONSE SUMMARY

Focus group and written survey results can be summarized according to 10 theme areas, listed in Table 5. These themes highlight (a) the preference and need that seniors express for driving; (b) the connection that transportation has to quality of life; (c) the importance of having viable transportation options available; and (d) the availability of transportation options sufficient to ensure usage.

## CONCLUSION: FIVE A’S OF TRANSPORTATION

Because of methodological limitations related to sample size and sample selection, the results of the project were not generalizable. However, the findings substantiated previous research that has been conducted in the field and suggested important directions for program and policy makers. One of the key findings related to what

seniors and caregivers said that they need and want in transportation—the five A’s of transportation.

- *Availability* refers to whether the transportation is available when needed (e.g., evenings, weekends, and specific times of the week).
- *Accessibility* means transportation can be reached and used (e.g., the stairs on the bus can be negotiated, the seats are high enough, the van comes to the door, the bus stop is within walking distance).
- *Acceptability* relates to standards: for example, cleanliness (Is the bus clean?), safety (Are the bus stops located in safe areas?), and user-friendliness (Are the transit operators courteous and helpful?).
- *Affordability* relates to the fee, how the fee relates to driving expenses, and whether vouchers or coupons are available to defray out-of-pocket expenses.
- *Adaptability* refers to whether transportation can be modified or adjusted to meet special needs, such as wheelchair accommodation, and the potential for handling multiple errands on a single trip.

In the past, much of the discussion about transportation for seniors has focused on availability. Although clearly necessary, availability is not sufficient. In designing and implementing transportation options for seniors, transportation planners and program providers must ensure that all of the five A’s are satisfied and that community and individual user needs are met.

# Research, Development, and Program Implementation

## Conference Breakout Sessions

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Rhonda Aizenberg, *Beverly Foundation, Pasadena, California*

In 1998 the Transportation Research Board (TRB) agreed to review and follow up *Special Report 218: Transportation in an Aging Society*. A committee was formed to guide the overall process and, specifically, to develop and implement an international conference. The purposes of the conference were to review research-related and other activities completed since the release of *Special Report 218* that dealt with older people transportation issues, identify future research needs, and address the implementation of research findings.

The conference was organized around a series of themes. Each of the theme areas was informed by one or more state-of-the-art reports, developed by experts in the area. To stimulate discussion among the participants, the program included 16 breakout sessions relating to the theme areas. Presented here are the results of the breakout sessions.

### THEMES AND PAPERS

#### Data and Characteristics of Older Drivers

- Mobility of the Elderly: Good News and Bad News—Sandra Rosenbloom;
- Safety of Older Persons in Traffic—Liisa Hakamies-Blomqvist;

- Adaptive Strategies of Older Drivers—Alison Smiley;
- Driver Capabilities—Cynthia Owsley; and
- Age-Related Disease, Mobility, and Driving—Desmond O'Neill and Bonnie M. Dobbs.

#### Highway Design

- Highway Research to Enhance Safety and Mobility of Older Road Users—Frank Schieber; and
- Highway Enhancements to Improve Safety and Mobility of Older Road Users: Practical Applications—Loren Staplin.

#### Vehicle Design and Intelligent Transportation Systems

- Reducing Injuries and Fatalities to Older Drivers: Vehicle Concepts—Jeffrey Pike;
- Automotive Adaptive Equipment and Vehicle Modifications—Rodger Koppa; and
- In-Vehicle Intelligent Transportation Systems: Safety and Mobility of Older Drivers—Jeffrey Caird.

#### Driver Programs

- Driver Programs—Loren Staplin and Linda Hunt.



## Mobility Solutions

- Mobility Options for Seniors—S. Ling Suen and Lalitia Sen; and
- Surviving Without Driving: Policy Options for Safe and Sustainable Senior Mobility—Katherine Freund.

## Public Education and Information

- Impact of Public Information on Safe Transportation of Older People—Kent Milton.

## Policy

- Transportation Policy for an Aging Society: Keeping Older Americans on the Move—Roger W. Cobb and Joseph F. Coughlin.

## BREAKOUT SESSION ASSIGNMENTS

A group leader facilitated each breakout session. Some participants were assigned to specific sessions to ensure that the dialog would be comprehensive and would reflect a broad representation of backgrounds and perspectives. Participants in each session were directed to address the following:

- Background papers—identify gaps, problems, missing issues, references, and suggestions;
  - Research and development—identify and prioritize research and data needs for the short, medium, and long term to fill critical knowledge gaps;
  - Research and program implementation—identify and prioritize promising research and data that should be developed further or used through demonstrations or pilot and operational tests; and
  - National agenda—develop suggestions.

A summary of the breakout sessions is presented below.

## SUMMARY OF BREAKOUT SESSIONS

For the development of this summary, breakout sessions were audiotaped and transcribed professionally. Many ideas and suggestions were expressed repeatedly and supported enthusiastically across and within sessions. This section summarizes the ideas and suggestions, organized by the assigned tasks.

## Background Papers

The comments on the background papers were highly favorable. The participants expressed a sense of the importance and timeliness for following up *Special Report 218* and a commitment to create a final product with immediate and long-term value. They proposed that the follow-up represent a comprehensive treatment of senior transportation issues and address the overall transportation system, including walking, public transportation, paratransit and specialized senior transportation services, and informal supplemental transportation options. These topics were considered imperative in relation to the demographic trends and the growing number and percentage of adults age 85 or older who are especially at risk of functional changes that may interfere with driving and may require the use of other forms of mobility.

The connection between land use and transportation also was identified as a subject for critical examination. Specific references were made to how land use patterns and policies affect traffic collisions, traffic casualties, and transit options. The participants strongly favored an in-depth analysis of these relationships in the follow-up. In response to these suggestions, TRB commissioned additional background papers on pedestrians (by Oxley, Fildes, and Dewar, pp. 167–191) and on land use (by Giuliano, pp. 192–210) after the international conference to ensure that the current state of knowledge in both of these areas was synthesized and used to inform future research, program, and policy direction.

Other comments by participants underscored the importance of a strong focus on the future. The participants stressed repeatedly that it is not sufficient to address only current thinking in the field and lessons learned since the release of *Special Report 218*. It is equally important to envision the future, so that realistic and feasible solutions can be identified. Suggestions focused on the value of exploring international and global experiences and technological advances, especially advances in the communications arena. Finally, there was considerable discussion during the breakout sessions about the need for consistency across the background papers in the conclusions drawn from available data and the use of measures and terminology. Examples included a uniform cutoff age to define the older population and the health-related correlates—such as illness, disability, and functional limitations—of driving performance and transportation options.

## Research and Development

In the breakout sessions, participants proposed research and data needs and identified the top three to five pri-

orities. The following text summarizes the discussion points. In some cases, a listing of specific recommendations for further research follows. (More detailed results from the breakout sessions can be found in the boxes on pages 308–312.)

### *Economic Analysis*

Several recommendations focused on the economics of transportation and the need to better understand the costs and benefits of transportation choices. Participants repeatedly pointed to the social benefits of mobility and to current linkages among transportation, quality of life, and health care. Comments were made repeatedly about the importance that transportation brings to aging in place “healthfully.” Many participants emphasized the need for further research to quantify these linkages.

- Evaluate how transportation relates to health status and how the loss of mobility affects health care costs.
- Evaluate the economics of nonmobility to the individual, family, and community.
- Analyze the costs and benefits of driver-assessment programs, highway treatments, and transportation options, including an examination of the cost-effectiveness of health-care–provided transportation for patients.

### *Driver Screening, Assessment, and Remediation*

Many suggestions fell within this category. Participants noted the lack of consensus on the purpose of driver screening and assessment, the factors that distinguish screening from assessment or referral, the criteria used to screen and assess, and the outcome measures for evaluating program effectiveness.

Problems were acknowledged with using crash involvement and crash causation as outcome measures, given that crashes are rare events. The development of valid, surrogate indicators was considered a priority. The participants also recognized the need to prepare certification standards and guidelines for professionals who conduct the assessments.

- Determine whether there is value in screening and assessing drivers, and if so, determine what kinds of assessments should occur.
  - Develop valid and reliable screening and assessment tools.
  - Establish the minimal thresholds of performance.
  - Operationalize an assessment cascade or levels of assessment.

- Conduct research that conclusively determines the physical and cognitive factors that increase collision risk and research that develops a hierarchy of risk factors.
  - Examine the costs and benefits of routine screening and the barriers for people seeking driver assessment.
  - Evaluate the remedial potential of different risk factors.
  - Develop corrective and mitigating strategies.
  - Examine the outcomes of remediation efforts to determine how participants subsequently perform on the road.

### *Universal Transportation Design*

A series of suggestions dealt with the design of universally accessible transportation that meets the needs of seniors and the wider community. Research was suggested to specify further the elements that comprise the system of transportation design and the performance standards that govern physical design and service. Political support for the system has to be created, and partnerships and alliances have to be formed between the public and private sectors. A method for encouraging and mandating participation by different organizations and groups has to be developed to ensure that the various segments and interests of the community are appropriately represented.

### *Information, Education, and Social Marketing*

Many proposals related to the development of public information, professional education, and social marketing programs. The key is to identify the elements of effective programs that build awareness and understanding about senior transportation issues. The discussions focused not only on driver-related topics but also on the availability and use of all transportation options. The value of examining current models for other social issues was emphasized for adapting and testing the lessons learned in the senior market.

The importance of evaluating the outcomes of these programs also was identified. Program evaluations were recommended for examining process and behavior changes, the appropriateness of the messages, the effectiveness of the presentation and delivery systems, and the cultural and geographic relevance for intended target audiences. Of ultimate importance was whether the desired behavior changes occur.

### *Transportation Options*

A strong appeal was made for additional research on transportation options to fill voids in understanding the

capabilities and needs of senior travelers and their facilitators and also the impediments to use of public transportation and paratransit.

- Review models and applications from other fields and other locations.
- Evaluate how intelligent transportation systems (ITS) can be used for designing and implementing public transportation.
- Conduct domestic and international community-based studies in sites with successful public transit systems to identify the factors that work.
- Identify and document best practices.
- Identify, catalog, and evaluate successful transportation programs and solutions to encourage replication and adaptation.
- Examine unsuccessful experiences to learn from the lessons and to avoid repeating mistakes.
- Examine the Americans with Disabilities Act and its effects on transportation access for older people.
- Study the services targeted to other groups and apply these services to the older population.

### *Driver Adaptation*

Recognizing that seniors tend to self-regulate their driving when performance problems are identified, many participants believed that further research in this area would have merit. Issues included an analysis of the prevalence of self-regulation among senior drivers, the factors that trigger adaptive behaviors, the specific compensatory measures used for different risk factors, and the effectiveness of changes in prolonging safe driving.

### *Vehicle Design and Safety*

Participants proposed a variety of strategies to enhance vehicle design and safety. There was a strong interest in building a crash test dummy for seniors. The results would provide valuable information on how to improve vehicle interior design to protect elderly and frail occupants. The need to improve occupant protection devices, particularly safety belts and airbags, for seniors was emphasized.

More research was proposed in the area of the crash avoidance systems (CAS), including studies that address the following:

- The value of daylight running lights and the level of light needed to alert older drivers,
- Auditory versus visual cues in the CAS,
- The best way to alert seniors to potential road hazards,

- The advantages and disadvantages of head-up displays for older drivers and the difficulties with driver overload that may result from in-vehicle navigation systems, and
- The road interactions of vehicles with mixed equipment.

### *Land Use and Public Policy Analysis*

More research was suggested to understand the process for improving land use patterns and policies to enhance transportation access. The importance of ensuring that senior housing is located in pedestrian-friendly areas and within close proximity to transportation was highlighted repeatedly.

The value of looking at land use planning in other countries was emphasized. For example, Scandinavia has much smaller long-term care facilities, which are located near schools. This juxtaposition allows for the use of the school cafeteria to feed the residents and for school buses to transport the residents on weekends. Other research could

- Determine how to get transit-oriented development and mixed-use zoning adopted,
- Evaluate the effects of government policies on access and patterns of mobility for older travelers, and
- Analyze the effects of federal laws and regulations on state and local services and the differential effects of these services on minorities.

### *Transportation Needs*

Many proposals were developed to better understand the mobility needs and travel patterns of seniors:

- Study origin and destination points.
- Examine driving exposure (e.g., the quality of the trip, not just the distance traveled).
- Study and understand the definitions that seniors give to necessary versus discretionary travel.
- Study the amount that older people are willing to pay for transportation through monetary costs and policy changes.

The importance of preparing realistic projections to anticipate and plan for future transportation demands was highlighted. Given socioeconomic and demographic trends, future cohorts of older people are expected to be different from current seniors. Improvements in health status and higher educational levels are expected to lead to significant changes in lifestyles, particularly among

older women. Recognizing that the older population is becoming increasingly diverse, participants also pointed out the value of undertaking a comparative study to examine mobility needs and patterns across racial and ethnic groups to better understand the reasons behind observed disparities and similarities.

### *Data Collection*

Repeated requests were made for more extensive and reliable data on senior transportation. Limitations in current databases were identified in terms of collection methods and available information. Several participants noted methodological limitations with the National Personal Transportation Survey because of limited sample sizes of older people; the participants strongly urged revising procedures, to oversample older people in the future. Reliability problems were noted with current data on nonfatal collisions and at-fault collisions among seniors.

Participants argued that the older population experiences significant and rapid transitions that only can be captured by a continuous method of data collection and the development of longitudinal databases. The value of including transportation-related questions on ongoing, national surveys was emphasized repeatedly, and the use of consistent measures across different cross-sectional databases was encouraged to ensure comparability of results.

### *Highway Engineering*

Research was proposed relating to highway engineering improvements that better accommodate the older road user; many of these improvements focused on signage:

- Dynamic field-testing of sign legibility,
- Determination of optimal sign spacing,
- Investigation of the safety benefits and problems of redundant signage and traffic-control devices,
- Benefits to seniors of alternative gap-acceptance models,
- Highway-related ITS devices,
- Traffic-calming techniques,
- Pavement markings, and
- Other types of geometric designs and traffic operations coordination.

### *Postcrash Detection and Response*

Participants expressed an interest in improving collision detection and response systems. The improvements included in-vehicle collision detection and alert systems.

An important priority was to train emergency medical response personnel on the special needs of older crash victims who may have increased frailty and greater vulnerability to serious injuries and complications that follow a crash.

### *New Technologies*

The participants identified another important research area: the impact of advances in computer and communications technology in altering transportation needs and patterns. Examples included home-based video technology, which already has reduced the need for many people to leave home for entertainment. Also, the Internet has had major implications for interpersonal communications, information access, and service delivery for frail and homebound older people. Technology could mean the difference between continued living in the community and assisted living in a nursing home.

### **Research and Program Implementation**

Participants in the breakout sessions were requested to develop proposals for research and program implementation. The suggestions for implementation overlapped with participants' suggestions for research and development. The following summarizes the proposals and related discussion points.

### *Information, Education, and Training*

Considerable discussion focused on the implementation of information, education, and training programs. The need for greater awareness and knowledge about senior transportation issues was reiterated across breakout sessions. Communications and education that target seniors, family members, and the general public, as well as the array of professionals who work with seniors or deal with aging issues, were considered critical. Participants singled out professional groups, including people in the media, policy makers, health care workers, social service providers, law-enforcement personnel, and representatives from the automobile insurance industry. The professionals must be kept informed about senior driving issues and use of transportation options. Suggestions involved training the media to frame news coverage more accurately; law-enforcement personnel to detect, remove, and refer unsafe older drivers to appropriate follow-up services; and health care providers to report and intervene with patients who have medical conditions that may interfere with driving performance.

Other proposed activities included the following:

- Pilot-test travel training among seniors and their lay and professional caregivers.
- Provide information on available mobility options.
- Determine the eligibility criteria for using specialized transportation programs.
- Develop hands-on training for accessing services, including instruction on how to read transit schedules, plan routes and locate transit stops, safely enter and exit public transit vehicles, transfer between transit services, and travel to multiple destinations.
- Establish a toll-free telephone number that provides mobility management and that addresses the transportation needs of callers.
- Use the World Wide Web, the Internet, and teleconferencing to disseminate transportation information.

### *Environmental Design*

A variety of highway enhancements were recommended to improve traffic safety for seniors; most of these suggestions were intended to improve street signage and included

- Greater use of mixed-case messages,
- Use of the Clearview font on highway signs,
- Redundant and improved sign placement,
- Use of fluorescent orange signs in work zones, and
- Placement of highway numbers on the pavement with arrows to designate directions for turning at intersections.

### *Interagency Collaborations and Partnerships*

Participants deemed that it was important to establish and enhance interagency collaborations and public and private partnerships to ensure financial and public support for transportation solutions.

### *Driver Assessment*

Participants placed a high priority on implementing driver-assessment programs, including

- A multiple-tier assessment approach that includes self-assessment and referral for high-risk drivers,
- Further pilot-testing of the Maryland driver-screening model in other locations,

- On-road driving assessments and in-vehicle retraining,
- Federal government indemnification for service program providers, and
- Certification for programs and providers administering driver assessments.

### *Transportation Options*

Expansion of transportation options also was highlighted across breakout sessions. The discussions focused on

- More widespread use of volunteers to transport seniors;
- Pilot programs (e.g., using county vans or used vans at car dealerships for volunteer programs that provide transportation to seniors during evenings and on weekends); and
- Demonstration programs that provide free public transportation for seniors.<sup>1</sup>

### *Vehicle Design and Safety*

Several suggestions related to the implementation of improved vehicle design and safety features:

- Retrofitting old vehicles with new safety features;
- Installing obstacle detection warning systems in vehicles (e.g., ultraviolet headlights, auditory beepers for backing up, blind spot detectors); and
- Standardizing all safety features installed in vehicles.

### *Public Policy*

Public policy enhancements also were suggested. Policies that provide incentives for private solutions were considered attractive in stimulating transportation innovations and community-based solutions.

### *National Agenda*

Under the leadership of the U.S. DOT and the Eno Transportation Foundation, several groups undertook

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<sup>1</sup> These programs can be found in Ireland, for example, where the use of trains and buses are free to everyone over age 75. Not only has ridership increased, but also older people have an incentive to become accustomed to public transit. Transportation planning also is encouraged before driving cessation.



the development of a national agenda to ensure the safe transportation of older people in the new millennium; many participants considered the agenda a blueprint for action. Comments and suggestions were made to ensure the agenda's usability and implementation.

- First, a national agenda should be innovative and forward thinking. To be effective, the agenda should extend beyond what is and what is possible today.

- Second, the emphasis should be on decision making at the local level. Participants noted that although the federal and state governments need to be involved, authority and responsibility should trickle down to the communities and involve the public and private sectors.

- Third, some observers maintained that a national agenda should address the issue of economic sustainability, including specifying the financial costs of pro-

posed priorities, identifying funding sources, and establishing priorities for implementation.

- Fourth, although the national agenda is not the same as a strategic plan, the agenda would be more valuable with a schedule for implementation. This schedule also would help establish priorities and focus.

- Finally, assigning a "caretaker" to the national agenda could make a difference in implementation and success. This organization or group would be responsible for coordinating, monitoring, and communicating progress to ensure successful implementation.

There was a high level of excitement and support for the development of a national agenda. By emphasizing innovation, accountability, and user needs, the agenda will provide a blueprint to guide future research, program, and policy decisions.

## RESEARCH AND DEVELOPMENT IDEAS

### Frequently Noted Needs

The following lists suggestions for research and development that were frequently noted in the breakout and plenary sessions of the international conference:

- Quantify the societal costs attributable to the loss of mobility.
- Conduct follow-up studies on assessment and retraining program outcomes, including qualification of remediation effectiveness.
- Focus on transportation needs for the wider community, and encourage local agencies to coordinate activities.
- Create social marketing strategies to inform older people about the availability of services to meet their needs.
- Identify and evaluate successful transportation solutions developed in and by communities and local groups.
- Quantify the social benefits of remaining mobile and connected to services.
- Develop, evaluate, and implement screening tests for visual, cognitive, and physical problems related to crashes.
- Investigate the development of behavioral, self-regulating adaptations by older drivers.
- Develop predictive models through assessment tools that take into account the role of higher-order functions (e.g., judgment, level of expertise).
- Determine the benefits and negative outcomes associated with routine screening of older drivers.

### Additional Research Needs

The participants identified a range of other topics for research. These are outlined below by relevant categories.

#### *Economic Analysis*

- Investigate the economics of nonmobility on individuals, families, and the community.
- Study the costs and benefits of treatments.
- Develop an understanding of economic incentives for using mobility options.
- Quantify the effects of service delivery on driving needs.

(continued)

## RESEARCH AND DEVELOPMENT IDEAS *(continued)*

### *Driver Screening, Assessment, and Remediation*

- Identify the barriers to seeking driver assessment.
- Conduct research on driving behavior during early-stage dementia.
- Study the connections and implications of medication for the older driver.
- Identify research issues associated with training and certification standards for driver rehabilitation and assessment professionals.
- Identify and characterize driver evaluators and driver evaluation programs.
- Study the effects of training versus assessment.
- Examine the outcomes of rehabilitation assessments in relation to on-road skills.
- Operationalize the assessment cascade.

### *Universal Transportation Design*

- Develop more efficient linkages across agencies, professions, and other areas involved in older-driver programs.
- Develop best practices from current knowledge.

### *Information, Education, and Social Marketing*

- Develop strategies to communicate the mobility alternatives.
- Develop an overall public information strategy or social marketing plan.
- Evaluate the community senior mobility materials and strategies for appropriateness of messages, delivery systems, cultural and geographic diversity, and financial feasibility.
- Identify the new messages from successful models for other social issues that can be adapted and tested for the senior market.

### *Transportation Options*

- Develop mobility alternatives.
- Develop an understanding of the symbolic value of the automobile and why transit is stigmatized.

### *Driver Adaptation*

- Develop an understanding of how older people define necessary versus discretionary trips.
- Evaluate the effectiveness of training.
- Conduct research on gap-acceptance models.
- Evaluate rehabilitation system strategies and programs.

### *Vehicle Design and Safety*

- Investigate the need for a crash test dummy to model the frailty of older people.
- Improve occupant protection devices for older drivers, including safety belts, airbags, and door panel design.
- Examine the effects of head-up displays and maps on older drivers.

*(continued)*

**RESEARCH AND DEVELOPMENT IDEAS** (*continued*)***Land Use and Public Policy Analysis***

- Determine the methods for encouraging the adoption of transit-oriented and mixed-use zoning.
- Evaluate the effects of government land use policies on access and mobility patterns of older travelers.
- Examine the effects of federal laws and regulations on state and local services.

***Transportation Needs***

- Determine the effects of lifestyle changes on mobility patterns and transportation needs.
- Determine the needs and capabilities of alternative transportation users.
- Quantify the number of senior trips not taken and the willingness of seniors to pay for these trips.
- Conduct comparative case studies on how older people meet their transportation needs.

***Data Collection***

- Examine ethnic and gender differences in licensing rates for older people.
- Identify gaps in transportation mobility data.

***Highway Engineering***

- Conduct research on visual and auditory obstacle detection.
- Conduct dynamic field-testing of sign legibility.

***New Technologies***

- Conduct research on highway-related ITS devices.

## RESEARCH AND PROGRAM IMPLEMENTATION NEEDS

### Frequently Noted Needs

The following list presents 10 suggestions for research and programs most frequently noted and discussed by participants at the international conference.

- Educate the media to frame the issues correctly.
- Develop training for seniors to overcome reluctance to use—and to increase familiarity with—alternative transportation options.
- Demonstrate the efficacy of highway improvements.
- Develop best practices on current public–private and interagency partnerships, with an emphasis on resolving barriers to implementation (e.g., financing).
- Develop multiple assessment tools for different audiences (e.g., seniors, medical personnel, law-enforcement personnel).
- Conduct further analysis of the National Personal Transportation Survey on the older-population sample.
- Identify best practices for establishing or resolving policy issues and for creating funding mechanisms for alternative transportation services.
- Develop self-assessment tools for different audiences.
- Document the classroom and on-road skills training programs that include information on alternative transportation options and adaptive strategies.
- Promote the awareness and education on aging and transportation issues and solutions. Include policy makers, consumers, professionals, service providers, and personnel in medical and public community organizations.

### Other Implementation Needs

The participants identified a range of other topics suggested for implementation. These are outlined below by relevant categories.

#### *Driver Screening, Assessment, and Remediation*

- Pilot-test comprehensive screening programs, and track the crash experience of high-risk versus other senior drivers.
- Pilot-test Maryland's at-risk program for test exportability.
- Develop functional descriptions of the safety issues involving older drivers.

#### *Universal Transportation Design*

- Develop methods for fast-tracking solutions.

#### *Information, Education, and Social Marketing*

- Implement a system for the effective dissemination of current knowledge (e.g., the effects of medication on driving skills).
- Promote the use of the World Wide Web to provide mobility information and shopping needs.
- Develop training programs for law-enforcement personnel to spot problem drivers, and provide referral avenues for all drivers.

*(continued)*

**RESEARCH AND PROGRAM IMPLEMENTATION NEEDS** *(continued)*

- Develop a forceful statement on the situation to convince private industry that older-people mobility is an economic issue.
- Increase the general awareness of communities with a stake in older-driver issues, such as insurance agents, the general public, government officials, industry leaders, and medical community personnel.
- Develop and test messages directed at policy makers.

***Transportation Options***

- Pilot test a program to make older drivers and their families aware of alternative options before the loss of driving privileges.
- Encourage states and communities to investigate, develop, and promote alternative solutions that empower individuals to make informed mobility choices.
- Provide additional transportation and transit mobility training.
- Catalog financial resources, and identify unique sources.

***Driver Adaptation***

- Encourage the federal government to indemnify companies that conduct in-vehicle retraining.

***Vehicle Design and Safety***

- Retrofit old vehicles with new safety features.

***Highway Engineering***

- Increase the use of mixed-case sign messages.
- Increase the dissemination and use of the Clearview font.



# Safe Mobility for a Maturing Society

## A National Agenda

Draft, October 18, 2002<sup>1</sup>

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Donald Trilling and John Eberhard, *U.S. Department of Transportation, Washington, D.C.*

The transportation system offers safe mobility to all people and allows older adults to remain independent and to age in place. Investments in highway and pedestrian infrastructure and public transportation services support independence. Medical and social service communities, transportation managers, motor vehicle administrators, and caregivers work together to enable safe driving as late in life as possible and to offer other convenient transportation options when driving and walking must be curtailed. Public and private organizations form new partnerships to enable all citizens to enjoy safe mobility for life.

### ENVISIONING SAFE MOBILITY FOR LIFE

The United States faces a revolution in transportation, driven by its growing population of older adults, those over 65. Health and medical advances make it possible for people to live without disabilities longer, and the baby boomers are moving toward their retirement years. People age 65 and older will be an ever-increasing proportion of the overall population—from 1 in 8 today (35 million) to 1 in 5 in 2030 (70 million). This unprecedented social achievement is not a blessing without costs. As age increases, older adults develop physical, sensory, and cognitive limitations that often restrict their ability to drive, walk, or use public transportation. Illnesses, med-

ications, and impairments make it difficult for them to use the transportation they need. Without mobility, people decrease their involvement in outside activities, and their health and well-being suffer. While some services exist to help people get to essential activities like medical appointments and grocery shopping, many older adults have difficulty getting to social or recreational activities that are an equally important part of their lives.

Older Americans, like their younger counterparts, depend on the automobile for 90% of their travel—it is pivotal to their quality of life. Most older adults are aging in place; they continue living in the same homes or near where they lived when they retired, close to family and friends, leading active lives in familiar surroundings. When physical disabilities or other limitations make driving impossible, most older adults withdraw from driving gradually and responsibly. At that point, many find themselves isolated from the activities—especially activities in suburban or rural areas where walking and transportation options are difficult—that fill their lives. Isolation can undermine seriously the quality of life for older adults and accelerate decline in personal health, potentially leading to earlier nursing home admittance.

Today, adults over 65 represent 12% of the population but account for 16% of all traffic deaths. As pedestrians, drivers, or passengers, older adults account for more than 6,600 fatalities a year—a number that should cause great concern. Figure 1 shows that although traffic fatalities for younger age groups have decreased significantly over the last 20 years, traffic fatalities for adults over 65 have not. The population of older adults will double by 2030, and they will drive

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<sup>1</sup> The draft National Agenda presented at the conference has been revised continuously. The latest draft of the agenda at the date of the Proceedings publication is described here.

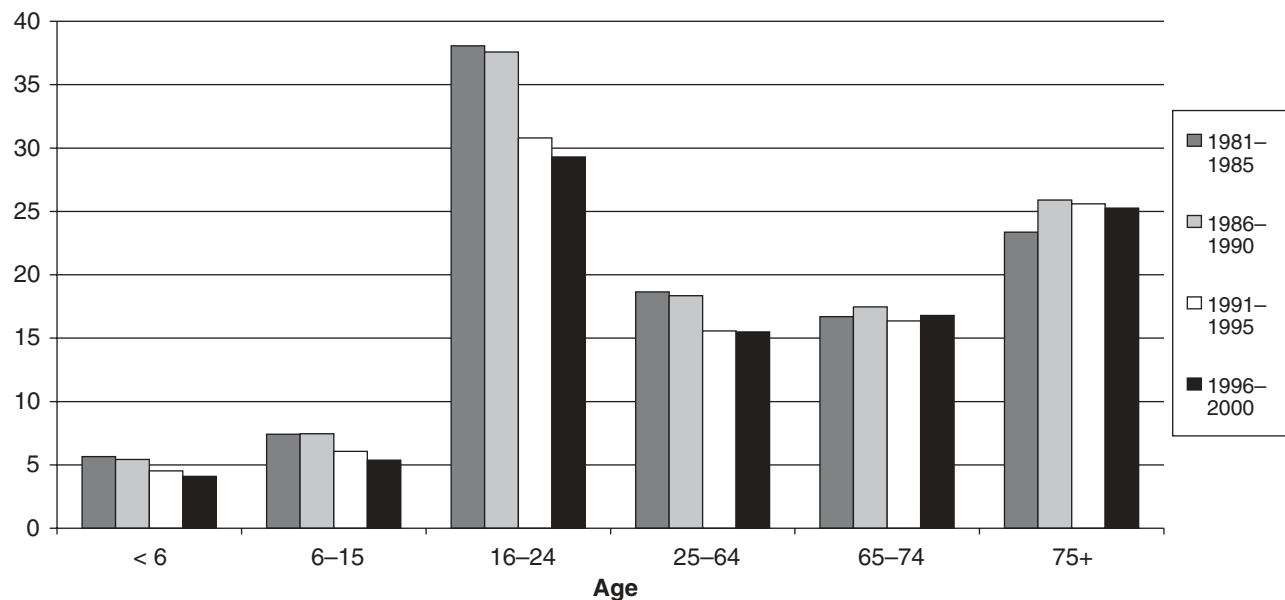
**Fatalities (per 100,000 population)**

FIGURE 1 Fatality rates per 100,000 for selected groups. (SOURCES: Fatal Accident Reporting System, 2002; U.S. Census Bureau, 2000.)

more than their counterparts today. The number of older drivers in fatal crashes could increase two to three times by 2030 (1, 2). Without improving the transportation system, the nation will face a major crisis with regard to older-adult safety and mobility.

To improve our transportation system, we must take action now on many fronts: safer roadways (highway and walking areas), safer automobiles, better alternative transportation services, and better driver safety procedures. We need creative, new partnerships for providing safe mobility for older people; states, Congress, federal agencies, counties, municipalities, and the private sector must work together to ensure that improvements are made. Social service and medical groups and agencies, automobile manufacturers and suppliers, insurance companies, airlines, railroads, bus operators, transit operators, and local businesses need to anticipate the coming era and become an integral part of the solution.

Out of a series of regional forums, focus groups, conferences, and stakeholder roundtables over the last several years, a vision of our transportation system has evolved. It is summarized in the opening paragraph and set forth as a National Agenda to provide safe mobility for a maturing society. Its organizing principle is to enable safe driving as late in life as possible and to offer other convenient transportation options when walking and driving are not feasible. The National Agenda identifies the following seven areas where professionals need to make concerted efforts to manage safe transportation for our aging population.

## DEVELOP STATE AND LOCAL SAFE-MOBILITY ACTION PLANS

Transportation is but one of a number of issues associated with elderly needs (e.g., health care and retirement security) that compete for public resources and attention. To give safe transportation the priority it warrants requires the formation of state and local planning groups. Organization of these groups should be a call to action to state offices (transportation, aging, motor vehicle, health, and housing), planning organizations, and community-based institutions to learn about transportation issues and to develop a plan of action that provides safe mobility for the aging population. The plan would guide transportation organizations and others to develop needed transportation services to make the drivers, walkers, and transportation users safer. An integral part of its development should be the views of older adults and their caregivers. As states and local communities implement and evaluate their programs, they should share the results with other states and communities.

## PROMOTE SAFER, EASIER-TO-USE ROADWAYS

### New Roadway Designs That Accommodate Limitations of Older Drivers

Roadways can be designed to help compensate for age-related losses of ability. Planners and highway engineers will find guidelines and recommended

designs in a series of Federal Highway Administration handbooks that can better accommodate the needs and limitations of older road users (3, 4). Promoting these recommendations can extend the period of time during which driving is safe for older adults and will make the roadways safer for all. Improvements include better pavement markings, intersection design, signage, lighting, and many other features. To accommodate older adults and to get the guidelines and recommended designs accepted as national standards, we need to continue training traffic engineers and highway departments.

### **Improve Pedestrian Facilities**

Walking is the second most frequent mode of transportation among older adults.<sup>2</sup> Better signalization, signing, speed management, and markings are needed, especially in areas or at intersections frequented by seniors. Pedestrian signal timing should be adjusted to reflect the often slower walking pace and slower “start up” time of the elderly. Greater use should be made of “smart” signals, which detect pedestrians in crosswalks. Pedestrian refuge islands should be provided on wide, busy streets. In locations with high volumes of elderly pedestrians, additional roadway signage warning of pedestrian crossings would be appropriate, as would better maintained sidewalks, benches, and covered areas; additional curb cuts; and upgraded signage and markings (5). More extensive traffic calming—which can reduce speed and lessen the opportunity for serious conflict with vehicles—is needed.

### **Improve Land Use**

Fifty years of suburbanization, with home sites dispersed across the community and beyond, can leave those aging in place completely automobile-dependent and thus stranded when they can no longer drive. New land use approaches that facilitate neighborhood-based living can minimize dependency on automobiles. Land use planning and zoning could lead communities to integrate services (medical services, houses of worship, shopping, social centers, assisted living facilities, etc.) needed by older adults. Land use planners need to

be informed of their role in accommodating the increasing numbers of older adults who will reside in their communities. Consumer advocates, health-care organizations, citizen groups, local governments, and older adults and their caregivers can aid this planning and encourage decision makers to anticipate their needs as they plan new development. A clearinghouse should be established covering innovative programs and best practices on land use planning and reengineering access patterns for the elderly. Metropolitan planning organizations and other agencies that plan public areas should include older adults or their caregivers on planning boards and other bodies responsible for planning, zoning, and programming street and pedestrian improvements.

## **CREATE SAFER, EASIER-TO-USE AUTOMOBILES**

### **Improve Crash Protection of Older Occupants**

Older adults are less able to withstand and to recover from the trauma of crashes, and they face a much higher likelihood that a crash will be fatal. When in a crash, occupants over the age of 80 are more than four times as likely to die than those under 60. More effective occupant protection systems for fragile older adults need to be developed. An accelerated campaign of designing and testing improved systems is needed, so that industry and government can develop the requirements for new occupant-protection standards on an informed, technologically advanced basis. These could include improved dummies to design and test improved occupant-protection systems, force-limiting seat belts, side air bags and protective devices, knee bolsters, and other occupant-protection systems that maximize protection for older users.

### **Improve Ease of Driving**

Vehicle systems and information technology designs should be developed to accommodate the needs and functional limitations of older drivers and occupants. Alerting drivers to oncoming traffic might have particular value among older drivers. Systems must recognize older adults’ diminishing ability to focus attention and their slower information processing capabilities. As new vehicle technology is designed, the needs and characteristics of elderly motorists should be taken into account. With advancing age, getting in and out of a car and stowing walking aids are more difficult and require new solutions. The federal government should partner with companies that work with disabled populations to examine advanced technology that could improve the

<sup>2</sup> Although only 12 percent of the population, older adults account for 21 percent of pedestrian deaths. It is notable that the pedestrian death rate for those adults 75 and older is more than double that of all other ages.

ability of disabled motorists to drive or to use other mobility systems.

## IMPROVE OLDER DRIVER COMPETENCY

### Develop Driver Wellness Programs to Enable Driving Later in Life

Older drivers tend to be safer because they drive less frequently and reduce their exposure to higher-risk circumstances. Some, because of a medical condition or functional limitations, are less able. Encouragement of general wellness programs that keep older adults more able to walk and drive should enable them to have safe mobility longer. Health and social service providers should work with seniors to develop, evaluate, and implement these programs.

### Develop Systems for Assessing and Regulating Older Drivers

A key issue brought to the attention of aging agencies is dealing with the unsafe older driver. Research is needed to identify what causes older drivers to be at increased risk of crashing and to better understand the extent to which older people appropriately self-regulate how long they drive.<sup>3</sup> New approaches are needed to develop and promote referral, testing, rehabilitation, and regulation programs, advancing safe mobility for functionally limited people. Older adults and their professional and lay caregivers need better ways to correctly identify and assess the ability to drive safely. Some older drivers, such as those who have had a stroke, need special attention to determine whether or not rehabilitation will enable them to drive safely. Ways to deal with drivers with serious cognitive deficits who may not recognize their condition and may be unwilling to cease driving need to be developed.

Since functional disabilities associated with increased crashes are found more frequently in older adults, age-based testing often is recommended. Age-based testing, however, raises discrimination concerns and is inappropriate until research determines that it can correctly identify unsafe drivers. Assessments can be performed in three possible venues: at the driver-licensing facility, in a health services setting, or in a social service setting. The most effective site to identify,

correct, and regulate functionally limited drivers should be established and promoted.

### Provide Resources to Better Address Older Driver Issues

Surveys indicate that professionals (physicians, other health and social service staff, and law enforcement personnel) and families have insufficient information to address older driver issues. The American Medical Association needs to promote the *Physicians Guide to Assessing and Counseling Older Drivers* (available online April 2003 and in hardcopy May 2003; for more information, see [www.ama-assn.org/ama/pub/category/9117.html](http://www.ama-assn.org/ama/pub/category/9117.html)). The National Highway Traffic Safety Administration needs to make available and evaluate current guides for families (6, 7).

## PROMOTE BETTER, EASIER-TO-USE PUBLIC TRANSPORTATION SERVICES

### Improved Design of Transportation Services for the Elderly

Having a viable alternative to the automobile is important if older adults are to maintain true independence once driving becomes unsafe or once they choose not to drive. The current 3% use by older adults shows that the potential of public transportation is not being fully realized. The reasons for lack of use need to be determined for conventional fixed-route public transportation and paratransit services.

Public and private transportation operators need to make their systems more older-adult-friendly—easier to use and more convenient to reach safely. The physical and functional impairments that limit or inhibit system use by older adults (e.g., walking to stops, recognizing entry and departure points, waiting outside in the weather, climbing aboard, paying for the ride, standing in a vehicle in motion) must be considered in the design and operation of the transportation system. Routes, schedules, and operating procedures must be simplified for the cognitively impaired older user.

### Develop a Mobility Management Approach

In the forums and focus groups conducted to develop the national agenda, a recurring suggestion was to have a single, user-friendly source of personalized information about transportation options and their use. An older adult or a

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<sup>3</sup> Fewer than 5% of older adults lose their licenses because of action by state licensing authorities.

caregiver could dial a one-call-does-it-all number, describe the specific trip desired, and get detailed help in arranging it. The mobility manager would counsel the elderly customer, family member, or caregiver on exactly how to accomplish all portions of the desired trip until the route becomes routine for the traveler. The mobility manager also might recommend alternative modes, list options, schedule pickups, provide contacts for service providers, arrange training to use the transportation services, or provide additional information. Public transportation organizations should develop one-call-does-it-all mobility managers to coordinate providers offering a network of services, from local providers of fixed-route bus and rail services to taxis to shared services on flexible routes with dynamic dispatching.

### **Establish and Demonstrate Innovative Transportation Programs**

Communities around the country should conduct demonstration programs of innovative transit and supplemental transportation systems for older adults in underserved and rural areas. Westat, Inc., has documented a number of excellent examples (8). The Beverly Foundation has identified more than 300 supplemental transportation systems that provide senior-friendly service (9). Most are targeted at those 85 and older, who often have special needs because of cognitive, visual, and hearing impairments and difficulties walking and climbing inclines. These systems have grown out of creative partnerships of elder advocates, governments, religious organizations, and care providers. Partnerships rely on local leadership and meet a need that is recognized at the grassroots level. Opportunities and needs vary widely from one community to another, and what works in one area may or may not work in another. As communities try different approaches, they should share their experiences to aid others developing programs.

### **Coordinate Services and Resources**

Many forms of specialized transportation service for older adults rely on support from federal and other sources programs.<sup>4</sup> These services and distributions of funds are frequently fragmented, uncoordinated, and not universally available. Developing partnerships among providers, often combined with private-sector interests, will facilitate a reduction in inefficiencies,

overlaps, and gaps and will promote a better overall level of service for the elderly.

### **BETTER PUBLIC INFORMATION**

The public—seniors in particular—needs more current information on how older adults can maintain safe mobility as late in life as possible. A national social marketing program can add substantially to their level of safety by providing information on corrective strategies that can enable them to drive safely longer and on available resources that can enable them to have continued mobility. Such a campaign can serve an ill-informed general public by providing facts that counter often-held views that older drivers are unsafe. It also can inform the media on issues surrounding the safe mobility of older people, dispelling inaccurate stereotypes. Further, it should educate older adults and their caregivers on how to evaluate their capabilities and extend their abilities to drive safely, walk, and use transit services.

### **BASIC AND SOCIAL RESEARCH NEEDS**

There are many proposals for ways to improve safe mobility for older adults, and additional research is needed to develop and evaluate them. Experts worldwide have updated the requirements for new research and development in several recent reports (10).<sup>5</sup>

Research is needed to better understand the role mobility plays in successful aging, including the costs in terms of deteriorating personal health and well-being and of providing versus not providing mobility to older adults. This research should afford a basis for evaluating the economic impacts of mobility and nonmobility on the individual, family, and community, and eventually to provide estimates of the value to society of supporting lifelong mobility. Research also is needed on what might induce additional private investment in mobility solutions from health, automobile, and life insurance companies; health-care providers; and others.

### **CONCLUSION**

Older adults enjoy a significantly better quality of life today than in the past largely because of their improved mobility. They are more active and more involved and look forward to many more active years in retirement

<sup>4</sup> Programs include the Transportation Efficiency Act for the 21st Century, the Older Americans Act, the Americans with Disabilities Act, the Civil Rights Act, and the Clean Air Act.

<sup>5</sup> See papers in this volume.



than earlier generations. Like everyone, they want mobility that is safe and convenient. If the nation is to meet the challenge of safe mobility as its people age, there is much to be done. The transportation system's infrastructure and vehicle fleet are massive. The above recommendations, designed to meet the goal of safe mobility for life, will require many years to implement. It is important to begin now, preparing today for needs that will be widespread 20 or so years hence.

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# Appendices

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## APPENDIX A

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