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Highway Crash Rates and Age-Related Driver Limitations:

Literature Review and Evaluation of Data Bases

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MANAGED BY
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DEPARTMENT OF ENERGY

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HIGHWAY CRASH RATES
AND
AGE-RELATED DRIVER LIMITATIONS:

Literature Review and Evaluation of Data Bases

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ACRONYMS AND ABBREVIATIONS

AAAM	Association for the Advancement of Automotive Medicine
AAMVA	American Association of Motor Vehicle Administrators
AD	Alzheimer's disease
AMA	American Medical Association
BCMA	British Columbia Medical Association
DMV	Department of Motor Vehicles
DOT	Department of Transportation
EPESE	Established Population for Epidemiological Studies of Elderly
FEV	Forced expiratory volume
FHWA	Federal Highway Administration
FVC	Forced vital capacity
HSIS	Highway Safety Information System
MCAP	Medical Commission on Accident Prevention
MVB	Motor Vehicle Branch
NCHS	National Center for Health Statistics
NHTSA	National Highway Traffic Safety Administration
NIA	National Institute on Aging
NPTS	Nationwide Personal Transportation Survey
NSC	National Safety Council
ORNL	Oak Ridge National Laboratory
SGI	Saskatchewan Government Insurance
TRB	Transportation Research Board
UFOV	Useful field of view

EXECUTIVE SUMMARY

American society is undergoing a major demographic transformation that is resulting in a larger proportion of older individuals in the population. Moreover, recent travel surveys show that an increasing number of older individuals are licensed to drive and that they drive more than their same age cohort a decade ago. However, they continue to take shorter trips than younger drivers and they avoid driving during congested hours. This recent demographic transformation in our society, the graying of America, coupled with the increasing mobility of the older population impose a serious highway safety issue that cannot be overlooked. Some of the major concerns are the identification of "high-risk" older drivers and the establishment of licensing guidelines and procedures that are based on conclusive scientific evidence.

Oak Ridge National Laboratory's (ORNL) objectives in this project can be characterized by the following tasks:

Task 1. Review and evaluate the 1980 American Association of Motor Vehicle Administrators (AAMVA) and National Highway Traffic Safety Administration (NHTSA) licensing guidelines. Determine whether the license restriction recommended in the 1980 AAMVA and NHTSA guidelines was based on scientific evidence or on judgement of medical advisors. Identify in the scientific literature any medical conditions which are found to be highly associated with highway crashes, and which are not mentioned in the 1980 guidelines. Summarize States' current licensing practices for drivers with age-related physical and mental limitations. Identify potential data sources to establish conclusive evidence on age-related functional impairments and highway crashes.

Task 2. Develop an analytical approach that uses epidemiological and/or medical data bases to establish the feasibility of statistically linking age-related functional impairments to increased highway risk;

Task 3. Conduct statistical analyses of data bases which are identified by ORNL as having sufficient information and adequate sample sizes; and

Task 4. Recommend future data needs should statistical analysis prove to be possible.

This report summarizes the findings of Task 1. First, an evaluation is given of whether licensing guidelines which appeared in the 1980 AAMVA and NHTSA licensing guidelines and other physicians' guidebooks are based on scientific considerations. Based on the assessment and a literature review, medical conditions for which more research is needed are identified. An inventory of medical and epidemiological data bases is included and each data base is briefly evaluated in terms of its feasibility for being used to develop conclusive statistical relationships between specific medical conditions and increased highway crashes. Evaluation of the data bases is based on four major criteria:

1. Is the data base complete? (i.e., a data base that is in the planning or implementation process is not reviewed).
2. Are data representative?
3. Are there sufficient data to establish a robust relationship between age-related functional impairment and increased highway risk? Each data base should have information on at least four major areas -- **the demographics of the drivers, age-related medical conditions afflicting the drivers, crash and moving violations**, and **the amount of driving (to serve as accident exposure data).** Data missing on any one of the three areas makes establishing this relationship impossible.
4. Are there sufficient data to consider effects of comorbid conditions? The possibility of "merging" different data sources to supplement each other's shortcomings is not discussed until a more comprehensive statistical framework is developed in the next task.

The assessment of various licensing guidelines suggests that medical conditions included in the 1980 AAMVA and NHTSA guidelines and other physicians' guidebooks can belong to one of the following two groups - those for which a relatively significant amount of research has been completed and those where basically no research was done. For medical conditions (such as epilepsy, diabetes, and impaired vision) which have been well studied, conclusive evidence is still limited. More research will be needed to overcome the problems of small sample sizes, discrepancies among methodologies, and selection bias. More research is also needed on medical conditions (such as impaired hearing, mental disorders, drug and medication-related conditions, and dementia) which were hardly studied for the 1980 AAMVA and NHTSA guidelines. In summary, much of the existing guidelines are based on consensus and professional judgement, rather than on scientific evidence.

To date, research has been limited on functional impairments in older drivers and the impacts of these functional impairments on their driving patterns. Waller (1992) summarizes obstacles to establishing statistical linkages between older drivers and highway crashes. He identified several methodological and administrative issues that contribute to the inconclusiveness in research involving older and medically impaired drivers. They include: diagnostic inaccuracy, small sample size, selection bias, inconsistent definition of criteria for excessive crash risk, the lack of research on the effect of combinations of medical conditions, and the subtle nature of the interaction between driver and environment.

In addition to the ongoing research, three areas are identified where more research will be needed to address older drivers' safety issues. The first is the effect of increased usage of prescribed and over-the-counter medication by older drivers on highway crashes. Second, although some studies were done in recent years on demented older drivers, methodological problems, small sample sizes and differences in the observations across these studies have prevented any confident conclusions regarding dementia and highway crashes. More empirical research will be needed with larger sample sizes in this area. The last, but perhaps the most important, area in which research is lacking are the synergistic effects of comorbid conditions on highway crashes. This area is especially relevant in trying to clearly identify older drivers who are frequently involved in highway crashes, since the aging process contributes to both physical and mental deterioration. Special attention should be given to the synergistic effects of alcohol and medication abuse and to other age-related physical and mental conditions.

Our preliminary assessment of the currently available data sources suggests that the majority of these data sources are significantly limited for the purposes of our study by their small sample sizes and incomplete information. Perhaps only three of them are suitable as a foundation to begin the work of identifying an appropriate statistical framework and of developing a preliminary model to establish relationships between age-related physical and mental limitations and increased highway risk. They are the Quebec data base, the Pennsylvania driver re-examination data, and the Established Population for Epidemiological Studies of Elderly (EPESE) at Iowa and at New Haven, Connecticut. However, they are not without limitations. Our assessments are preliminary and are without the benefit of actually obtaining and analyzing the data. The feasibility of using these data bases to establish statistical link(s) can not be assessed until possible selection bias issues and other possible shortcomings of these three data bases are thoroughly examined. Information that none of these three data sources can provide is the severity of the medical conditions.

HIGHWAY CRASH RATES AND AGE-RELATED DRIVER LIMITATIONS:
Literature Review and Evaluation of Data Bases

1. INTRODUCTION

Despite decreasing traffic crash rates, the impact of motor vehicle crashes on our society and economy continues to be great. Motor vehicle crashes alone claimed 46 thousand lives and 89 billion dollars in economic losses in 1990, and damages are projected to increase in the future (National Safety Council [NSC], 1991). This estimated cost only reflects the economic loss to our society resulting from motor vehicle crashes, such as wage loss, medical expense, insurance cost, and property damage; and does not include "...the value of a person's natural desire to live longer or to protect the quality of one's life" (NSC, 1991).

In trying to alleviate highway safety problems, three major factors that contribute to highway crashes have been extensively studied to better understand the nature of the problem and to identify "solutions." The three major factors contributing to motor vehicle crashes are highways, vehicles, and drivers. To successfully address the problem of the driver, the *identification and control* of drivers, especially those medically impaired who present an unusually high risk to themselves and to the general public, is one of the most important concerns. Medically impaired drivers include those suffering from physiological and psychological changes as well as those suffering from self-induced impairment, such as excessive use of alcohol and other drugs.

In 1980, the American Association of Motor Vehicle Administrators (AAMVA) and the National Highway Traffic Safety Administration (NHTSA) outlined four basic approaches to assist licensing agencies and physicians to better identify and control medically impaired drivers:

1. identifying critical issues that are related to medically impaired drivers;
2. developing programs and conducting seminars for driver examiners to better recognize signs and symptoms of potential medical conditions;
3. developing medical guidelines for physicians to better determine the fitness of a driver for safely operating a motor vehicle; and

4. establishing Medical Advisory Boards to provide medical evaluation of individuals whom licensing agencies have reason to believe are medically impaired.

In their 1980 guidelines, AAMVA and NHTSA outlined some examples implemented over the years in each of these four initiatives, and provided certain guidelines for evaluating functional impairment in relation to driving. However, they emphasized that these guidelines should not be viewed as medically-acceptable criteria since the guidelines were not supported by empirical data showing a direct relationship between specific medical conditions and increased highway risk. As a matter of fact, AAMVA and NHTSA noted that such medical criteria do not exist. Hames (1976) reported that most of the states' licensing guidelines and policies were usually based on arbitrary agreement and medical judgement. He urged that medical criteria be set, which would provide proven and direct relationships between medical conditions and increased highway risks, based on sufficient statistical data. He pointed out that before licensing agencies can fairly and legally restrict or remove drivers' licenses from impaired drivers, and before physicians are willing to cooperate in any program to identify impaired drivers, they must be proven to be indeed a dangerous hazard on the highway based on medical criteria.

A recent major demographic change in our society further aggravates the highway safety problem. In the 1900's, American society is undergoing a major demographic transformation that will continue into the next century. At the beginning of this century, only 1 in every 25 persons in the United States was 65 years of age or older. By 1984, about 1 in 9 persons was 65 years or older. If birth rates stay low, 20 percent of the U.S. population (1 in every 5 persons) will be 65 or older between 2020 and 2030 (U.S. Bureau of Census). Furthermore, data show that the number of older persons who are licensed to drive continues to increase steadily (Federal Highway Administration [FHWA], 1992 and previous editions). Although older drivers drive fewer miles than do the rest of the population and generally avoid hazardous traffic conditions, they drive more miles than that of the same age-cohort in past years. The "graying of America" and the increased mobility of older persons have captured the attention of policy makers and researchers, and the proper balance between the mobility and safety of older drivers has become a crucial issue in our society.

In 1986, Congress passed the Surface Transportation Act of 1987, calling for a Transportation Research Board study of the safety and mobility of older drivers. Results from this study call for a re-evaluation of the licensing, screening and testing practices to better identify older drivers who may have physiological and psychological functional impairments that may affect their ability to drive safely.

Much research has been devoted to examining older drivers' driving behavior, age-related physiological and psychological changes, crash patterns, and involvement rate in traffic crashes. However, little has been done to establish scientific evidence to link age-related functional and mental limitations to driving performance in terms of traffic crashes and moving violations. The objectives of this research project are:

1. to review and to evaluate the 1980 AAMVA and NHTSA licensing guidelines. The evaluation would determine the current basis for license denial and license restriction for drivers with age-related physical and mental limitations. Oak Ridge National Laboratory will determine whether the license restriction recommended in the 1980 AAMVA and NHTSA guidelines is based on scientific evidence or on judgement of medical advisors;
2. to develop an analytical approach using existing epidemiological and/or medical data bases to establish the feasibility of statistically linking age-related functional impairments to increased highway risk;
3. to conduct statistical analyses of data bases which are identified by ORNL as having sufficient information and adequate sample sizes; and
4. to recommend future data needs should statistical analysis prove to be possible.

This report summarizes the steps performed and the findings of the first objective by assessing whether the license restrictions as recommended in the 1980 AAMVA and NHTSA guidelines are based on scientific evidence. States' current licensing practices and research evidence reported since the release of the 1980 AAMVA and NHTSA guidelines are also summarized in this report. In addition, age-related physical and mental limitations which are suggested in the literature as having high associations with increased highway risk, but which are not included in the aforementioned 1980 guidelines, are identified. Trends in demographic patterns and the driving behavior of older drivers as well as types and severity levels of crashes in which older drivers are involved are discussed in Section 3. This section provides background information on safety issues with older drivers. Finally,. the report identifies and evaluates existing data sources that might allow the establishing of more conclusive scientific links between age-related physical and mental functional impairments and increased highway risk.

2. EVALUATION OF LICENSING GUIDELINES

Medical conditions that might impair a person's functional capability to operate a motor vehicle safely may be grouped into three broad categories (AAMVA & NHTSA, 1980):

1. those that affect the level of consciousness or perception,
2. those that alter judgmental processes, and
3. those that limit motor ability.

Some medical conditions may individually influence the safe operation of a motor vehicle, while others may be harmless individually but a combination of them may pose serious risk. Furthermore, while some medical conditions impair a single functional capability, others impair more than one type of function. For example, cardiovascular patients might initially have their level of consciousness altered and then have their motor ability limited while they are driving. Therefore, it is difficult to discuss general licensing restrictions either by medical condition alone or by functional capability alone. The 1980 AAMVA and NHTSA guidelines as well as other physician guidelines adopt the approach of providing licensing recommendations mostly by medical condition. This report follows the same approach.

The 1980 AAMVA and NHTSA guidelines include licensing guidelines for medical conditions that are recognized by the medical community and licensing officials as having potential to impair functional capability to operate a motor vehicle safely. Physicians and licensing officials are advised to use published guidelines to determine whether license applicants with certain medical conditions should be granted driver's licenses. They are also reminded that evaluation of any medical condition must consider the extent to which driving may be functionally impaired, and not merely to identify the presence or absence of a certain disorder.

The purpose of our evaluation of licensing guidelines is to assess whether a relationship was established between an age-related functional impairment and driving performance in terms of crashes and moving violations, and if so, whether it was based on a scientific considerations. As mentioned earlier, this report also identifies medical conditions that are suggested in the literature as highly associated with increased highway risk and that are not yet included in the licensing guidelines. What is, however, not included in this report is a detailed description of how these physiological and psychological conditions affect the ability of individuals to operate motor vehicles safely, manifested symptoms of these conditions, and specific licensing recommendations.

AAMVA and NHTSA (1980) broadly described the risk associated with each of the medical disorders in their handbook and recommended acceptable levels of function for driver licensing. Considerably more detail on how various medical conditions are manifested and how they might impair functional capability to operate motor vehicles can be found in a number of physician guidelines. Some examples of these guidelines are Medical Aspects of Fitness to Drive: A Guide for Medical Practitioners (The Medical Commission on Accident Prevention [MCAP], 1985), Guide for Physicians in Determining Fitness to Drive a Motor Vehicle (The British Columbia Medical Association [BCMA], 1989) and Guidelines on Medical Conditions that Affect Driving (The American Medical Association [AMA], 1984). In these physician guidelines, considerations and recommendations for licensing are also included. In the context of screening high-risk drivers, two NHTSA documents (AAMVA, AMA & NHTSA, 1976; Brainin, Breedlove & Naughton, 1977) outlined different screening procedures, behavioral observations and "questions for the applicant" to assist licensing examiners to "spot" potentially medically-impaired drivers and to determine the fitness of these applicants to safely operate motor vehicles.

Before providing a discussion of age-related functional limitations, this report gives a summary of all medical conditions that are included in the aforementioned guidelines as having potential to impair the functional capability of drivers of all ages to operate a motor vehicle safely. These medical conditions are:

- disorders of the nervous system,
- cardiovascular diseases,
- metabolic conditions,
- vision,
- drugs and medication,
- mental disorders,
- musculoskeletal conditions,
- respiratory function,
- hearing, and
- aging.

Since recommendation for licensing should be based on functional capability and not merely on the presence of a certain disease, the term "disorder", instead of the term "disease", is used in this report when appropriate.

2.1 Disorders of the Nervous System

In order to operate a motor vehicle safely in today's traffic, a driver must be able to manage complex muscular movements without hesitation and with great precision. Among the most serious concerns about drivers with neurological disorders are the loss of consciousness and the loss of muscle strength and coordination. Some of the more common neurologic conditions that can impair driving ability are categorized into three groups as follows.

2.1.1 Conditions that Alter the State of Consciousness

Epilepsy

Epilepsy, the most common neurological disorder affecting the safe operation of a motor vehicle, is a disease which affects the brain and causes seizures (Brainin et al, 1977). Epilepsy comes in many forms. Although the actual number of Americans who have epilepsy is unknown, the National Center for Health Statistics (NCHS, 1989) estimated that in every 1,000 persons there are 3.8 persons reportedly having epilepsy. Epilepsy may cause sudden loss of consciousness, muscular convulsions or spasms, or it may cause only a slight temporary change in a person's conscious awareness.

Licensing recommendations on individuals with epilepsy vary. Based on broad functional capabilities of affected individuals, regardless of the type of epilepsy, AAMVA and NHTSA recommended that individuals who have had an episode of altered consciousness in the preceding year, whether or not the episode occurred while on medication, should not be granted any type of driver's license (i.e., privately-owned-vehicle, commercial vehicle); and that individuals who have not had an episode of altered consciousness for the preceding 3 years, and who are not on any medication, could be considered for any type of driver's license. Published guidelines to physicians (MCAP, 1985; BCMA, 1989) described manifesting symptoms of various forms of epilepsy and attempted to illustrate how different forms of epilepsy adversely affect the safe driving of a motor vehicle. These guidelines suggested a similar recommendation -- that a patient should be free from seizures for at least 12 months before being recommended for licensing. On the other hand, the American Medical Association (1984) suggested that a patient should be seizure-free for 18 months before being considered for licensing.

Narcolepsy And Others

Narcolepsy, a considerably rarer disorder, is characterized by falling asleep suddenly without warning. Suddenly falling asleep can also be a side effect caused by a wide variety of drugs in common use. Parkes (1977) reported in "The Sleepy Patient" that in a group of 64 narcoleptic people, 48% of them had gone to sleep while driving and 25% of them had been involved in road crashes due to sleeping while driving.

The American Medical Association (1984) recommended that narcoleptic patients should be allowed to drive after successfully responding to medication and that they should have a trial period of six months. Other medical guidelines (BCMA, 1989; MCAP, 1985) suggested a period of no uncontrolled sleepiness for a period of from 3 to 12 months.

2.1.2 Conditions Involving Disturbed Motor and Coordination Function

Conditions included in this category weaken muscle control and reflexes, and disturb coordination, two of the most important functions in operating a motor vehicle safely. Included in this group are conditions such as:

- *cerebral palsy*, which is a group of conditions that are caused by non-progressive damage to the brain before the age of three years. In all forms of cerebral palsy, brain damage impairs movement reflexes and/or motor control in at least one part of the body.
- *muscular dystrophy,* which is characterized by weakness and atrophy of muscle without involvement of the nervous system.
- *multiple sclerosis*, which is the most common of the degenerative diseases that affects the human nervous system; this disease causes poor motor coordination, impaired vision, impaired perception, or changes in emotion.
- *Parkinson's disease*, a progressive neurological condition characterized by a rhythmic tremor, a slowing of voluntary movements, and weakness of the muscles; the disease usually begins between the ages of 40 and 70.
- *tumors of the brain* or organic brain damage following a stroke or head injury.

AAMVA and NHTSA (1980) suggested that if an individual is tested with normal muscle power at all joints and good muscle power in flexion of the right knee, he/she should be granted all types of driver's licenses. They also recommended that individuals who are tested with fair muscle power at all joints and poor or worse muscle power in flexion of the right knee should not be considered for licenses. Other guidelines (AMA, 1984; BCMA, 1989; MCAP, 1985) suggested that individuals in the early stages of these disorders should be free to drive and that once the condition advances, close evaluation and follow-up are recommended.

2.1.3 **Conditions that Affect Higher Cerebral Functions**

Conditions included in this category are those that cause a dementing process in affected individuals, such as Huntington's chorea. Several sources (AMA, 1984; BCMA, 1989; MCAP, 1985) recommended that individuals manifested with these conditions be "evaluated on an individual basis."

Were the 1980 AAMVA and NHTSA guidelines for licensing drivers with *neurological disorders* based on scientific considerations?

The 1980 licensing guidelines for epileptic patients were based on limited scientific findings. Waller in 1965 (Waller, 1965) published findings from a study in which 2,672 drivers who were known by the California Department of Motor Vehicles to have chronic medical conditions were compared to 922 California drivers renewing their licenses who were not known to have any chronic medical conditions. He concluded that drivers with epilepsy had, on average, twice as many crashes per 1,000,000 vehicle miles as drivers in the comparison group. However, Waller emphasized that his study was limited to drivers whose medical conditions were known to the Department of Motor Vehicles and encouraged future research on unreported drivers with the same chronic medical conditions.

Research since the release of the 1980 AAMVA and NHTSA guidelines

Hansotia and Broste (1991) studied 240 epileptic patients who had valid drivers' licenses and who were still driving, and concluded that these patients had a slightly increased risk of traffic crashes as compared to unaffected individuals. However, the authors claimed that the increased risk of traffic crash observed in these patients is generally smaller than that found in previous studies (Waller, 1965), and that the increased risk is not great enough to warrant further restrictions on driving privileges.

This claim is believed by other researchers to be somewhat premature since the group of epileptic patients who had valid drivers' licenses and were still driving is in a significantly lower risk category than epileptic patients who had their drivers' licenses suspended by the Department of Motor Vehicles.

Current state and provincial licensing practices

All states and provinces have licensing policies on epileptic drivers (Anapolle, 1992). Table 1 lists the required seizure-free period before the applicant is considered for licensing (Petrucelli & Malinowski, 1992).

Table 1. Required Seizure-Free Period before Licensing

Time Interval	No. of States in U.S.A.	No. of Canadian Provinces
3 Months	7 (13.5%)	0 (0.0%)
6 Months	11 (21.2%)	0 (0.0%)
6 months - 1 year	1 (1.9%)	0 (0.0%)
1 year	21 (40.4%)	10 (83.4%)
0 - 2 years	1 (1.9%)	0 (0.0%)
4 year	1 (1.9%)	0 (0.0%)
Individually evaluated	8 (15.4%)	1 (8.3%)
N/A	1 (1.9%)	1 (8.3%)
Affidavit, met medical qualification	1 (1.9%)	0 (0.0%)
TOTAL	**52[1] (100.0%)**	**12[2] (100.0%)**

[1]Includes District of Columbia and Puerto Rico.
[2]Includes two territories.

Driving behavior of epileptic drivers

Waller in his 1965 paper noted that drivers known to the Department of Motor Vehicles to have epilepsy drove less than their control counterparts (Waller, 1965). However, a Washington study suggested that although the overall estimates of annual miles driven by both afflicted and unafflicted groups were found to be the same, the control group did twice as much out-of-state driving as their epileptic counterparts (Paulsride & McMurray, 1978).

2.2 Cardiovascular Diseases

The most significant signs of cardiovascular disorders affecting safe operation of a motor vehicle are: (1) losses of consciousness, (2) anginal pain, and (3) other symptoms (such as dizziness, blurred vision) that cause inability to control a motor vehicle. In their 1968 study, West, Neilsen, Gilmore and Ryan found that 15% of the drivers who died in single-vehicle crashes died of natural causes, and 97% of those drivers who died of natural causes died of heart disease. However, the role of cardiovascular disorders in operating motor vehicles safely has not been established statistically. Despite the lack of conclusive statistics to relate cardiovascular diseases and vehicle crashes, there is general agreement that a physician usually can provide a medical opinion as to the probability of functionally impaired conditions that may cause loss of control of a motor vehicle. There are many forms of cardiovascular diseases that might impair functional capability to operate a motor vehicle, such as acute myocardial infarction, angina pectoris, cardiac arrhythmias, arteriosclerotic heart disease. The causes and clinical manifestations of these diseases are described in detail in guidelines by AAMVA and NHTSA (1980), MCAP (1985), BCMA (1989) and the AMA (1984) and will not be repeated here. AAMVA and NHTSA in their 1980 guidelines classified the functional capability of cardiovascular patients based on a classification scheme developed in 1960 by an AMA Committee on Medical Rating of Physical Impairment. This 1960 cardiovascular impairment evaluation and classification scheme was developed based on medical judgement and laboratory tests.

In general, licensing recommendations for cardiovascular patients depend on the nature and the severity of the disease. Licensing for operating passenger- or freight-carrying vehicles is significantly more stringent than licensing for operating privately owned vehicles.

Were the 1980 AAMVA and NHTSA licensing guidelines on *cardiovascular* patients based on scientific considerations?

They were based on limited scientific evidence. Waller (1965) showed that drivers who were known to the Department of Motor Vehicles to have cardiovascular disease had twice the number of crashes per 1,000,000 vehicle miles as those in the comparison group.

Research since the release of the 1980 AAMVA and NHTSA guidelines

There is little research done on the relationship between heart disease and crash involvement. Research findings are inconclusive and sometimes contradicting. Waller and Naughton (1983) found in 725 Vermont drivers hospitalized for heart disease that these patients have a lower overall crash rate than age- and sex-controlled comparison groups. This conclusion contradicts earlier findings by Waller (1965; 1967). These earlier studies only considered drivers who were typically known by the Department of Motor Vehicles to have functional impairments resulting from their medical conditions. As a result, these drivers were already in a higher risk group.

Current state and provincial licensing practices

Table 2 shows the number of states and provinces that have licensing regulations on cardiovascular diseases (Anapolle, 1992).

Table 2. State and Provincial Licensing Practices on Drivers with Stroke and Cardiovascular Diseases

	No. of States		No. of Provinces	
Any licensing policies regulating drivers with the following conditions?	YES	NO	YES	NO
Strokes	46 (88.5%)	6 (11.5%)	10 (100.0%)	0 (0.0%)
Other cardiovascular diseases	42 (80.8%)	10 (19.2%)	10 (100.0%)	0 (0.0%)

Driving behavior of drivers with cardiovascular diseases

Waller (1987) examined changes in driving patterns of 119 patients before and after hospitalization for heart disease. An age- and sex-controlled but disease-free comparison group was used to remove the influence of factors other than heart disease on driving patterns. An empirical scoring system was developed to take into account not only the primary condition of concern (in this case, heart disease), but also other conditions such as diabetes, dementia, etc. that may contribute as well to driving impairment. These "other" conditions are designated as comorbid conditions.

In this 1987 study, Waller showed that only about half of the patients returned to their pre-hospitalization rate of driving and about 40% drove at most half as much as their pre-hospitalization rate. When examining the effect of heart disease on specific types of driving, Waller noted that the comparison respondents showed only modest shifts in most driving patterns over the previous couple of years. The patient group, however, responded differently, with much more substantial proportions reporting cutbacks in bad-weather and long-distance driving. As for the reasons for changes in driving patterns, patients reported that half of the time these changes were for health reasons and in most other cases the changes were because of altered life style, such as retirement from employment and/or reduction of more strenuous recreational activities. Waller concluded that altered driving pattern in heart disease patients was largely a reflection of altered life style resulting from the heart disease and comorbid conditions; and only partly because the patients were less capable or unwilling to drive as before hospitalization.

2.3 Metabolic Conditions

Metabolic diseases are due to disturbances in the functioning of the endocrine glands. These diseases are manifested by symptoms such as muscle weakness and spasms, sudden episodes of dizziness and unconsciousness. Some of these symptoms may, in many cases, impair ability to operate a motor vehicle safely. Of those conditions impairing functional capability, *diabetes mellitus* is the most prevalent metabolic disease.

Diabetes Mellitus

Diabetes Mellitus is a term used to describe a number of related medical conditions that affect the human body's ability to produce appropriate levels of insulin. Insulin plays the major role in regulating blood sugar levels which provide essential nutrients to the brain. Too high of a blood sugar level (hyperglycemia) or too low of a blood sugar level (hypoglycemia) may lead to unconsciousness. Furthermore, diabetes affects other parts of the body: the vascular or circulatory system, and vision. Diabetes in all ages is associated with the thickening (hardening) of the artery which in turn leads to faintness or loss of consciousness. Diabetes also affects the vision of the affected individuals. The longer a person has diabetes, the more likely that retinal damage of some degree will occurred. Therefore, American Medical Association (1984) suggested that a diabetic patient should always have a full review of his/her cardiovascular system and visual acuity before a license is granted since some diabetics, even though their blood sugar level may be under control, have cardiac and visual complications that make driving unsafe. Based on the 1988 National Health Interview Survey, there are 26 persons out of every 1,000 persons who are diagnosed as having diabetes (NCHS, 1989). The prevalence rate increases with age.

Diabetes mellitus can either be controlled by diet alone, by a combination of diet and oral medication, or by injection of insulin. Since the level of successfully controlling the disease varies, AAMVA and NHTSA in their 1980 guidebook suggested that whether a diabetic patient should be considered for a driver's license depends on several factors: (1) whether the individual is under regular medical supervision, (2) whether insulin is required, (3) whether the individual is in compliance with the prescribed medical and/or dietary regimen, (4) whether a warning is experienced before onset of any symptoms, and (5) whether the disease is under control (AAMVA & NHTSA, 1980).

AAMVA and NHTSA (1980) recommended that anyone with **uncontrolled** diabetes should not have the privilege to drive, and that anyone who has not had any episode of altered consciousness for the past 3 years and who is not on any medication should be allowed to drive. The Medical Commission on Accident Prevention (1985) in Great Britain required that every diabetic patient **must** declare their diagnosis when making application for a driver's license. Although the Driver Vehicle Licensing Agency in Great Britain reported that drivers' licenses had only been refused or revoked in about 0.23% of the cases, mostly because of impaired vision (Frier, 1992), a study done in Yorkshire showed that about a fifth of the diabetic drivers did not inform the Driver and Vehicle Licensing Agency or their motor insurers of their diabetes (Saunders, 1992). The study in Yorkshire also showed that insulin-dependent drivers were more likely to inform the licensing authority of their diabetes than other diabetic drivers.

Were the 1980 AAMVA and NHTSA licensing guidelines of patients with *diabetes mellitus* based on scientific findings?

Waller (1965) concluded that diabetic drivers whose medical conditions were known to the Department of Motor Vehicles (DMV) had two times more crashes on a per 1,000,000 vehicle miles basis than drivers who were known to DMV not to have diabetes. This was the first study that took risk exposure into account. However, the author cautioned against the use of this study to make general inferences since this was a highly selected group of drivers in terms of their medical condition being known to the DMV.

Research findings since the release of the 1980 AAMVA and NHTSA guidelines

Several methodological issues have contributed to the inconclusiveness found in much of the research relating diabetes to traffic crashes. First, most of the earlier studies focused on diabetic drivers known to the licensing agencies. These drivers were known either by voluntary admission or by police reports. Several reports documented that relatively few persons with diabetes are identified to the authorities. Thus, diabetic drivers known to the Departments of Motor Vehicles tend to be a rather selective group and their crash experience might not reflect the true experience of the diabetic population as a whole. Second, a number of studies have failed to include a comparison group and/or failed to take into account driving exposure. Consequently, studies comparing traffic crash patterns of diabetic drivers to non-diabetic drivers have reported mixed results -- either an increased, decreased or similar frequency for crashes (as summarized in Laporte, 1991). Cox, et. al. (1993) tested 25 diabetic patients in a driving simulator and found that although mild hypoglycemia was not associated with disruption in driving performance, moderate hypoglycemia was associated with driving decrements in 35% of the patients -- mainly affecting steering capability.

Current State and Provincial Licensing Practices

Forty-three States and all 10 Canadian Provinces have licensing policies regulating diabetic drivers (Anapolle, 1992). Table 1 (repeated here for reader's convenience) gives the time intervals required by different States and Provinces that should be seizure-free before the applicant can be considered for licensing.

Table 1. Required Seizure-Free Period before Licensing

Time Interval	No. of States in U.S.A.	No. of Canadian Provinces
3 Months	7 (13.5%)	0 (0.0%)
6 Months	11 (21.2%)	0 (0.0%)
6 months - 1 year	1 (1.9%)	0 (0.0%)
1 year	21 (40.4%)	10 (83.3%)
0 - 2 years	1 (1.9%)	0 (0.0%)
4 year	1 (1.9%)	0 (0.0%)
Individually evaluated	8 (15.4%)	1 (8.3%)
N/A	1 (1.9%)	1 (8.3%)
No time specified	4 (7.7%)	1 (1.9%)
TOTAL	52[1] (100.0%)	12[2] (100.0%)

[1] Includes District of Columbia and Puerto Rico.
[2] Includes two territories.

Other Metabolic Diseases

Some of the other metabolic diseases that might impair the functional capability of safely operating a motor vehicle, such as muscular weakness, fatigue, visual disturbances, include thyroid disease, and adrenal diseases. Symptoms from these diseases usually have an onset so gradual that the patient is well aware of them before serious problems occur. Therefore, licensing recommendations for these patients are considerably more liberal compared to those for diabetic patients.

2.4 Vision

There is no doubt that good vision is necessary for the safe operation of a motor vehicle and that any significant loss of visual function such as visual acuity or field of

Were the 1980 AAMVA and NHTSA licensing guidelines on patients with *other metabolic conditions*, such as *thyroid* or *adrenal diseases*, based on scientific considerations?

No. There were no references cited in the 1980 AAMVA and NHTSA guidelines on the relationship between metabolic conditions, except diabetes mellitus, and increased highway crashes. Therefore, the 1980 guidelines were not based on scientific findings.

vision can seriously affect one's safe driving, especially on today's congested high-speed roadways. AAMVA and NHTSA in their 1980 guidelines suggested that when evaluating overall visual functional capability, the following functions be examined: (1) visual acuity, (2) visual fields, (3) ocular motility, (4) color vision, (5) dark adaptation and others.

Visual Acuity

Licensing standards on visual acuity vary from state to state and country to country. AAMVA and NHTSA (1980) recommended that those who have the ability to coordinate the use of both eyes and who have corrected visual acuity in each eye of at least 20/25 be considered for all levels of licensing (i.e., commercial and personal). AAMVA and NHTSA also recommended additional related guidelines. Anyone who has corrected visual acuity in each eye of less than 20/25 can not operate for-hire vehicles that haul passengers or hazardous cargo or operate emergency vehicles. Anyone who has visual acuity in the better eye of 20/80 or worse should not operate any vehicle. Anyone who use telescopic device is not recommended to be licensed, except after the applicant has demonstrated functional capability through a road test. Visual acuity standards in the United Kingdom are set at 20/32 (MCAP, 1985). Canada's Province of British Columbia suggested that the visual acuity of the better eye be no less than 20/40 to operate privately owned vehicles. In order to operate commercial or for-hire passenger vehicles in British Columbia, one needs to have no less than 20/30 in the better eye, and no less than 20/50 in the poorer eye (BCMA, 1989).

Although the current visual standard for licensing is a measure of static visual acuity, studies have suggested that dynamic visual acuity, which is tested by looking at moving objects, and other measures on visual function would be better measures of safe-driving capability than static acuity (Shinar, 1977; Shinar & Schieber, 1991; Johnson & Keltner, 1983). Shinar also suggested that static acuity under low levels of illumination and central angular movement is most consistently related to crashes.

Visual Fields

The most common ocular diseases that cause visual field loss are glaucoma, retinal disorders and cataracts. AAMVA and NHTSA (1980) stated that in order to operate any vehicle, one needs to have a horizontal visual field of 140° or more in each eye. When one does not have a total horizontal visual field of at least 140°, he/she should not be allowed to operate any vehicle. The Canadian Province of British Columbia suggested that individuals with both eyes examined together at 120° should be allowed to operate only passenger vehicle and light commercial vehicles (BCMA, 1989). United Kingdom's Medical Commission on Accident Prevention stated in its guide to medical practitioners that "... it is reasonable to suggest that to drive with a field of binocular vision which is less than 120 degrees is unsafe" (MCAP, 1985).

Ocular Motility

A mild case of ocular muscle imbalance, when there is no diplopia (double vision), is not a concern for safe driving. However, drivers with a history of uncontrolled diplopia should not be licensed for for-hire or emergency vehicles and should be carefully evaluated before being granted a private vehicle license (AAMVA & NHTSA, 1980).

Color Vision

At one point, indiscriminant red-green color vision was considered one of the causes of road crashes. However, with the mixture of additional color to the signals, the problem of red-green confusion has been reduced. Furthermore, standardization of the position of the traffic signals has further reduced the impact of defective color vision on highway safety. Defective color vision becomes a safety issue only when the condition is so severe that visual acuity is also affected (BCMA, 1989).

Dark Adaptation and Other Conditions

Dark adaptation and glare tolerance are important for night driving. However, there are no valid data linking road crashes to an inability to adapt to decreased illumination and to recover rapidly from exposure to glaring headlights. A contributing factor for the lack of data is that no tests are available to measure accurately these two functions. Individuals with problems in adapting to decreased illumination and in adjusting to glare should limit their driving to daylight hours.

Were the 1980 AAMVA and NHTSA licensing guidelines on patients with *vision impairment (e.g., visual acuity, visual fields, ocular motility)* based on scientific findings?

The 1980 guidelines were based on limited scientific findings. Henderson and Burg in their 1973 study examined 236 commercial drivers and bus drivers and found a statistically significant relationship between poor visual performance and high crash involvement. Despite this finding, they cautioned that due to the limited sample size, the study should not be used to draw inferences about the entire population. A small but consistent correlation between photopic acuity and crash involvement was found by Shinar (1977). He also found that the combination of mesopic acuity and dynamic visual acuity has the highest correlation with crash involvement. Motion perception was found by different researchers to be slightly but significantly correlated with crash involvement in older drivers (Shinar, 1977; Henderson et al., 1973). Glare tolerance and glare recovery time were found to have little relationship with driving safety (Shinar, 1977). Visual field was found not to be correlated with driving safety (Council & Allen, 1974).

Research since the release of the 1980 AAMVA and NHTSA guidelines

A significant amount of research on the relationship between visual impairment and crash involvement has been conducted since the release of the 1980 guidelines. A comprehensive review of the literature on the causal links between vision and crash involvement can be found in Shinar & Schieber (1991) and is summarized as follows:

- **photopic static acuity** is weakly but consistently correlated with crash involvement; this relationship becomes stronger in older drivers (Davidson, 1985).
- **mesopic static acuity** is one of the best predictors of crash involvement in older drivers (Shinar, 1977).

- **dynamic visual acuity** is a more important measure of visual acuity for predicting crash involvement than static acuity (Shinar, 1977; Retchin, Cox, Fox & Irwin, 1988).
- **motion perception** is slightly but significantly correlated with crash involvement (Shinar, 1977; Henderson & Burg, 1973; Hills, 1975).
- **visual field**: contrary to previous findings, Johnson and Keltner found that subjects with severe visual field loss in both eyes have a traffic crash and conviction rate twice as high as that of age and sex controlled groups with a normal visual field (Johnson & Keltner, 1983).
- **disability glare** is weakly linked to crash involvement; and
- **contrast sensitivity**, for which data are lacking to establish any statistical relationship.

The relationship between glaucoma and driving was examined and was found to have little correlation (MacKean & Elkington, 1982). A group of researchers from the University of Illinois at Chicago's Eye Center suggested in a recent report that visual function alone does not predict driving performance and that driving performance is best predicted by the interaction of visual and visuocognitive/motor skill (Szlyk, Severing & Fishman, 1991). The study uses an interactive driving simulator to measure driving performance.

Owsley, Ball, Sloane, Roenker and Bruni (1991) reached a similar conclusion by studying 53 subjects. These researchers concluded that the useful field of view (UFOV), which is found to reflect the speed of visual information processing and mental status combined, accounted for a significant amount of the statistical variance in predicting crashes. They also found little relationship between traditional visual measures (e.g., visual acuity) and crashes. In their 1993 article, Ball, Owsley, Sloane, Roenker and Bruni (1993) not only confirmed their 1991 conclusions with data from a larger sample ($n=294$) but also concluded from their data that restricting drivers' licenses based solely on age or on common stereotypes of age-related declines in vision and cognition is scientifically unfounded.

Current state and provincial licensing practices

Thirty-nine states and 6 provinces require in-person license renewal, of which 32 states and 3 provinces require vision screening at the time of the renewal (NHTSA & Association for the Advancement of Automotive Medicine [AAAM], 1992). Another survey conducted by Anapolle (1992) provided data which summarized the current state and provincial licensing practices regarding vision screening (Table 3). Based on the survey results, recommended minimal visual acuity levels for both eyes or one blind eye, with or without glasses are summarized in Table 4, and recommended minimal peripheral vision levels are given in Table 5 (NHTSA & AAMVA, 1986).

Driving behavior of drivers with reduced vision

In their 1991 paper, Laberge-Nadeau et al. compared a group of individuals between the ages of 70 and 85 with impaired visual acuity to an age- and sex-controlled group. They noted that the proportion of older individuals with impaired visual acuity who drove was statistically smaller than that of the control group; and that visually impaired male drivers (between 70 and 85 years old) were more likely to drive 3,100 miles a year less than male drivers of the same age group who had good health. They also observed that older drivers with impaired visual acuity refrained from driving at night more so than their control counterparts, and that the proportion of older drivers refraining from driving at night increased with age for both the patient and the control groups. This self-restricted behavior was also found in a group of California drivers who were known to the Department of Motor Vehicles to use bioptic telescopic lenses (Janke, 1983).

The visually-impaired drivers who participated in the Established Populations for Epidemiologic Studies of the Elderly (EPESE) in Iowa were found to drive significantly less, and they had no significantly different crash involvement rate than drivers with unimpaired vision (Foley, Wallace, Colsher, Eberhard, Ostfeld, and Marottoli, 1993). However, the visually-impaired drivers who participated in the EPESE in New Haven showed no difference in their driving, but had a significantly higher rate of one or more

Table 3. Summary of State and Provincial Practices Pertaining to Vision Standards

	YES	NO
Required vision screening at renewal?		
Number of States in USA	42 (80.8%)	10 (19.2%)
Number of Canadian Provinces	2 (20.0%)	8 (80.0%)
Allowing telescopic lenses?		
Number of States in USA	30 (57.7%)	22 (42.3%)
Number of Canadian Provinces	0 (0.0%)	10 (100.0%)
Any age-based vision standards exist?		
Number of States in USA	13 (25.0%)	39 (75.0%)
Number of Canadian Provinces	4 (40.0%)	6 (60.0%)
Required screening on peripheral vision?		
Number of States in USA	17 (32.7%)	35 (67.3%)
Number of Canadian Provinces	1 (10.0%)	9 (90.0%)
Required screening on sign-recognition?		
Number of States in USA	8 (15.4%)	44 (84.6%)
Number of Canadian Provinces	1 (10.0%)	9 (90.0%)
Required screening on depth perception?		
Number of States in USA	9 (17.3%)	43 (82.7%)
Number of Canadian Provinces	1 (10.0%)	9 (90.0%)
Required screening on color vision?		
Number of States in USA	9 (17.3%)	43 (82.7%)
Number of Canadian Provinces	1 (10.0%)	9 (90.0%)
Required screening on acuity?		
Number of States in USA	42 (80.8%)	10 (19.2%)
Number of Canadian Provinces	2 (20.0%)	8 (80.0%)

Source: Anapolle, 1992.

Table 4. Recommended Minimal Visual Acuity Levels for both Eyes or One Blind Eye with or without Glasses (Of the jurisdictions that responded)

Visual acuity standards	Both eyes w/ or w/o glasses		One blind eye w/ or w/o glasses	
	No. of States	No. of Provinces	No. of States	No. of Provinces
20/30	0	0	8	0
20/33	0	0	2	0
20/40	37	8	30	8
20/50	5	0	4	0
20/60	3	0	3	0
20/70	5	0	1	0
TOTAL	51	8	48	8

Source: NHTSA & AAMVA, 1986.

Table 5. Recommended Minimal Peripheral Vision Levels for Both Eyes (Of the jurisdictions that responded)

Peripheral vision guidelines	No. of States in USA	No. of Canadian Provinces
70°	1	0
100°	1	0
110°	1	0
120°	3	5
130°	2	0
140°	8	1
240°	0	1
No standard	26	1
Based on examiner's judgement	1	0
TOTAL	43	8

Source: NHTSA & AAMVA, 1986.

state-reported crashes than the unimpaired drivers. The authors attributed these conflicting findings to the vision screening required for license renewal in Iowa.

Although older drivers with visual problems reportedly limited their driving to daylight, less congested hours and good weather conditions, Shinar, Phillips, Wallace and Colsher (1991) found that the extent to which older drivers can assess their own visual capability and then compensate for the impairment in their driving is limited.

2.5 Drugs and Medication

The impact of the use of prescribed drugs on highway safety, and the extent to which use of these drugs contributed to the risk of being involved in road crashes is unknown. However, the use of such drugs has increased significantly in the past decade and has raised an important safety issue with older drivers.

Since the influence of prescribed drugs varies so widely from individual to individual, it is extremely difficult to regulate the usage of such drugs. In licensing guidelines, physicians who prescribe drugs which are known to have impacts on individuals' capability to safely operate a motor vehicle are advised to warn their patients about the side effects and about the potential effect of alcohol in particular.

Were the 1980 AAMVA and NHTSA licensing guidelines on patients with *excessive consumption of alcohol and drugs*, both *illegal* and *prescribed*, based on scientific considerations?

The relationship between excessive consumption of alcohol and highway crashes is well established. The National Safety Council reported in its 1991 *Accident Facts* that about 49% of all traffic fatalities in 1989 involved an intoxicated or alcohol-impaired driver or non-occupant. Although there is a general public perception that excessive consumption of drugs significantly increased crash involvement, there were no references cited in the 1980 AAMVA and NHTSA guidelines, and little is found in the literature on the relationship between excessive intake of prescribed or over-the-counter drugs and increased highway crash risk. Therefore, the 1980 guidelines on medication were not based on scientific considerations.

Research since the release of the 1980 AAMVA and NHTSA guidelines

In their recent report, Stewart, Moore, Marks, May, and Hale (1993) concluded that the usage of the 50 most frequently reported drug ingredients and the 15 most frequently reported therapeutic drug categories (such as antihypertensives, analgesics, anticoagulants, hypothyroid) in older drivers was found to be not associated with traffic accidents.

Current state and provincial licensing practices

Thirty-one States and all 10 Canadian Provinces have licensing regulations on excessive consumption of alcohol and drugs. The regulations state that any individual who consumes alcohol and any type of drug to a degree that affects his/her safe operation of a motor vehicle will not be granted a driver's license (Anapolle, 1992).

2.6 Mental Disorders

Mental disorders include psychotic and neurotic illnesses, mental handicap, and personality disorders. Because of a wide range of psychiatric disorders, different forms of treatment, and individual variation, it is extremely difficult to assess accurately the level of mental impairment. Also, it is extremely difficult to assess to what extent mental impairment impairs safe driving. It is also difficult to identify which attributes of mental impairment contribute to road crashes. Consequently, medical guidelines have suggested that medical advisory boards or physicians evaluate licensing applicants with mental disorders on an individual basis. Four personality characteristics in mentally impaired patients seemed to be most closely associated with increased risk of crash involvement (AAMVA & NHTSA, 1980; Waller, 1973). They are: paranoid thinking, suicidal tendencies, impulsiveness, and violent or aggressive behavior against others. Physicians are advised to evaluate their presence or absence.

Were the 1980 AAMVA and NHTSA licensing guidelines on *mentally impaired* patients based on scientific findings?

Little was found in the literature relating mentally impaired drivers with higher crash rates. Waller examined California drivers with their mental condition known to the Department of Motor Vehicles (DMV) and found that mentally impaired drivers had crash rates more than twice the rates of comparison groups (Waller, 1965). Again, patients with their medical condition known to the DMV are usually in high-risk category. Based on the limited number of studies, the 1980 guidelines were based on limited scientific findings.

Current state and provincial licensing practices

Thirty-seven States and all 10 Canadian Provinces have polices which deny driver's licenses from individuals who have previously been adjudged to be afflicted with or suffering from any mental disability or disease (Anapolle, 1992). Mental disability or disease that is the basis for denying driver's license is not explicitly stated in any state's licensing policies. If an applicant is denied a driver's license due to mental disability or disease, the applicant either has been previously judged insane or is afflicted with a mental disability or disease "...which could affect the safe operation of a motor vehicle..."

2.7 Musculoskeletal Conditions

Musculoskeletal conditions refer to those that weaken the strength of muscle and bones, and that impair the flexibility of joints and limbs. Many of these conditions can be compensated by installing adaptive equipment in motor vehicles. Since there is no single standard design for motor vehicles, licensing guidelines for musculoskeletal conditions are advised to be used as a flexible basis.

AAMVA and NHTSA (1980) suggested that muscle strength be tested on several different joints before granting driver's licenses. Whether a license applicant should be considered for a certain type of license depends on the outcome of these muscle strength tests. Whether a driver's license applicant has adequate active range of joint motion to safely operate a motor vehicle should be evaluated individually. Similarly, whether loss of a part or the whole of a critical limb will impair safe driving should also be evaluated on an individual basis.

Were the 1980 AAMVA and NHTSA licensing guidelines of patients with *orthopedic impairments* based on scientific considerations?

A Swedish study was used by AAMVA and NHTSA to establish the relationship between orthopedically impaired drivers and highway crashes. In that study, drivers with orthopedic impairments did not constitute an increased risk in hi[illegible]ays, and it was concluded that their impairments can be adequately compensated by in-vehicle devices (Ysander, 1966). This study also showed that drivers who lost function in their right arms or rights legs had a disproportionately higher crash frequency than other disabled drivers. One might say that the 1980 guidelines on musculoskeletal conditions were based on limited scientific findings.

2.8 Respiratory Function

Severe respiratory conditions which limit sufficient oxygen to the brain may lead to impaired judgement, slowed response time and physical weakness. Consequently, the ability to operate a motor vehicle safety may be jeopardized.

AAMVA and NHTSA (1980) suggested that the impairment level to drive due to respiratory deficiency be assessed. The 1980 AAMVA and NHTSA guidelines stated that individuals who usually have abnormal chest X-rays, and difficulty breathing when climbing one flight of stairs or when walking 100 yards on a level plane, should not be considered for any type of driver's license. AMA (1984) used tests that measure respiratory capability such as forced vital capacity (FVC) , forced expiratory volume in 1 second (FEV_1), and FEV_1/FEV ratio to establish licensing standards. On the other hand, the Medical Commission on Accident Prevention (1985) of the United Kingdom did not specifically regulate respiratory conditions for licensing. The Canadian Province of British Columbia only discussed severe respiratory conditions in their guidelines (BCMA, 1989).

Were the 1980 AAMVA and NHTSA licensing guidelines of patients with *respiratory impairments* based on scientific findings?

AAMVA and NHTSA's 1980 guidelines used a scheme to classify permanent impairment of the respiratory system that was developed in 1965 by the AMA Committee on Rating of Mental and Physical Impairment. This 1965 classification scheme was largely based on clinical and laboratory observations. A link between impairment of the respiratory system and increased highway risk was not established based on scientific data.

2.8 Hearing

Despite the fact that the effect of impaired hearing on the safe operation of a motor vehicle is still controversial, licensing guidelines were established by AAMVA and NHTSA in 1980, and by AMA in 1986. A 1963 study conducted by the State of California's Department of Motor Vehicles concluded that "...contrary to the opinions and preconceptions of many in the area of traffic safety, deaf drivers do not appear to have better driving records than non-deaf drivers. In fact, statistical tests on the crash ... indicate that the deaf, as a group, have somewhat the poorer driving record (than the non-deaf)..." (Coppin & Peck, 1963). In 1973, Henderson and Burg, however, concluded that there was no significant evidence to indicate that drivers with greater hearing loss were associated with greater number of crashes. "Hard of hearing" in the 1980 AAMVA and NHTSA guidelines was defined as "the inability to identify correctly four out of five numerals spoken in each ear with the examiner standing two feet behind the patient".

Were the 1980 AAMVA and NHTSA licensing guidelines of patients *hard of hearing* based on scientific considerations?

There were contradicting findings to even determine the impact of hearing impairment on highway safety. The 1980 guidelines on hearing impairments were not based on scientific findings.

Current state and provincial licensing practices

A 1981 report by NHTSA summarizes that 8 states do not deny driver's licenses due to deafness; one state requires a hearing examination for license renewal; two jurisdictions require the vehicle of a hearing-impaired person be specially equipped; and one state issues stickers to be placed on the windshield or on the license plate of the vehicle used by a deaf or hearing-impaired person (NHTSA, 1981). More recent summary data on state policies governing impaired hearing are not available.

Driving behavior of hearing-impaired drivers

There has been little research done on driving behavior of hearing-impaired or deaf drivers. A group of 1,400 totally deaf drivers was found to drive, on average, more than a group of non-deaf drivers in a 1963 study (Coppin & Peck, 1963). However, this difference in the amount of driving might partly be due to the needs of the deaf and perhaps largely because of the uneven age distribution of the drivers among the two groups -- the proportion of deaf drivers under 25 years old was greater than the one for the non-deaf group and the proportion of deaf drivers more than 65 years old was smaller than the one for the non-deaf group.

2.9 Aging

The aging process causes physiological changes, structural changes, nervous system changes, deterioration in vision and hearing, and other changes. Table 6 shows the prevalence of older individuals being afflicted by selected chronic conditions (National

Center for Health Statistics, 1993). Intellectual and cognitive functions also decline with age. Some of these changes impair the functional capabilities of older drivers to such an extent that the driving of these older drivers is affected. In a study involving North Carolinian drivers, Stutts and Martell (1992) found that although crash rates per driver for drivers 65 and older have decreased in the past 15 years, drivers 75 and older still have the highest crash rate per estimated vehicle mile. The results of this study also seem to indicate that older drivers limit their driving to times and situations that they feel capable of handling.

Older drivers, in general, tend to have slower reaction time, poorer vision, deteriorating memory, and stiffer reflexes. Studies categorized three major aging factors that make driving more problematic for older drivers. They are: **visual limitation, cognitive/attention limitation**, and **motor limitation** (McKnight, Simmone & Weidman, 1982). More specifically, a study by the Transportation Research Board (TRB, 1992) suggested that future research should be focused on dementia, stroke/head injury, insulin dependent diabetes, macular degeneration (degeneration of retina), and arthritis as age-related functional and mental limitations that are thought to impact highly on driving behavior.

Table 6. Average Number of Selected Chronic Conditions[1] and Impairments per 1,000 Persons 55 Years or Older, 1985-1987

AGE	Heart Disease	Hypertension	Diabetes	Visual Impairment[2]	Cataract	Deformity/ Orthopedic Imp.
55-64	70.1	302.7	76.1	51.3	33.6	178.8
65-74	114.1	400.8	99.0	69.7	71.1	220.2
75 and over	133.6	379.3	100.8	125.2	246.9	222.4

[1] Based on unduplicated counts -- a person was counted only once for each condition regardless of the number of mentions of that condition.

[2] Includes blindness in both eyes and other visual impairments.

What was suggested in the 1980 AAMVA and NHTSA guidelines regarding older drivers was that if an older driver suffered from a particular medical condition (e.g., cardiovascular disorder), then licensing guidelines for that medical condition should be used when considering a license for this individual. Due to the variation in which aging affects the driving performance of older drivers as a group and the variation among older drivers in terms of driving performance, the 1980 AAMVA and NHTSA guidelines offered limited suggestions for licensing older individuals. However, it is clear among the safety research community that the optimal goal in addressing transportation issues of this aging society is to reach an equilibrium between the mobility and the safety of elderly. In order to establish a licensing procedure that strives to identify and regulate "high-risk" older drivers in a fair and appropriate manner, licensing of senior individuals should not be based on *chronological age*; instead, it should be based on *functional criteria*.

Research on dementia or aging since the release the 1980 AAMVA and NHTSA guidelines

Dementia is characterized by cognitive and perceptual deficits which may interfere with safe driving. In the most common form of dementia, Alzheimer's disease, these deficits include memory loss, reduction in attention span and difficulties in visual perception, such as disordered scan-paths, impaired visuo-spatial discrimination and reduction in visual fields. Some research has been devoted to older drivers with dementia and their driving performance since 1980 and research results are summarized in "Dementia and the Older Driver" (Kaszniak, Keyl & Albert, 1991). Friedland et al. (1988) found that 47% of a group of 30 patients with dementia of the Alzheimer type (AD) had been involved in a crash over a five-year period compared to 10% of the control group, and 23 of the 30 AD patients reportedly (by proxies) changed their driving behavior while no one in the control group did. Of 80 patients evaluated in an outpatient dementia diagnostic clinic for possible cognitive impairment, 30% who were currently driving had a significantly higher mental status score than those who had stopped driving (Coyne, Feins, Power & Joslin, 1990). However, those 30% who were currently driving had a greater rate of abnormal driving events (e.g., crashes, getting lost)

Were the 1980 AAMVA and NHTSA licensing guidelines on patients with *age-related physical and mental limitations* based on scientific findings?

The 1980 guidelines on patients with age-related physical and mental limitations refer to licensing recommendations for a specific limitation. For example, licensing recommendations for older drivers with cardiovascular diseases are the same as those for drivers with cardiovascular disease in general. The interaction between aging and medical condition is usually overlooked. Therefore, most of the 1980 guidelines specifically for age-related limitations are actually based on whatever scientific bases there are for the general population. One exception is dementia. Waller (1967) found that older drivers with dementia have twice the crash rate as that of non-demented older drivers and that older drivers with dementia and cardiovascular disease have a crash rate four times the rate of unafflicted older drivers. However, the author concluded that since the diagnoses for older drivers with cognitive impairment were imprecise, the relationship between crash risk and different level of dementia severity cannot be established.

than those who had stopped driving, indicating that even mild cognitive impairment may pose a higher risk.

Kaszniak, Nussbaum and Allender (1990) compared a group of mildly demented patients to a group of senior individuals with major depression. A significantly greater proportion of depressed patients continued to drive than did the AD patients. Significantly more AD patients than depressed patients were reported to have been lost while driving and were reported to have had a crash. Kaszniak et al. (1991) concluded that all previous studies reached a similar conclusion in that dementia patients have a higher crash rate than non-demented drivers, with results controlled by age and sex. More recent studies also reached a similar conclusion. A study conducted by Cooper et. al. (1993) using 165 dementia patients and a control group of 165 persons matched by age, sex and dwelling area, established that the cognitively impaired drivers were involved in over twice the number of crashes as the controls during the identical time periods. The study also found that although there seemed to be no significant difference between the two groups in terms of driving exposure and purpose of the trips, the dementia clinic patients seemed to have more crashes at intersections, had a higher proportion of their accidents on wet roads, and were more commonly associated with accident contributors (improper turning or passing, following too closely, unsafe backing or driving without due care and attention). Drachman and Swearer (1993) investigated crash rates per year, rather than crash rates per mile, and found that AD patients have more crashes per year than did matched elderly control group, but their annual reported crash rate was only moderately greater than that for drivers of all ages and lower than that for young (16-24-year old) adults. The authors also noted that the crash rate was found to increase by approximately 134% from the first to the forth year after the onset of AD.

However, a different conclusion was reached by Foley, et al. (1993). Data from two cohorts (Iowa and New Haven) of the Established Populations for Epidemiologic Studies of the Elderly (EPESE) indicated that drivers with lower scores on a mini-mental status questionnaire showed no significant differences in driving or in crash involvement rate compared to drivers with higher scores.

In addressing the effect of physical frailty due to normal aging on driving and crash involvement, Foley, et al. (1993) concluded that frail individuals, with a low level of physical functioning, drove significantly less and had a slightly lower rate of having one or more state-recorded crashes when compared to those with medium and high levels of physical functioning.

Current state and provincial license practices

When asked whether their licensing agencies have separate policies for older drivers, 19 States and 6 Provinces responded "yes" (Anapolle, 1992). Since licensing policies for older drivers vary from state to state, it is not within the scope of this project to review and summarize individual state's policies. However, Table 7 presents summary data on the year interval required by states for in-person renewal. The data are categorized by applicant's age. These data suggest that a four-year interval is the predominant interval for in-person renewal and that older drivers are required by more states to have in-person renewal more frequently than younger drivers.

Opinion differs as to whether screening older drivers for dementia should be conducted and how and where driving capability of demented older drivers should be assessed. Retchin and Hillner (1992) used a decision analysis technique and concluded that screening older drivers for dementia was expensive compared to the limited public health benefits it would provide. Reuben (1991) suggested that since the privilege of driving is granted by the state, it would, therefore, seem most appropriate for the state to take the responsibility for the decision to license demented patients. He quoted California's mandatory reporting of demented drivers as an example for other states to follow.

Driving behavior of demented older drivers

Gilley, et al. (1991) surveyed 487 dementia patients (with a mean age of 72 and a standard deviation of 9.7) on their current driving status, reasons for stopped driving, duration of driving after disease onset, and instances of unsafe operation in the preceding 6 months for those patients who were still driving (1991). Almost one-third (n=154) of the patients were not driving at the time of disease onset. Among the 73 patients who stopped driving prior to the onset, sensory or motor limitations were the primary reasons for their stop in driving. Comparisons between patients currently driving and those who continued to drive after disease onset, but who had stopped driving at the time of the survey, showed that patients currently driving had shorter disease duration and higher scores on the Mini-Mental State Examination (less impaired.) The percentage of AD patients still driving was found to decrease with increase in disease duration (Friedland et al, 1988).

In a comparable study, O'Neill, et al. (1992) surveyed 329 patients attending a memory disorders clinic in Bristol, United Kingdom. All patients were tested with a neuropsychological test battery including simple cognitive screening tests as well as a test of visuo-spatial ability. Caretakers of these patients were contacted to determine if the patients were driving at the onset of symptoms of their disease. Nearly one-fifth (n=57) of the 329 patients continued to drive after the onset of the symptoms of dementia. Of these, 65% reported (by proxy) a marked reduction in driving ability and almost 50% of these patients got lost at least occasionally while driving. Forty-five (78%) drivers stopped driving, after a mean disease duration of 2.7 years. The authors concluded that a significant number of patients with dementia continued to drive despite a significant deterioration in driving performance.

In another study where 67 subjects with AD were compared to 100 elderly, non-spousal controls, about 30% of the AD subjects were still driving at the time of the survey while 98% of the controls continued to drive (Dubinsky, Williamson, Gray & Glatt, 1992). Safety concerns were the primary reasons for the AD patients to stop driving. The AD patients tended to avoid driving in bad weather, drove more often below the speed limit, and avoided rush hour traffic and highway driving. Two other studies (Kaszniak et al., 1990; Lucas-Blaustein, Filipp, Dungan & Tune, 1988) also found that the majority of dementia patients who continued to drive made efforts to compensate for their impairment, such as not driving at night and driving only in their

Table 7. Summary Data on the Year Interval Required by Different Jurisdictions for In-person Renewal

	40<=Age<65		65<=Age<68		68<=Age<70		70<=Age<75		75<=Age<80		80<=Age<=86		86<Age	
Year Interval	No. of States	No. of Provinces	No. of States	No. of Provinces	No. of States	No. of Provinces	No. of States	No. of Provinces	No. of States	No. of Provinces	No. of States	No. of Provinces	No. of States	No. of Provinces
1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (2.6%)	0 (0.0%)	2 (5.1%)	0 (0.0%)	3 (7.7%)	1 (16.7%)	4 (10.3%)	1 (16.7%)
2	0 (0.0%)	1 (16.7%)	1 (2.6%)	1 (16.7%)	3 (7.7%)	1 (16.7%)	3 (7.7%)	2 (33.3%)	3 (7.7%)	2 (33.3%)	4 (10.3%)	1 (16.7%)	3 (7.7%)	1 (16.7%)
3	1 (2.6%)	2 (33.3%)	1 (2.6%)	2 (33.3%)	1 (2.6%)	2 (33.3%)	1 (2.6%)	2 (33.3%)	2 (5.1%)	2 (33.3%)	2 (5.1%)	2 (33.3%)	2 (5.1%)	2 (33.3%)
4	30 (76.9%)	1 (16.7%)	30 (76.9%)	1 (16.7%)	29 (74.4%)	1 (16.7%)	28 (71.8%)	1 (16.7%)	26 (66.7%)	1 (16.7%)	25 (64.1%)	1 (16.7%)	25 (64.1%)	1 (16.7%)
5	4 (10.3%)	2 (33.3%)	5 (12.8%)	2 (33.3%)	4 (7.7%)	2 (33.3%)	4 (10.3%)	1 (16.7%)	4 (10.3%)	1 (16.7%)	3 (7.7%)	1 (16.7%)	3 (7.7%)	1 (16.7%)
6	1 (2.6%)	0 (0.0%)	1 (2.6%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.6%)	0 (0.0%)	1 (2.6%)	0 (0.0%)	1 (2.6%)	0 (0.0%)
8	1 (2.6%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	0 (0.0%)
10	1 (2.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
12	1 (2.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
SUM	39 (100%) (76.5%)	6 (100%) (50%)	39 (100%) (76.5%)	6 (100%) (50%)	39 (100%) (76.5%)	6 (100%) (50%)	39 (100%) (76.5%)	6 (100%) (50%)	39 (100%) (76.5%)	6 (100%) (50%)	39 (100%) (76.5%)	6 (100%) (50%)	39 (100%) (76.5%)	6 (100%) (50%)

Sources: Petrucelli & Malinowski, 1992.

own neighborhood. Despite this self-regulated driving, demented drivers were still over-involved in crashes.

2.10 Obstacles to Establish Statistical Links between Older Drivers and Highway Crashes

Most research on medical impairment on older drivers and driving has been limited. Waller (1992) points out several methodological and administrative issues that contribute to the inconclusiveness in research involving older and medically impaired drivers. His view is summarized below:

- Diagnostic accuracy, sample size and sample selection procedure should all be carefully planned; and any selection bias, its implication, and whether it can be avoided, should be clearly stated.
- The research community and departments of motor vehicles should jointly define criteria for excessive crash risk -- should it be measured per unit driver or per unit mile driven?
- In examining the medical condition of older drivers and their driving performance, one should not ignore the effect of mixes of medical conditions and the subtle interaction between driver and environment.

2.11 Areas where More Research Is Needed

Based on the literature review, more research will be needed in three areas to address older drivers' safety issues with more conclusive evidence:

1. The effect of increased usage of prescribed and over-the-counter medication by older drivers on highway crashes. Special attention should be paid to the effects of alcohol abuse and medication known to affect cognition in already functionally impaired older drivers.
2. Although some studies were done in recent years on demented older drivers, methodological problems, small sample sizes and differences in the observations across these studies have prevented any confident conclusions regarding dementia and highway crashes. More empirical research with larger sample sizes in this area will be needed.

3. The last, but perhaps the most important, area in which research is lacking is the synergistic effects of comorbid conditions on highway crashes. While single conditions might not affect the safe operation of a motor vehicle, the combination of several conditions may present an unacceptable risk. This area is especially relevant in trying to clearly identify "high-risk" older drivers, since the aging process contributes to both physical and mental deterioration. One of the most common comorbid conditions in many older individuals is reduced vision combined with other medical conditions.

3. DRIVING AND TRAFFIC CRASH PROFILE OF OLDER DRIVERS

Much research has been devoted to examining older drivers' involvement rates in various types of crashes, changes in driving behavior in older individuals, and the impact of these changes on the safety of our nation as a whole. This section discusses the changes in the driving patterns of older drivers over the last decade, and whether older drivers are indeed over-involved in traffic crashes as the public perceives. If so, what types of traffic crashes are they more likely to be involved in, and are they more susceptible to injury than younger drivers? However, there is little evidence directly linking age-related physical and mental limitations in older drivers to their driving performance, as reflected by traffic crashes and moving violations.

3.1 Demographic Change

Data used to examine trends in the driving behavior of the older drivers in the past decade are from the 1983 and 1990 Nationwide Personal Transportation Surveys (NPTS). A total of 6,500 households were interviewed in the 1983 survey and 22,000 households in the 1990 Survey (Hu & Lee, 1992). Although there are other sources providing data on population and licensed drivers, for the purpose of consistency, these data are also generated for both years from the NPTS's. The NPTS data show that 10.6% of the 1983 population was 65 years of age or older and that this percentage increased to 12.1% in 1990 (Table 8). The NPTS data agree, in general, with the population data published by the Bureau of the Census which projects that individuals 65 or older will constitute 13.9% of the total population in 2010 and 21.8% in 2030 (Figure 1). These data all point to a commonly perceived fact: an aging society.

When looking at the distribution of licensed driver by age (Table 9), drivers 65 years or older were not over-represented in the overall driver population -- 10.6% of all licensed drivers were 65 years or older in 1983, and 12.5% in 1990, similar to their percentage in the general population. However, the percentage of individuals within a specific age group who are licensed to drive presents a different picture. The overall trend from 1983 to 1990 was that more individuals in each age group were licensed to drive (Figure 2). The rate of increase in older individuals being licensed to drive was greater than for drivers in other age groups. While 74% of individuals between 65 and 74 years of age were licensed to drive in 1983, the percentage increased to 83% in 1990. Similarly, 52% of individuals between 75 and 84 years old were licensed drivers in 1983, while 69% were licensed in 1990. Figure 3 illustrates the distribution of individuals licensed to drive by different age and gender categories. After the age of 65, the percentage of females licensed to drive becomes significantly smaller than the percentage of males.

3.2 <u>Driving and Travel Patterns</u>

On average, licensed drivers took more vehicle trips in 1983 than in 1990, at an annual rate of increase of 2.1%. The annual rate of increase for drivers between 55 and 64 years of age, as a whole, was slightly above the overall rate, while the one for drivers between 65 and 74 was below the overall rate. Drivers between 75 and 84 as a group actually took fewer vehicle trips in 1990 than in 1983.

Regardless of drivers' ages, the majority of the trips were for the purpose of driving to places for family and personal business (Table 10). However, the second most common reason to drive was different for different age groups. For individuals younger than 65, the second most common reason to drive was for earning a living. For individuals 65 or older, it was for social and recreational purposes. Privately-owned vehicles are the most common mode of transportation, and walking to places is more common among individuals 65 or older than middle-age groups (Table 11).

Table 8. Number of Persons[1] by Age and Sex 1983 and 1990 NPTS (thousands)

Age	Male		Female		TOTAL	
	1983	1990	1983	1990	1983	1990[2]
19 and Under	35,413	25,724	33,533	25,097	68,946	50,839
	(31.8%)	*(24.2%)*	*(28.4%)*	*(21.7%)*	*(30.0%)*	*(22.9%)*
20 - 24	10,351	8,277	10,679	9,451	21,030	17,728
	(9.3%)	*(7.8%)*	*(9.1%)*	*(8.2%)*	*(9.2%)*	*(8.0%)*
25 - 34	19,562	20,286	20,189	21,502	39,751	41,789
	(17.5%)	*(19.1%)*	*(17.1%)*	*(18.6%)*	*(17.3%)*	*(18.8%)*
35 - 44	14,416	18,257	14,990	19,207	29,406	37,464
	(12.9%)	*(17.2%)*	*(12.7%)*	*(16.6%)*	*(12.8%)*	*(16.9%)*
45 - 54	10,762	11,910	11,471	12,575	22,233	24,486
	(9.7%)	*(11.2%)*	*(9.7%)*	*(10.9%)*	*(9.7%)*	*(11.0%)*
55 - 64	11,185	9,645	12,544	10,885	23,729	20,530
	(10.0%)	*(9.1%)*	*(10.6%)*	*(9.4%)*	*(10.3%)*	*(9.2%)*
65 - 74	6,448	7,256	8,482	9,397	14,930	16,654
	(5.8%)	*(6.8%)*	*(7.2%)*	*(8.1%)*	*(6.5%)*	*(7.5%)*
75 - 84	2,886	3,455	4,759	4,969	7,645	8,424
	(2.6%)	*(3.3%)*	*(4.0%)*	*(4.3%)*	*(3.3%)*	*(3.8%)*
85 and above	492	618	1,290	1,259	1,782	1,877
	(0.4%)	*(0.6%)*	*(1.1%)*	*(1.1%)*	*(0.8%)*	*(0.8%)*
TOTAL	111,514	106,164[2]	117,939	115,849[2]	229,453	222,101
	(100.0%)	*(100.0%)*	*(100.0%)*	*(100.0%)*	*(100.0%)*	*(100.0%)*

[1] 1990 data includes persons 5 years of age or older only.
[2] Includes drivers where age, sex, or both were unreported.

Figure 1. Population Projection by Age, 1990, 2010, 2030
(percent)

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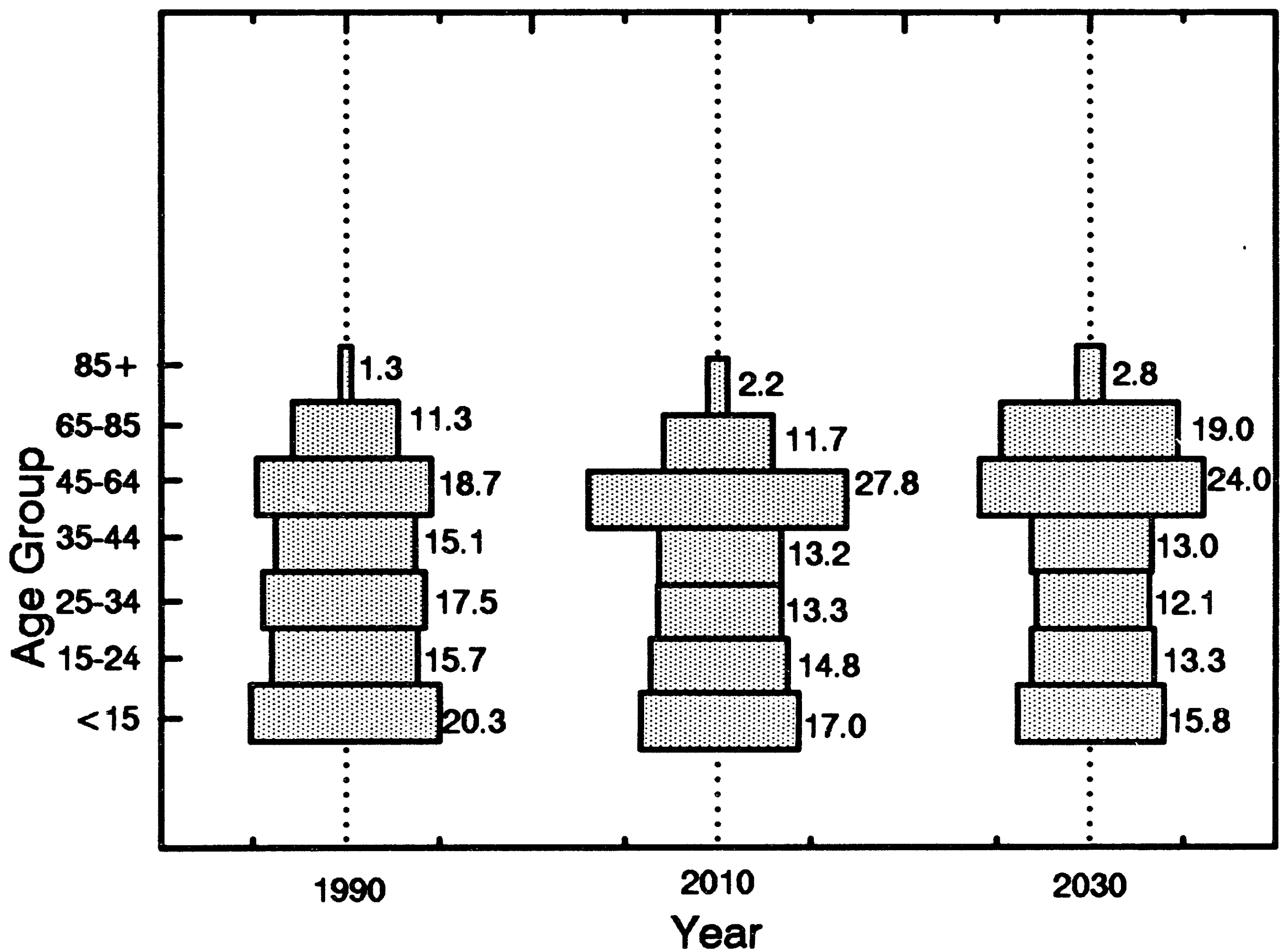

Table 9. Number of Licensed Drivers by Driver's Age and Sex
1983 and 1990 NPTS
(thousands)

Age	Male		Female		TOTAL	
	1983	1990	1983	1990	1983	1990[1]
19 and Under	5,356	4,633	4,409	4,913	9,765	9546
	(7.1%)	*(5.8%)*	*(6.2%)*	*(5.9%)*	*(6.6%)*	*(5.9%)*
20 - 24	9,297	7,464	8,997	8,194	18,294	15,658
	(12.3%)	*(9.3%)*	*(12.6%)*	*(9.9%)*	*(12.4%)*	*(9.6%)*
25 - 34	18,445	19,263	17,883	19,827	36,328	39,091
	(24.4%)	*(24.0%)*	*(25.1%)*	*(24.0%)*	*(24.7%)*	*(24.0%)*
35 - 44	13,728	17,507	13,365	17,969	27,093	35,476
	(18.1%)	*(21.8%)*	*(18.7%)*	*(21.7%)*	*(18.4%)*	*(21.8%)*
45 - 54	9,873	11,522	9,757	11,359	19,630	22,881
	(13.1%)	*(14.4%)*	*(13.7%)*	*(13.7%)*	*(13.4%)*	*(14.0%)*
55 - 64	10,767	9,229	9,818	9,057	20,585	18,285
	(14.2%)	*(11.5%)*	*(13.8%)*	*(11.0%)*	*(14.0%)*	*(11.2%)*
65 - 74	5,705	6,706	5,278	7,116	10,983	13,822
	(7.5%)	*(8.4%)*	*(7.4%)*	*(8.6%)*	*(7.5%)*	*(8.5%)*
75 - 84	2,218	2,973	1,718	2,827	3,936	5,799
	(2.9%)	*(3.7%)*	*(2.4%)*	*(3.4%)*	*(2.7%)*	*(3.6%)*
85 and above	249	347	151	313	400	660
	(0.3%)	*(0.4%)*	*(0.2%)*	*(0.4%)*	*(0.3%)*	*(0.4%)*
TOTAL	75,639	80,289[1]	71,376	82,707[1]	147,015	163,025
	(100.0%)	*(100.0%)*	*(100.0%)*	*(100.0%)*	*(100.0%)*	*(100.0%)*

[1] Includes drivers where age, sex, or both were unreported.

Figure 2. Distribution of Individuals Licensed to Drive by Driver's Age 1983 and 1990 NPTS (percent)

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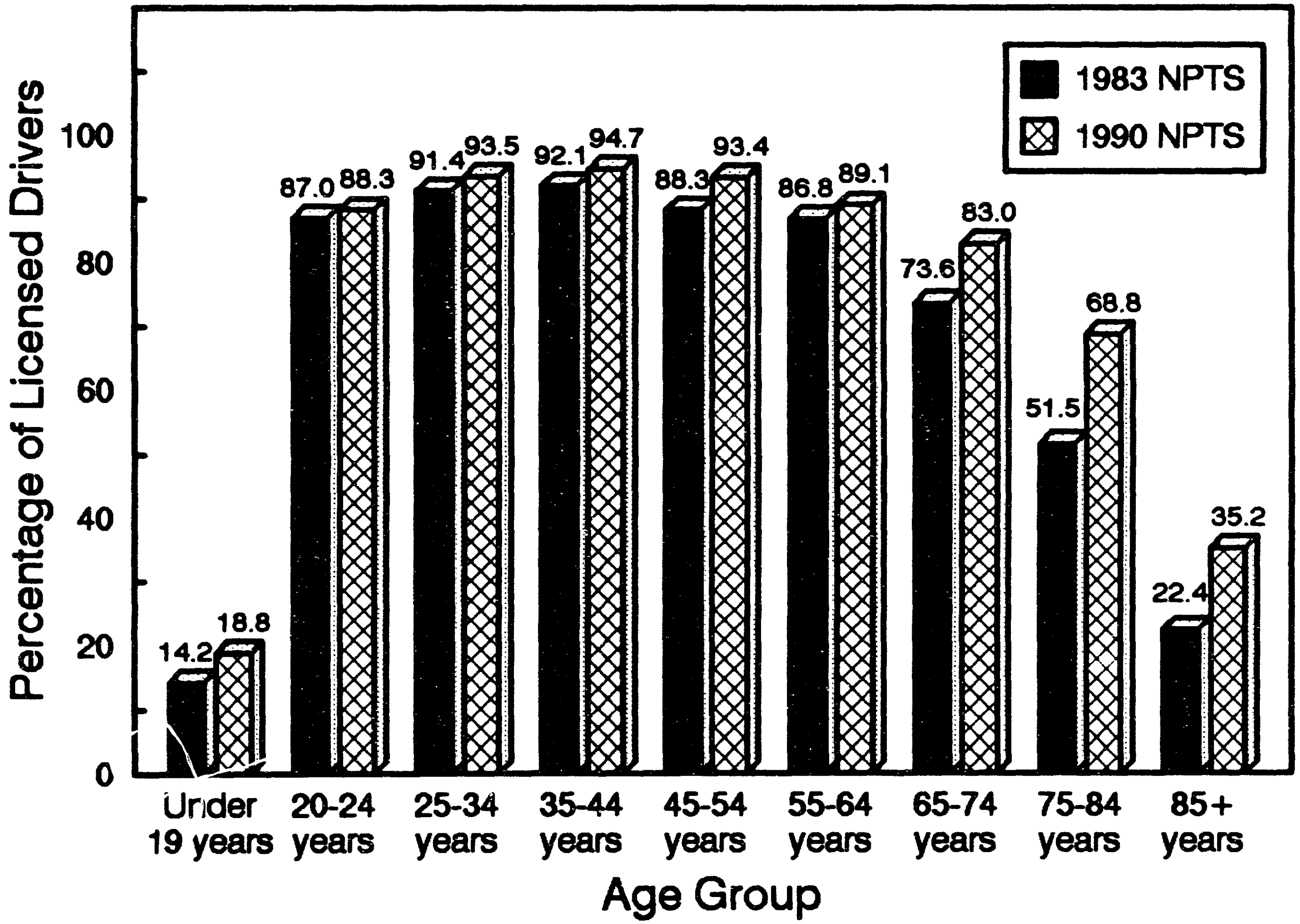

Figure 3. Distribution of Individuals Licensed to Drive by Driver's Age and Sex
1990 NPTS
(percent)

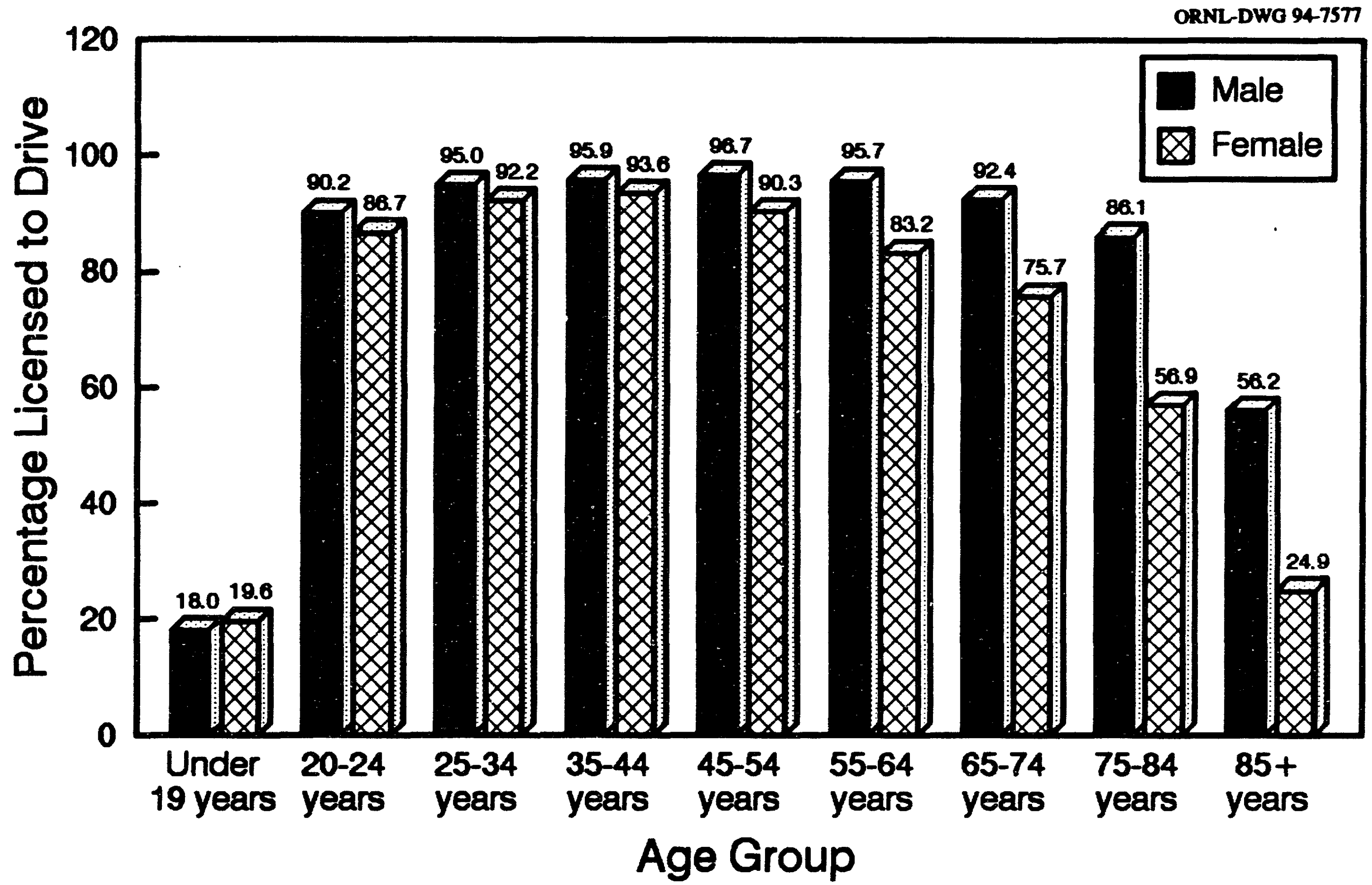

Table 10. Number of Vehicle Trips by Driver's Age and Trip Purpose
1990 NPTS
(millions)

Age	Work Related	Family and Personal Business	Civic, Educational and Religious	Social and Recreational	Other	TOTAL[1]
Under 19	1,776	2,395	1,817	3,284	181	9,459
20 - 24	5,423	5,100	958	4,859	159	16,498
25 - 34	11,673	13,106	1,427	7,291	326	33,823
35 - 44	8,431	10,973	1,216	4,964	387	25,974
45 - 54	5,947	6,970	735	2,723	144	16,518
55 - 64	4,860	6,392	647	3,096	176	15,170
65 - 74	835	3,920	432	1,795	227	7,209
75 - 84	123	1,233	210	590	19	2,175
85 and above	-[2]	15	-	32	-	47
TOTAL	39,066	50,104	7,442	28,634	1,618	126,874

[1] Includes trips where trip purpose was unreported.
[2] Indicates no data reported.

Table 11. Number of Person Trips by Age, Mode of Transportation, and Place of Residence 1990 NPTS (millions)

	Urban					Non-Urban				
Age	Private	Public	Walk	Other	TOTAL[1]	Private	Public	Walk	Other	TOTAL[1]
19 and Under	21,515	1,012	5,115	3,742	**31,434**	15,165	259	2,134	3,409	**20,980**
	(68.4%)	*(3.2%)*	*(16.3%)*	*(11.9%)*	***(100.0%)***	*(72.3%)*	*(1.2%)*	*(10.2%)*	*(16.3%)*	***(100.0%)***
20 - 24	13,738	704	1,488	248	**16,192**	6,315	15	497	58	**6,894**
	(84.8%)	*(4.3%)*	*(9.2%)*	*(1.5%)*	***(100.0%)***	*(91.6%)*	*(0.2%)*	*(7.2%)*	*(0.8%)*	***(100.0%)***
25 - 34	32,597	1,030	2,339	418	**36,415**	17,910	29	633	142	**18,722**
	(89.5%)	*(2.8%)*	*(6.4%)*	*(1.1%)*	***(100.0%)***	*(95.7%)*	*(0.2%)*	*(3.4%)*	*(0.8%)*	***(100.0%)***
35 - 44	28,410	741	1,543	252	**30,970**	17,733	67	650	134	**18,601**
	(91.7%)	*(2.4%)*	*(5.0%)*	*(0.8%)*	***(100.0%)***	*(95.3%)*	*(0.4%)*	*(3.5%)*	*(0.7%)*	***(100.0%)***
45 - 54	14,997	308	772	136	**16,220**	11,028	10	330	70	**11,440**
	(92.5%)	*(1.9%)*	*(4.8%)*	*(0.8%)*	***(100.0%)***	*(96.4%)*	*(0.1%)*	*(2.9%)*	*(0.6%)*	***(100.0%)***
55 - 64	11,324	309	773	58	**12,471**	7,703	21	300	51	**8,081**
	(90.8%)	*(2.5%)*	*(6.2%)*	*(0.5%)*	***(100.0%)***	*(95.3%)*	*(0.3%)*	*(3.7%)*	*(0.6%)*	***(100.0%)***
65 - 74	7,210	200	632	82	**8,129**	5,574	23	220	72	**5,891**
	(88.7%)	*(2.5%)*	*(7.8%)*	*(1.0%)*	***(100.0%)***	*(94.6%)*	*(0.4%)*	*(3.7%)*	*(1.2%)*	***(100.0%)***
75 - 84	2,175	101	235	31	**2,551**	1,929	6	123	40	**2,097**
	(85.2%)	*(4.0%)*	*(9.2%)*	*(1.2%)*	***(100.0%)***	*(92.0%)*	*(0.3%)*	*(5.9%)*	*(1.9%)*	***(100.0%)***
85 and above	270	11	46	17	**343**	189	11	16	5	**221**
	(78.6%)	*(3.1%)*	*(13.4%)*	*(4.8%)*	***(100.0%)***	*(85.8%)*	*(5.0%)*	*(7.1%)*	*(2.1%)*	***(100.0%)***
TOTAL[1]	**133,415**	**4,505**	**13,071**	**5,000**	**156,139**	**83,978**	**442**	**4,936**	**4,011**	**93,423**
	(85.4%)	***(2.9%)***	***(8.4%)***	***(3.2%)***	***(100.0%)***	***(89.9%)***	***(0.5%)***	***(5.3%)***	***(4.3%)***	***(100.0%)***

[1] Includes trips where age, mode of transportation, or both were unreported.

On a per licensed driver basis, Americans in 1990 not only took more trips but also took longer trips than in 1983 (Table 12). Although trips became significantly longer for drivers 65 years or older in 1990 than in 1983, they continued to take shorter trips than younger drivers. The fact remains that, on average, trip distance decreased as age increased in older drivers. .

More trips and longer trips in 1990 resulted in more overall driving. On average, licensed individuals drove 13,000 miles in a year in 1990, which was an increase of 25% from 1983 (Table 13). Drivers in age categories 65 years or older drove at least 30% more in 1990 than in 1983 (increased at least 4% per year between 1983 and 1990). The amount of driving for older drivers also decreased with increasing age. Although females drove, on average, more in 1990 than their age cohort in 1983, they still drove 700 miles less than males.

Temporal patterns in older drivers' driving behavior were relatively unchanged between 1983 and 1990. Between drivers 65 years or older and drivers younger than 65, there was no noticeable difference in terms of the day of the week when trips were more likely to take place (Table 14). Older drivers continued to concentrate their driving between 9:00 am and 4:00 pm. Their presence on the roads during this time period was remarkably frequent. For example, trips taken by drivers 65 years or older represent approximately 8% of the total trips without taking into account the temporal variation. However, between 9:00 am and 1:00 pm and between 1:00 pm and 4:00 pm, drivers 65 years or older represent 13% and 11% of the total traffic flow, respectively (Table 15).

For trips to places at least 75 miles away home, individuals 65 years or older used public transportation or airplanes more frequently than those between 25 and 54 years of age (Table 16). The most remarkable difference was observed in individuals between the ages of 75 and 84. They were almost three times more likely to use public transit and twice more likely to travel by airplane than those between 25 and 54 for long trips (Table 16).

**Table 12. Annual Driving Statistics[1] by Driver's Age
1983 and 1990 NPTS**

Age	Annual Vehicle Trips Per Driver		Average Vehicle Trip Length (miles)	
	1983	1990	1983	1990
19 and Under	969	927	6.40	7.86
20 - 24	902	1,010	8.47	9.49
25 - 34	931	1,091	8.44	9.62
35 - 44	959	1,127	8.09	8.99
45 - 54	841	957	8.05	9.56
55 - 64	737	838	7.75	8.45
65 - 74	656	713	6.35	6.74
75 - 84	553	528	4.59	5.96
85 and above	-[2]	365	1.95	6.13
TOTAL	863	975	7.90	8.98

1 Based on daily travel data.
2 Insufficient data to produce valid statistics.

Table 13. Average Annual Miles Driven[1] by Driver's Age and Sex 1983 and 1990 NPTS

	1983			1990		
	Male	Female	Total	Male	Female	Total
19 and Under	5,909	3,881	4,986	9,543	7,389	8,485
20 - 24	13,431	7,108	10,287	16,634	11,807	14,179
25 - 34	17,125	7,123	12,153	18,937	10,920	15,007
35 - 44	19,249	7,648	13,472	19,115	11,245	15,252
45 - 54	15,938	6,916	11,444	18,494	9,373	14,171
55 - 64	13,451	5,429	9,611	15,224	7,211	11,436
65 - 74	7,950	3,820	5,975	10,150	5,376	7,856
75 - 84	5,949	1,961	4,194	7,501	3,480	5,691
85 and above	1,238	692	1,029	3,764	1,615	2,798
TOTAL	14,510	6,380	10,536	16,536	9,528	13,125

[1] Based on self-estimated annual miles driven.

Table 14. Number of Vehicle Trips by Driver's Age and Day of Week
1983 and 1990 NPTS
(millions)

Age	Weekday		Weekend		TOTAL[1]	
	Male	Female	Male	Female	Male	Female
19 and Under	3,314 *(71.3%)*	3,111 *(74.1%)*	1,315 *(28.3%)*	1,076 *(25.6%)*	**4,647 *(100.0%)***	**4,198 *(100.0%)***
20 - 24	5,162 *(67.2%)*	5,677 *(69.9%)*	2,504 *(32.6%)*	2,404 *(29.6%)*	**7,685 *(100.0%)***	**8,124 *(100.0%)***
25 - 34	14,657 *(68.0%)*	15,528 *(73.6%)*	6,813 *(31.6%)*	5,443 *(25.8%)*	**21,559 *(100.0%)***	**21,085 *(100.0%)***
35 - 44	12,927 *(68.0%)*	16,102 *(76.8%)*	5,963 *(31.4%)*	4,772 *(22.8%)*	**19,015 *(100.0%)***	**20,955 *(100.0%)***
45 - 54	8,007 *(70.2%)*	7,939 *(75.6%)*	3,330 *(29.2%)*	2,471 *(23.5%)*	**11,399 *(100.0%)***	**10,500 *(100.0%)***
55 - 64	5,946 *(68.3%)*	4,955 *(74.9%)*	2,719 *(31.2%)*	1,590 *(24.0%)*	**8,710 *(100.0%)***	**6,614 *(100.0%)***
65 - 74	3,847 *(68.3%)*	2,929 *(69.3%)*	1,734 *(30.8%)*	1,231 *(29.1%)*	**5,629 *(100.0%)***	**4,226 *(100.0%)***
75 - 84	1,312 *(71.5%)*	831 *(67.6%)*	502 *(27.4%)*	365 *(29.7%)*	**1,835 *(100.0%)***	**1,229 *(100.0%)***
85 and above	124 *(80.8%)*	71 *(81.9%)*	30 *(19.2%)*	16 *(18.1%)*	**154 *(100.0%)***	**87 *(100.0%)***
TOTAL[1]	55,513 *(68.5%)*	57,691 *(74.1%)*	25,126 *(31.0%)*	19,612 *(25.2%)*	**81,079 *(100.0%)***	**77,832 *(100.0%)***

[1] Includes trips where weekday/weekend status, driver's sex, and/or driver's age were unreported.

Table 15. Number of Vehicle Trips by Driver's Age and Time of Day
1983 and 1990 NPTS
(millions)

Age	1:00am - 6:00am		6:00am - 9:00am		9:00am - 1:00pm		1:00pm - 4:00pm		4:00pm - 7:00pm		7:00pm - 10:00pm		10:00pm - 1:00am		TOTAL[1]	
	1983	1990	1983	1990	1983	1990	1983	1990	1983	1990	1983	1990	1983	1990	1983	1990
19 and Under	211	237	1,192	1,068	1,826	1,342	1,927	1,895	2,050	1,958	1,492	1,478	744	629	9,459	8,845
	(2.2%)	*(2.7%)*	*(12.6%)*	*(12.1%)*	*(19.3%)*	*(15.2%)*	*(20.4%)*	*(21.4%)*	*(21.7%)*	*(22.1%)*	*(15.8%)*	*(16.7%)*	*(7.9%)*	*(7.1%)*	*(100.0%)*	*(100.0%)*
20 - 24	885	455	2,264	1,991	3,435	2,835	2,787	2,955	3,542	3,655	2,333	2,403	1,197	1,075	16,498	15,889
	(5.4%)	*(2.9%)*	*(13.7%)*	*(12.6%)*	*(20.8%)*	*(17.9%)*	*(16.9%)*	*(18.7%)*	*(21.5%)*	*(23.1%)*	*(14.1%)*	*(15.2%)*	*(7.3%)*	*(6.8%)*	*(100.0%)*	*(100.0%)*
25 - 34	1,313	1,157	5,327	6,146	7,417	8,378	6,615	7,490	7,791	10,606	3,840	5,511	1,408	2,027	33,823	42,645
	(3.9%)	*(2.7%)*	*(15.7%)*	*(14.4%)*	*(21.9%)*	*(19.6%)*	*(19.6%)*	*(17.6%)*	*(23.0%)*	*(24.9%)*	*(11.4%)*	*(12.9%)*	*(4.2%)*	*(4.8%)*	*(100.0%)*	*(100.0%)*
35 - 44	715	828	4,506	6,427	5,965	7,642	4,821	7,481	5,927	10,202	3,121	4,972	827	1,294	25,974	39,971
	(2.8%)	*(2.1%)*	*(17.3%)*	*(16.1%)*	*(23.0%)*	*(19.1%)*	*(18.6%)*	*(18.7%)*	*(22.8%)*	*(25.5%)*	*(12.0%)*	*(12.4%)*	*(3.2%)*	*(3.2%)*	*(100.0%)*	*(100.0%)*
45 - 54	509	587	2,582	3,495	4,318	4,450	3,332	4,195	3,661	5,167	1,572	2,464	454	711	16,518	21,859
	(3.1%)	*(2.7%)*	*(15.6%)*	*(16.0%)*	*(26.1%)*	*(20.3%)*	*(20.2%)*	*(19.2%)*	*(22.2%)*	*(23.6%)*	*(9.5%)*	*(11.3%)*	*(2.7%)*	*(3.2%)*	*(100.0%)*	*(100.0%)*
55 - 64	458	293	2,461	2,078	4,371	4,014	2,964	3,203	3,155	3,129	1,256	1,336	400	418	15,170	15,324
	(3.0%)	*(1.9%)*	*(16.2%)*	*(13.6%)*	*(28.8%)*	*(26.2%)*	*(19.5%)*	*(20.9%)*	*(20.8%)*	*(20.4%)*	*(8.3%)*	*(8.7%)*	*(2.6%)*	*(2.7%)*	*(100.0%)*	*(100.0%)*
65 - 74	150	51	607	872	2,645	3,308	1,816	2,388	1,195	1,650	527	633	129	169	7,289	9,856
	(2.1%)	*(0.5%)*	*(8.4%)*	*(8.8%)*	*(36.7%)*	*(33.6%)*	*(25.2%)*	*(24.2%)*	*(16.6%)*	*(16.7%)*	*(7.3%)*	*(6.4%)*	*(1.8%)*	*(1.7%)*	*(100.0%)*	*(100.0%)*
75 - 84	12	9	151	197	928	1,012	631	760	300	512	129	153	5	65	2,175	3,064
	(0.6%)	*(0.3%)*	*(6.9%)*	*(6.4%)*	*(42.7%)*	*(33.0%)*	*(29.0%)*	*(24.8%)*	*(13.8%)*	*(16.7%)*	*(5.9%)*	*(5.0%)*	*(0.2%)*	*(2.1%)*	*(100.0%)*	*(100.0%)*
85 and above	-[2]	-[2]	5	14	18	104	14	74	10	34	-[2]	2	-[2]	3	47	241
	(0.0%)	*(0.0%)*	*(10.6%)*	*(5.8%)*	*(38.3%)*	*(43.2%)*	*(29.8%)*	*(30.7%)*	*(21.3%)*	*(14.1%)*	*(0.0%)*	*(0.8%)*	*(0.0%)*	*(1.2%)*	*(100.0%)*	*(100.0%)*
TOTAL[1]	4,253	3,635	19,095	22,459	30,925	33,350	24,908	30,670	27,630	37,177	14,271	19,057	5,163	6,431	126,874	158,927
	(3.4%)	*(2.3%)*	*(15.1%)*	*(14.1%)*	*(24.4%)*	*(21.0%)*	*(19.6%)*	*(19.3%)*	*(21.8%)*	*(23.4%)*	*(11.2%)*	*(12.0%)*	*(4.1%)*	*(4.0%)*	*(100.0%)*	*(100.0%)*

[1] Includes trips where driver's age, time of day, or both were unreported.
[2] Indicates no data reported.

Table 16. Number of Person Trips 75 Miles or Longer by Age and Mode of Transportation 1983 and 1990 NPTS (millions)

Age	Private Vehicle		Public Transportation		Airplane		Other Means		TOTAL[1]	
	1983	1990	1983	1990	1983	1990	1983	1990	1983	1990
19 and Under	322 (83.9%)	467 (93.0%)	13 (3.4%)	15 (3.0%)	12 (3.1%)	12 (2.4%)	6 (1.6%)	9 (1.8%)	384 (100.0%)	502 (100.0%)
20 - 24	180 (87.8%)	267 (94.7%)	5 (2.4%)	6 (2.1%)	8 (3.9%)	9 (3.2%)	0 (0.0%)	0 (0.0%)	205 (100.0%)	282 (100.0%)
25 - 34	358 (84.2%)	597 (93.9%)	3 (0.7%)	7 (1.1%)	42 (9.9%)	31 (4.9%)	3 (0.7%)	2 (0.3%)	425 (100.0%)	636 (100.0%)
35 - 44	315 (80.6%)	536 (93.9%)	15 (3.8%)	7 (1.2%)	31 (7.9%)	27 (4.7%)	3 (0.8%)	1 (0.2%)	391 (100.0%)	571 (100.0%)
45 - 54	242 (80.4%)	365 (93.6%)	6 (2.0%)	4 (1.0%)	16 (5.3%)	19 (4.9%)	3 (1.0%)	1 (0.3%)	301 (100.0%)	390 (100.0%)
55 - 64	228 (81.7%)	255 (91.1%)	8 (2.9%)	4 (1.4%)	26 (9.3%)	19 (6.8%)	1 (0.4%)	1 (0.4%)	279 (100.0%)	280 (100.0%)
65 - 74	81 (80.2%)	150 (91.5%)	9 (8.9%)	4 (2.4%)	8 (7.9%)	9 (5.5%)	1 (1.0%)	2 (1.2%)	101 (100.0%)	164 (100.0%)
75 - 84	16 (80.0%)	44 (84.6%)	1 (5.0%)	2 (3.8%)	2 (10.0%)	5 (9.6%)	-[2]	-[2]	20 (100.0%)	52 (100.0%)
85 and above	3 (42.9%)	4 (100.0%)	2 (28.6%)	-[2]	-[2]	0 (0.0%)	1 (14.3%)	0 (0.0%)	7 (100.0%)	4 (100.0%)
TOTAL[1]	1,745 (82.6%)	2,706 (93.1%)	63 (3.0%)	50 (1.7%)	145 (6.9%)	133 (4.6%)	17 (0.8%)	17 (0.6%)	2,112 (100.0%)	2,907 (100.0%)

[1] Includes miles of travel where age, mode of transportation, or both were unreported.

[2] Indicates no data reported.

In sum, beyond the age of 65, driving in terms of the number of trips, trip length, and the amount of driving (vehicle miles of travel) decreased with increasing age, as observed in both the 1983 and 1990 NPTSs. Drivers 65 years or older took more trips and took longer trips in 1990 than their same age-cohort in 1983. The NPTS data show that drivers 65 years or older minimized driving problems by avoiding congested hours, as found in other studies. There was no difference between older and other drivers in terms of which day of the week trips were more likely to take place.

3.3 Traffic Crash Involvement Rate

In order to make meaningful comparisons of crash experience among various age groups of individuals, a measure of "exposure" to traffic crashes is usually used to calculate traffic crash rates. Throughout the literature, there are a number of different ways used to measure highway crash "exposure". The first one normalizes crash rate into a per capita basis, the second one into a per licensed driver basis, the third one into a per mile driven, and the last one into an induced accident exposure measurement that takes into account the proportion of drivers at fault. Traffic crash involvement rates calculated using these different exposure measurements tell very different stories and are open to very different interpretations. Therefore, to answer the question as to whether older drivers are truly over-involved in traffic crashes depends on how the traffic crash involvement rate is calculated. Researchers disagree somewhat on older drivers' involvement in traffic crashes due to these differences in crash exposure measurement.

The Insurance Institute for Highway Safety issued a report in September of 1992 summarizing statistics on crashes and fatal crashes calculated using various exposure measures. On a per capita basis, drivers 65 years or older have only a slightly higher fatal crash involvement rate than drivers younger than 65. With the fatal crash involvement rate based on the number of miles driven, the rate distribution by age group is U-shaped; and older drivers, as well as drivers younger than 25, have significantly higher involvement than drivers between 25 and 64 years of age. Furthermore, the fatal crash involvement rate for drivers 65 years or older increases with age, and is similar to the rate for drivers age 16 to 24. These findings echoed the conclusion drawn by Evans

(1988). Cerrelli (1989) also noted the rate of crash involvement on a per mile-driven basis increases after the age of 70, and is greater yet beyond age 80. Similar observations on all crashes (fatal and non-fatal crashes combined) were also noted by Cooper (1990).

A Michigan study of multi-vehicle crashes concluded that when using the number of licensed drivers as the exposure measure, older drivers (60 and older) are considerably under-involved in crashes than drivers younger than 24. The same study also concluded that when using the number of miles driven as the exposure measurement, older drivers (60 and older) are involved in crashes at a slightly higher rate (McKelvey & Stamatiadis, 1988). The use of the "induced exposure method" resulted in a U-shaped curve similar to the one if crash rate is normalized by miles driven, indicating that by using this measure, older drivers are more likely to be involved in highway crashes than drivers in the middle age groups.

However, by relating various published crash data to the number of licensed drivers in different age groups, a somewhat different conclusion was reached by Yanik (1985). He claimed that older drivers (65 and over) are under-represented in fatal traffic crashes, and that older drivers "do not constitute a gross threat to others on the road".

Mortimer and Fell (1989) analyzed fatal crash involvement of older drivers at night (calculated using miles driven) and concluded that fatal crash rates for all age groups are substantially greater between midnight and 6:00 am during which darkness is assumed to be most likely to prevail. However, the rate for drivers 65 or older is higher than that for drivers between 25 and 64, but considerably less than that for drivers younger than 25 during this period. During this period, female drivers 65 or older have a substantially lower crash involvement rate than male drivers in the same age category. Studies also pointed out that older drivers have a higher proportion of crash events in urban areas and that the over-involvement of older drivers in traffic crashes disappears in rural areas (Maleck & Hummer, 1986).

Regardless of which exposure measurement is used and despite some limited contradicting evidence, researchers in general agree that older drivers, as a group, are more likely to be involved in a traffic crash than other drivers. However, older drivers are still involved in a substantially smaller total number of crashes.

3.4 Crash Patterns and Contributing Factors

Driving requires several different sets of functional capabilities. First, drivers need the sensory ability to perceive changes in a rapidly changing traffic environment. Second, one needs the mental ability to judge and process the perceived information and to make appropriate decisions. Third, motor skills are essential to execute these decisions. Lastly, should there be some losses of these abilities, one needs an ability to compensate for these losses. Understanding crash patterns of older drivers allows the identification of driving problems most frequently experienced by older drivers, the impaired functionality attributable to the driving problem, and the establishment of better screening procedures of high-risk older drivers.

It is well documented that older drivers experienced a greater proportion of intersection crashes and multi-vehicle crashes than younger drivers (Cerrelli, 1989). They have a higher percentage of citations for "failing to yield for right-of-way" and for "ignoring traffic signals" (Cerrelli, 1989; Brainin, 1980; Hildebrand & Wilson, 1990). Furthermore, they are more likely to be cited as "at fault" in crashes in which they are involved than middle-age drivers, and they are equally likely to be cited as "at fault" as drivers under 25 (McKelvey & Stamatiadis, 1988; Hildebrand & Wilson, 1990). Cooper (1990) also showed that the probability of older drivers being cited in crashes in which they are involved is increasing.

McKelvey and Stamatiadis (1988) noted that when older drivers are involved in non-interstate trunkline crashes, their crashes are more likely to be attributed by the investigating officer at the scene to contributing circumstances such as illness, fatigue, inattention or obscured vision. Alcohol and speeding are the least likely contributing factors for older drivers involved in crashes. However, Michigan data showed that about an equal percentage of younger (25 or younger) and older drivers (60 or older) have driving under the influence as the contributing factor in crashes in which they were involved (McKelvey & Stamatiadis, 1988).

Staplin and Lyles (1991) studied the age difference in motion perception ability and found that older drivers have the highest crash involvement rate for turning left against oncoming traffic, and the next highest rate occurred when older drivers were crossing or turning into a traffic stream. They did not find significant difference between older and younger drivers in overtaking and passing, and contributed this to the lower frequency of older drivers overtaking. From these results, the authors concluded that there is an age difference in motion perception between older and other drivers and that motion perception is an important factor in older drivers' over-involvement in certain types of crashes.

The over-involvement rate in these crash types and moving violations of older drivers suggest a decline with advancing age in sensory perceptual (especially visual) skills, cognitive function, and the speed of psychomotor responses.

3.5 Crash Severity

The Michigan study by McKelvey and Stamatiadis (1988) examined non-interstate crashes of different levels of severity (i.e., fatal, incapacitating injury, non-incapacitating injury, property damage). They found that older drivers are involved in fatal crashes more than in other types of crash. Furthermore, the fatality rate for older drivers is significantly higher than for drivers in other age categories, either normalized by miles driven or by the "induced exposure" method. According to the study, the fatality rate for older drivers is almost 34% higher than those of other drivers (normalized by miles driven), indicating the greater probability for an older driver to be a fatality in an crash than other drivers. Evans (1988) suggested that the increase in fatality for older drivers was caused by the increase in fatality risk with increasing age from the same impact, and not by an increase in involvement with increasing age. In other words, older drivers are more vulnerable to injury and fatality than other drivers once involved in crashes. Barr (1991) supported Evans' findings in his recent paper and attributed the increase in vulnerability of older drivers to the increase in average age of licensed older drivers.

4. EXISTING EPIDEMIOLOGICAL AND/OR MEDICAL DATA BASES

Several data bases are identified as potential sources to establish statistical link(s) between age-related physical and mental functional limitations and increased highway risk. Descriptions of individual data bases provide information on how the data are collected, the sample size, and the willingness of the responsible institute to share data or collaborate in research. The overall sample size of each data base is reported in the description. The number of older drivers included in each data base is reported in Table 17. Brief evaluations of these data bases are given based on the following set of criteria:

1. Is the data base .completed ? (i.e., a data base that is in the planning or implementation process is not reviewed)
2. Are data representative?
3. Are there sufficient data to build a robust relationship between age-related functional impairment and increased highway risk? Each data base should have information on at least four major areas -- **demographics of the drivers, medical conditions afflicting the drivers, crash and moving violations,** and **the amount of driving (to serve as accident exposure data).** Data missing on any one of the three areas makes establishing this relationship .
4. Are there sufficient data to consider effects of comorbid conditions?

NAME OF THE DATA SOURCE: Data on California's Special Drive Test (SDT)
ORGANIZATION: California Department of Motor Vehicles
CONTACT PERSON: Ray Peck, (916)657-7031 and Robert Hagge (916)657-7030
DESCRIPTION:

How the participants are selected:

There are two circumstances when license applicants are subject to take a special drive test: (1) when individuals renew their drivers' licenses and fail the standard drive test; and (2) when individuals are referred by law enforcement, physician, family members and relatives due to physical and mental disabilities such as those listed below. The policies for referring license applicants or licensees to the special drive test are inconsistent and under review. The special drive test does not follow a standard route as a regular drive test does. Instead, the special drive test is tailored to test the driver in relevant situations. For example, additional right turns are included in the special drive test if the driving of the applicant is affected by a physical condition with the right side of the body.

What data are collected:

Some of the age-related physical and mental conditions that require a special drivers' test are:

- o Alzheimer's disease,
- o bioptic telescopic lens,
- o diabetic retinopathy,
- o Huntington's chorea and Parkinson's,
- o multiple sclerosis,
- o myasthenia gravis,
- o Joseph's disease,
- o retinitis pigmentosa, and
- o stroke.

Before the special drive test is administrated, a vision test is usually performed on the Opitec Vision Tester or Ortho-Rater. Other than test for specific driving skills, the special drive test also tests for motor functionality, concentration, reaction time (to hazards and to traffic), and visual search. However, there are no standard criteria for evaluating the test results. For those who did not pass the regular drive test, data on the previous drive test may be obtained.

Sample size:

There are an estimated 9,500 applicants taking special drive tests per year. Of these cases, about 12% of the tests take place for renewal license applicants and the remaining 88% are by referral.

Willingness to share:

Test performance data on these special drive tests are not in a computer readable format and would need to be keyed in. A formal request will be needed from ORNL to request these forms. However, medical condition will be kept confidential.

Assessment:

Pros

- o With data being compiled by the Department of Motor Vehicles (DMV), data on special drive test and on traffic crashes and moving violations are more likely to be consistent for the purpose of merging these data sets. Data compatibility will be less of an issue.
- o There may be a large enough number of cases per year to establish age-related impaired functionality and increased risk. Since the California DMV has not carefully examined the data, the exact number of individuals 55 years or older who have any of the aforementioned physical and mental conditions and who have taken a special test drive is unknown. However, based on

comments by a field officer of the California DMV, the majority of the individuals subject to a special drive test are older drivers with the aforementioned physical and mental conditions.

Cons

- o There are no consistent policies in referring licensees or original applicants to the special drive test.
- o No data on medical condition will be available due to confidentiality.
- o A significant amount of effort will be required to prepare these data for analysis, as summarized below:
    1. Convert data on hard-copy to computer readable format.
    2. Match data on special drive test to traffic crash or moving violation data files.
    3. Estimate crash exposure from different data sources, perhaps based on demographic and socio-economic variables.
    4. Develop a statistical procedure to make certain that applicants with physical and mental disabilities that are subject to the special drive test do not represent a statistically biased group.
    5. Search for an age and sex controlled comparison group.

NAME OF THE DATA SOURCE: Vision Test Study by the California Department of Motor Vehicles

ORGANIZATION: California Department of Motor Vehicles

CONTACT PERSON: David Hennessy, (916)657-7048

DESCRIPTION:

The purpose of the study is to identify to what extent vision test scores predict traffic convictions and crash involvement for individuals in different age groups, and to determine whether vision test scores are better predictors for one or more of the age groups than for the others.

<u>How the participants are selected</u>:

Data collection was conducted in three field offices: Roseville, Carmichael, and El Cerrito. Renewal applicants who could not renew their licenses by mail were randomly selected to participate in this study. These applicants were not able to renew their licenses by mail due to (1) having their licenses already renewed by mail in two consecutive times , or (2) their medical conditions or traffic convictions.

Study participants were stratified into four age groups (28-39, 40-51, 52-69, and 70 or older). For each of three vision test batteries, at least 350 subjects were to be randomly selected from each stratum. The test protocol calls for at least 4,200 subjects (= 350 subjects x 4 strata x 3 vision test batteries). A recent note from the California DMV on the actual number of participants indicated that about 300 drivers 70 years or older were tested on each of the three vision tests. Different drivers were tested on different vision tests.

<u>What data are collected</u>:

Vision test scores were collected for one of three test batteries: (1) glare test, contrast sensitivity test, and the test for acuity under low luminance, (2) visual field test, and (3) the useful field of view (UFOV) test developed by K. Ball and C. Owsley.

Data was also collected on self reported exposure and driving behavior. Data on driving records for the past three years are also obtained to merge with driving data and vision data.

There is a plan to collect data on motor skill and higher-order cognition in the future to determine the best vision tests (to predict crash involvements for individuals in different age groups) in combination with motor and higher-order cognitive ability.

Sample size: $n = 4{,}200$ at most.

Willingness to share data:

The study will not be completed until late 1993. Collaboration might be possible.

Assessment:

Pros

- One can estimate the number of miles driven (as the exposure risk).
- Relatively detailed data on driving behavior are included.
- Limited information on crash environment (e.g., time of day, direction of traffic) is available to further account for variation in crash data due to driving circumstance.

Cons

- The sample size is somewhat small (350 subjects between ages 52 and 69, and 350 subjects 70 year or older). This problem may be aggravated when the sample is further subdivided for older drivers with age-related functional impairment.
- Information on the severity of the medical conditions is not available.

NAME OF THE DATA SOURCE: Florida Geriatric Research Program (formerly the Dunedin Program)

ORGANIZATION: University of Florida, Gainesville

CONTACT PERSON: Ronald Stewart (904)392-3155

DESCRIPTION:

The original goal of the study was to screen individuals for hypertension. Gradually, it has evolved into a more general health screening program of elderly for undetected medical conditions. The hope is that individuals with early-stage symptoms can be detected earlier and disease prevented. The current research focus of the University of Florida is to predict when individuals stop driving and to predict traffic crash rates.

How participants are selected:

Volunteers in Dunedin, Florida, through local groups and newspaper advertisement are tested for general health status. The program started in 1975 and is still ongoing. There were 3,000 participants in the original study. When these participants dropped out or died, new volunteers were added.

What data are collected:

Volunteers are given a health screening every year. The data base is updated annually. Other than the physical condition and general health status of the participants, a mental status and a depression measure were also recorded for participants who completed an eighth visit after July 1, 1987. As part of the evaluation, participants identified both prescribed and nonprescribed medications used on a regular basis. A series of questions relating to driving was included in the eighth visit. At their eighth visit, participants were asked if they ever drove regularly in the past, whether they drive currently, whether their license was revoked and the reason that the license was revoked (e.g., health reasons, or crash-related license suspension).

Sample size:

The case group included 241 participants who reported that they drove regularly in the past but were no longer driving. The control group included 1,229 participants who were still driving regularly.

Willingness to share data:

University of Florida will consider collaboration for a fee.

Assessment:

Pros

- One of the longest epidemiological data bases. This time series of data allows one to establish historical trends.
- Data on specific diseases are available, allowing for the modeling of joint impacts of multiple conditions.

Cons

- The samp is not statistically representative of the population. Instead, it is based on a convenient sample.
- Although crash involvement data are collected, there are no data on miles driven. Estimates of the miles driven would be necessary.
- Information on the severity of the medical conditions is not available.
- When and why the participant stopped driving is unknown.
- There is no information on moving violations and driving patterns.

NAME OF THE DATA SOURCE: British Columbia Crash and Insurance Claim Data
ORGANIZATION: Insurance Corporation of British Columbia (Crown Corporation)
CONTACT PERSON: Peter Cooper (604)661-6982
DESCRIPTION:

How the participants are selected:

In this data base, individuals do not actively "participate" in a study. They are automatically included in the data base once they are insured by the Crown Corporation. Every motor vehicle in British Columbia is required to have at least $200,000 coverage of basic third party personal liability insurance with the Crown Corporation. The regulations governing the operations of the Insurance Corporation require that information identifying individuals insured be kept confidential.

What data are collected:

For research purposes, four different files are compiled:

- **Accident file**, from the Motor Vehicle Branch (MVB), contains information regarding a specific crash including crash contributing factors recorded by the investigating officer at the scene.
- **Driver file**, from the MVB, mainly contains licensing history. MVB might have data on medical condition of some licensees in its files, but would not release the data to the Crown Corporation for fear of breaching confidentiality.
- **Insurance Claim file**, from the Crown Corporation, contains insurance claim data.
- **Policy and Vehicle file**, from the Crown Corporation, contains data on insurance policy and vehicle covered by the policy.

Sample size:

There are approximately 2.5 million drivers' licenses issued in a year. However, since medical conditions of licensees are unknown, the size of the sample that will provide data for this study is unknown.

Willingness to share data:

The Crown Corporation cannot provide the data to us. However, it is willing to collaborate with NHTSA/ORNL.

Assessment:

Pros

- o There is a wealth of information in the data base -- information on drivers, vehicles, and environments.

Cons

- o Data on medical conditions are not readily available. Even with medical data made available from MVB, there will still be bias in the data for two reasons. First, the British Columbia Superintendent of Motor Vehicles can require a license applicant to take a medical examination only if there is evidence of some kind of impairing medical condition. Second, only applicants or licensees 80 years or older are required to have a medical examination every two years and may be required to re-take the road test. Consequently, only very few applicants with medical conditions will be included in the data base (i.e., very sick or very old).
- o Only an estimated 60% of all crashes are included in the Accident file due to the reporting nature of the crash. For example, if individuals involved in minor crashes did not report the incidents, the crash will not be included in the file. The crashes included in this file are mostly body-injury type of crashes, and most of the property damage may not included, especially minor property damage.
- o Information on the severity of the medical conditions is not available.

NAME OF THE DATA SOURCE: Integrated Information Data Base

ORGANIZATION: Saskatchewan Government Insurance (SGI)

CONTACT PERSON: David Coch, (306)566-6007

DESCRIPTION:

How the participants are selected:

Since Saskatchewan Government Insurance (SGI) administers compulsory automobile insurance required by legislation, anyone who registers vehicles and anyone who applies for a driver's license is included in the data base.

What data are collected:

The Integrated Information Data Base (IIDB) is derived from several data bases. SGI maintains files on drivers and vehicles, and on the medical conditions of a limited number of drivers. The crash data (Traffic Accident Information System (TAIS)) are maintained by the Saskatchewan Highways and Transportation. Linking SGI's "internal" files was relatively straightforward. However, linking SGI's files to crash data became tedious when individuals involved in the crashes are not licensed. In that situation, only common names and addresses of involved individuals were recorded in the TAIS.

The **TAIS** is based on police reports usually completed at the scene of the crash. It includes crash location, road and weather condition, damage severity and injury type, driver conditions, actions taken before and after the crash, and other crash data. For drivers who are not licensed, no license identification number will be available in the system. Under this circumstance, only common names and addresses are recorded.

Since SGI maintains data on everyone who registers vehicles and everyone who applies for a driver's license, SGI has complete data on drivers and vehicles. The **Driver History File** includes data on demographic attributes, conviction history, and insurance claims on drivers; and the **Vehicle Experience File** has detailed vehicle configuration data. These two files can be linked by using driver's license ID.

SGI's **Medical Review Program** monitors individuals who must submit regular medical or vision records as a condition of maintaining their license status. Currently, the Program monitors between 7,500 and 10,000 drivers. Data on these individuals include information such as what types of medical examinations are required. Half a year ago, SGI began to collect more detailed information on medical condition. Individuals in this program are brought to SGI's attention by police reports, physicians, family members or self-reporting.

Sample size:

IIDB contains crash data for the past five years and driver and vehicle data for the past six years. There are an estimated 35,000 crashes per year, 640,000 licensed drivers and 800,000 vehicles listed in each year. As mentioned earlier, medical information is on about 7,500 to 10,000 drivers.

Willingness to share data:

Due to limited resources, IIDB is intended for internal use only. However, under special circumstances, SGI is willing to collaborate with NHTSA/ORNL.

Assessment:

Pros

- o There is a wealth of information in this data base -- data on drivers, vehicles, and crash environment. Furthermore, medical data are available for about 7,500 drivers. It should be noted that this integrated system is still undergoing refinement.

Cons

- o Depending on the reporting nature of the crashes, some crashes are not reported.
- o Data on the medical condition do not indicate the severity of the condition.

NAME OF THE DATA SOURCE: Epidemiological Study on Vision in Elderly Drivers in Quebec.

ORGANIZATION: University de Montreal

CONTACT PERSON: Claire Laberge-Nadeau, (514)343-7575

DESCRIPTION:

An epidemiological data base was established to answer the question of whether relaxing certain medical and optometric requirements had any detrimental effects on highway safety. University de Montreal undertook the project to develop a scientific approach regarding the relationship between drivers suffering health problems (e.g., diabetes, coronary heart disease and visual impairment) and increased highway risk.

How the participants are selected:

Permit holders of Classes 1 through 5 in the Canadian province of Quebec (the Class 1 permit class is for trucks with trailers, while the Class 5 permits are for cars).

What data are collected:

A large data file is integrated using various computer files on permit holders, crashes, licensing history, and medical conditions. Information on the medical condition of permit holders is obtained either when permit holders declare their medical condition at the time of obtaining their first permit or at renewal, or when permit holders are requested to undergo a medical examination required by the licensing agency.

Exposure data are also collected using a telephone survey. In addition to distance driven and the length of time "behind" wheel, the questionnaire asked other questions such as the frequency of night driving and the types of roads most frequently used. The survey also collected limited information on the vehicle driven to work and on the number of crashes which occurred during the past 12 months.

Sample size: $n = 20{,}000$.

Willingness to share data:

The University de Montreal is willing to collaborate with NHTSA and ORNL.

Assessment:

Pros

- o This data base maintained by the University de Montreal is a large epidemiological data base that contains relatively complete information on driver, licensing history, crash, medical conditions, and exposure data.
- o When studying Class 5 drivers between the ages of 70 and 85, there are 7,500 subjects who qualify under these criteria. Of the 7,500 subjects, about 70% have visual impairment. This leads us to believe that the sample is large enough to be subdivided in many different ways and still maintain an adequate number of cases for statistical analysis.

Cons

- o It is not clear whether the severity of the medical condition is recorded.
- o One of the occasions when data on medical condition are collected is when permit holders' conditions are brought to official attention by physicians, family members, friends, or self-reported. Some selection biases may exist in this group of permit holders.

NAME OF THE DATA SOURCE: Health and Functioning in Marin County, California
ORGANIZATION: Buck Center for Research in Aging
CONTACT PERSON: Bill Satariano, School of Public Health, University of California, Berkeley, (510)642-6641
DESCRIPTION:

The data collection effort is still ongoing. One half of the 2,019 individuals will be tested for vision assessment.

How the participants are selected:

A sample of residents of Marin County who are 55 years of age or over and do not currently live in a long-term care facility.

What data are collected:

Data on general health, functional status (which includes driving patterns), utilization of health care, and other demographic characteristics are collected. Respondents were asked whether they still hold a driver's license. If they do, they are asked how often they drive before and after dark, and whether they avoid or limit their driving.

Sample size:

This study interviewed 2,019 individuals 55 years or older about their health and how they function in their daily activities. The older age group is intentionally oversampled. There are about 500 individuals for each age group defined by 10-year increments (55-64, 65-74, 75-84, and 85+), with 507 in the 85+ age group. Approximately 600 individuals 75 years or older were still driving.

Willingness to share data:

Health and functionality have yet to be linked to the motor vehicle data base (with information on moving violations, crashes and licensing history). In a proposal to NHTSA, the Center proposes to do so and an arrangement with the

California Department of Motor Vehicles to obtain the driving records of all participants in the study is already made. This type of funding request suggests that the Buck Center for Research in Aging would share their data for a fee.

Assessment:

Pros

- The Marin County study is a fairly complete study containing information on general health status, and daily activity level.
- Since Marin County is a suburban area, data from this study might be complementary to data collected in rural Iowa counties and an urban Connecticut county for the Established Population for Epidemiological Studies of Elderly (EPESE).

Cons

- Marin county is an unique community in that the majority of county residents are very affluent. There is a larger percentage of drivers' license holders, compared to other California counties. In addition, California is unique in that there are more freeways, more dependence on privately-owned vehicles, and little public transit.
- There are limited data on medical condition and miles driven.

NAME OF THE DATA SOURCE: Established Population for Epidemiological Studies of Elderly (EPESE) at Iowa and at Yale

ORGANIZATION: University of Iowa, Yale University, National Institute on Aging (NIA)

CONTACT PERSON: Dan Foley, NIA (301)496-9795.

DESCRIPTION:

NIA funded four longitudinal studies on four sites, including two rural counties in Iowa and New Haven. The Iowa and Yale studies have a seven-year follow-up while the other two have a six-year follow-up.

How the participants are selected:

In Iowa, all individuals 65 years or older in two Iowa counties (Iowa and Washington) were included in 1982. The participation rate was 80% (3,673 persons). By 1989, there were 1,300 surviving drivers eligible for the seventh follow-up in which questions about driving patterns were asked.

In New Haven, a stratified cluster sample of 3,433 non-institutionalized individuals 65 years or older was selected in 1982. The participation rate was 82%. About 500 drivers were eligible for the seventh follow-up in which questions about driving patterns were asked.

What data are collected:

Data on self-perceived health status, chronic condition (such as stroke, cancer, diabetes), vision, functional status, and transportation and health services are collected. Not until the seventh follow-up, were data on driving behavior obtained.

In the last in-person interview, vision acuity and other functional capabilities were objectively assessed by trained interviewers.

Sample size:

Sample size varies depending on the follow-up. At the time of the seventh follow-up, there were 1,300 and 500 surviving drivers in Iowa and New Haven, respectively.

Willingness to share data:

The University of Iowa and Yale University are reluctant to share their data without NIA's approval and restrictions protecting confidentiality of respondents.

Assessment:

Pros

- o EPESE is a large and relatively complete epidemiological data base containing historical data on general health status, medical condition and functional status.
- o Health data have been linked with data on crashes and moving violations and medical records in Iowa.
- o Data are supplemented by information on driving behavior at the seventh follow-up.
- o Iowa EPESE is implementing a follow-up to its 1989 survey which was a part of the seventh-year follow-up.
- o Drivers are all over the age of 70.

Cons

- o Although each of the EPESE sites has an overall large sample size, further subdividing the sample by license status (current, former, never drove) and specific disorder may not produce enough cases to establish a statistical link between that disorder and the increased highway risk. Unfortunately, one of the EPESE sites consists of two rural counties while the other site mainly includes residents from an urban area. The difference in land use makes it difficult to compare data between these two sites. As a result, consolidating data from these two sites to increase the overall sample size is problematic. This point needs further investigation.

- Based on New Haven's sampling frame (compiled from a utility listing), there were 17% senior individuals living in restricted housing units. However, over half of the sample were senior individuals living in restricted housing units, indicating an over-sampling of senior individuals living in restricted housing units. This type of housing unit usually has transportation services and recreational activities arranged for their residents. Therefore, the need for driving is greatly reduced.
- Most of the medical and visual condition data were self-reported. A considerable amount of self-reporting bias might be introduced.
- EPESE contains crash and moving violation data for selected years in each site with only a few years overlapped, i.e.

  crash data: New Haven from 1988 to 1990,
Iowa from 1985 to 1989;

  moving violation data: New Haven from 1986 to 1989,
Iowa from 1985 to 1989.

NAME OF THE DATA SOURCE: Visual/Cognitive Study of Older Drivers

ORGANIZATION: University of Alabama and Western Kentucky University, sponsored by National Institute on Aging (NIA)

CONTACT PERSON: Karlene Ball, Western Kentucky University, (502)745-2094; and Cynthia Owsley, University of Alabama at Birmingham, (205)325-8635

DESCRIPTION:

How the participants are selected:

All licensed drivers aged 55 or older who lived in Jefferson County, Alabama (*N*=118,553) were categorized into strata defined by the number of crashes in the last five year period (0 crash, 1 to 3 crashes and 4 or more crashes) and by the age of the driver (55-59, 60-64, 65-69, 70-74, 75-79, 80-84, and 85+). The first 15 licensees who called in within each category were tested. The higher crash frequency category was intentionally over-sampled.

What data are collected:

Subjects were tested for visual sensory function, mental status, the useful field of view (UFOV), and eye health. Subjects were also asked about driving habits beginning at the second year of the study. Mental status was assessed by a test specifically designed to assess the cognitive capability of senior subjects. Detailed information on data collected can be found in "Modelling Correlates of Accident Involvement in Older Drivers" (Ball, 1991).

Sample size:

There were 294 eligible participants.

Willingness to share data:

Collaborating with NHTSA/ORNL will be more likely than in most other cases.

Assessment:

Pros

- This is a very focused and complete data base specifically designed and collected to study the relationship between vision, cognitive capability, and traffic crashes of older drivers.

Cons

- The sample size is relatively small to draw national inferences.
- One may need to ascertain that the difference between participants who called in first and those who called in later is insignificant.

NAME OF THE DATA SOURCE: North Carolina Older Drivers

ORGANIZATION: Highway Safety Research Center, University of North Carolina

CONTACT PERSON: Jane Stutts, (919)962-2202

DESCRIPTION:

The Highway Safety Research Center at the University of North Carolina is beginning a study to examine the relationship between prior and future traffic crashes and convictions and functional capabilities of older drivers.

How the participants are selected:

Approximately 5,000 North Carolina residents aged 65 or older who are renewing their drivers licenses will be recruited.

What data are collected:

Functional capability, particularly cognitive function and higher order visual/attention abilities, and data on traffic crashes and convictions will be collected.

Sample size:

Approximately 5,000 older drivers will be selected.

Willingness to share data:

Collaborating with NHTSA/ORNL will be more likely than in most other data sources.

Assessment:

Pros

- o Presumably, this study will expand on the Visual/Cognitive study of older drivers conducted by University of Alabama and Western Kentucky University. If so, the sample size of the North Carolina study will compensate for the possible shortcoming of the Alabama/Western Kentucky study.

Cons

- o Actual data collection will not begin until the fall of 1993. The timing might delay or alter the schedule of our study.
- o Again, one needs to ascertain that the difference between those who participated and those who were recruited and refused to participate is insignificant.

NAME OF THE DATA SOURCE: Marshfield's Diabetic and Epileptic Older Drivers

ORGANIZATION: Marshfield Clinic, Marshfield, Wisconsin

CONTACT PERSON: Steve Broste (715)387-9140

DESCRIPTION:

How the participants are selected:

Diabetic patients and epileptic patients were first identified from the Clinic's computer file. Almost all epileptic patients who were from a defined geographical area in which the Marshfield Clinic is virtually the sole source of medical care were included. A sample of diabetic patients was selected from the file.

What data are collected:

Medical data on disease severity, treatment and complications were abstracted from the charts of the patients. Data on traffic violations and crashes were obtained from the Wisconsin Department of Transportation.

Sample size:

After eliminating patients who did not have a driver's license at any time during the four-year study period, 484 diabetes and 241 epilepsy cases remained in the sample.

Willingness to share data:

The authors were unable to share their data due to data confidentiality.

Assessment:

Pros

o The data are rather "population-based" since almost all epileptic patients who were from a defined geographical area in which the Marshfield Clinic is virtually the sole source of medical care were included in the study.

Cons

- Since patients included in this study are those who still hold a valid drivers' license and who are still driving, they might present a rather selective group. The subjects included could be in a considerably lower risk category compared to those patients eliminated from the study due to the fact that their drivers' licenses have been suspended by the licensing authorities or surrendered voluntarily.

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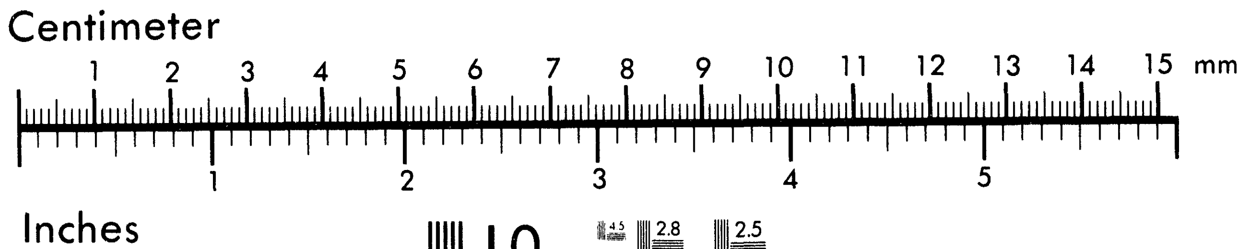

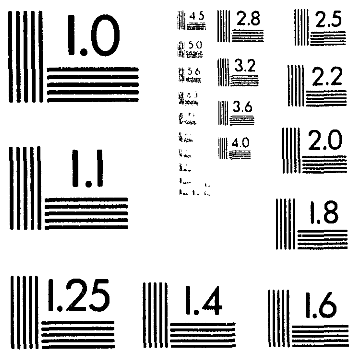

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NAME OF THE DATA SOURCE: Pennsylvania Department of Transportation's Visual Screening Data

ORGANIZATION: Pennsylvania Department of Transportation (PennDOT)

CONTACT PERSON: Doug Tobin of PennDOT, (717)787-4701; or Larry Decina of Ketron, (215)648-9000

DESCRIPTION:

How the participants are selected:

Although periodic vision test for license renewal is not required in Pennsylvania, licensed drivers are required to have new photographs taken every four years at the time of renewal. The license examiner selected the first available driver for visual screening either as the person entered the room for identification photo, or after his/her photo was taken and the person was waiting for the photo to be developed. This visual screening took place at three PennDOT Photo Identification License Centers between February and August of 1989.

What data are collected:

Participants were tested for static visual acuity, horizontal visual field test and contrast sensitivity. In addition, preliminary information was obtained, including corrective lens use, eye examination history, and driving experience (weekly, monthly, or annual mileage). Vision scores were then linked to crash information extracted from PennDOT's Operator License/Traffic Safety IMS Database and Accident Analysis DB2 Database.

Sample size:

12,400 drivers in Pennsylvania were visually screened at the time of license renewal between February and August of 1989 of which 3,000 were over 65 years old.

Willingness to share data:

PennDOT is willing to share the data provided that confidentiality of participants is protected.

Assessment:

Pros

- o Data incompatibility is minimized by linking visual screening data with crash and moving violation data, both compiled by PennDOT.
- o Sample size is sufficiently large for statistical analysis.
- o Selection bias exists since individuals with severe visual impairment might choose not to renew their driver's licenses. However, this bias might be desirable in formulating licensing regulations since it is more likely to lead to conservative results.

Cons

- o Some visual functionalities that are recently established in other studies as potentially important predictors in highway crashes are not included, such as dynamic visual acuity and useful field of vision (UFOV).

NAME OF THE DATA SOURCE: Pennsylvania Department of Transportation's Driver Re-Examination Program

ORGANIZATION: Pennsylvania Department of Transportation (PennDOT)

CONTACT PERSON: Doug Tobin of PennDOT, (717)787-4701; or Larry Decina of Ketron, (215)648-9000

DESCRIPTION:

How the participants are selected:

A statistical sample of drivers 45 years or older is selected in each region monthly. This statistical selection process takes into account the driver's age and the number of years since the last driver examination. Oldest drivers who have the greatest number of years since their last examination will be chosen first. Selected drivers are asked to complete a physical examination.

What data are collected:

In addition to data on physical and mental conditions, medical re-examination status (e.g., passed examination, license restrictions added or deleted), medical reason for failing the examination (e.g., visual deficiency, lapse of consciousness), and the types of restriction added (e.g., daylight driving only, special hand control equipments) are included in the database. Specific medical conditions included in the program are: psychiatric, cardiovascular, convulsive disorder, diabetes, neurologic, orthopedic and otological. Data collected between 1982 and 1985 from this program are already linked to crash and moving violation data obtained from PennDOT.

Sample size:

6,000 licensed drivers are notified every month for medical re-examination. In the mid 1980s, over 150,000 drivers participated in this medical re-examination program, most of whom were over 65 years old.

Willingness to share data:

PennDOT is willing to share the data provided that confidentiality of participants is protected.

Assessment:

Pros

- o Data incompatibility is minimized by linking medical examination data with crash and moving violation data, both compiled by PennDOT.
- o Sample size is sufficiently large for statistical analysis.
- o These medical examination data can be further linked to the visual screening data (mentioned above) to build an integrated database containing not only data on visual functionality and crash and moving violations, but also data on other physical and mental impairments. However, the probability of having an individual being selected for both vision test and medical re-examination is extremely small. One possible solution to this problem is for PennDOT to consider eliminating the visual screening test and modifying the medical examination program slightly to include information collected in the visual screening test. This type of integrated database would allow interaction analysis between visual impairment and other physical and mental limitations.

Cons

- o Data from 1989 onward have not been keyed into the database.
- o Information on the severity of the medical conditions is not available.
- o Since information on driving experience (number of miles driven) is lacking, crash involvement rate cannot be controlled by risk exposure.
- o Medical reasons for failing the medical re-examination are categorized into aggregate categories, preventing in-depth investigations of more specific physical and mental impairment.

NAME OF THE DATA SOURCE: Wisconsin Beaver Dam Eye Study

ORGANIZATION: University of Wisconsin

CONTACT PERSON: Ron Klein, (608)263-6641

DESCRIPTION:

How the participants are selected:

In the fall of 1987, residents between the ages of 43 and 84 in Beaver Dam, Wisconsin (*n=5,924*) were contacted either by phone or mail asking their participation in the eye study.

What data are collected:

Data on blood pressure, medical history, and visual acuity were obtained at the time of the eye examination. In addition, color photographs of the eyes were taken.

Sample size:

A total of 4,926 people between the ages of 43 and 86 were examined from 1988 to 1990.

Willingness to share data:

The University of Wisconsin appears to be willing to collaborate. However, no data are available yet.

Assessment:

Pros

- o This database has relatively comprehensive information on eye health of all adults in a total community.

Cons

- o Data on driving patterns and on crash and moving violations are not available. Thus, this database provides only one-third of the information needed to establish a statistical relationship between visual impairment and highway crashes. While the database contains participants' social security numbers, which allow some future linkage with the Department of Motor Vehicles' crash and moving violation data, this linkage, and the re-surveying of participants for their driving experience is not a small task.

NAME OF THE DATA SOURCE: Wisconsin Epidemiological Study of Diabetics

ORGANIZATION: University of Wisconsin

CONTACT PERSON: Ron Klein, (608)263-6641

DESCRIPTION:

How the participants are selected:

Diabetic patients who receive medical care in 11 counties in southern Wisconsin were sampled. The cohort, which ranged from 19 to 97 years of age, was followed for 10 years.

What data are collected:

Data were obtained on medical history, visual acuity, whether currently driving, and whether diabetic condition affected driving behavior.

Sample size:

About 3,000 diabetic patients were included in this study, of whom approximately 800 were 65 years or older.

Willingness to share data:

The University of Wisconsin appears to be willing to collaborate.

Assessment:

Con

o This study is a population-based epidemiological study on diabetics. However, little was recorded on driving patterns and no data were available on highway crashes and moving violations.

Table 17 summarizes a brief assessment of the aforementioned data sources in a tabular format. It should be emphasized that the assessment of these data sources at this stage of the study is preliminary, without the benefit of actually obtaining and analyzing the data. Furthermore, thorough examination of the data will be needed once the statistical framework and the preliminary model are developed during the Task 3 of this study.

There are several other data sources worth mentioning. Detailed descriptions and assessments are not provided for these sources because they either lack data on drivers' medical condition or data on crashes and moving violations. Basically, they can only provide either crash data or crash exposure data. They are:

1. **Nationwide Personal Transportation Surveys (NPTS)** - The NPTS series is conducted approximately every seven years, in 1969, 1977, 1983 and 1990; and is sponsored by the U.S. Department of Transportation. The purpose of the survey is to provide detailed travel data by trip purpose, transportation mode, and temporal distribution of travel patterns. NPTS's monitor trends in Americans' travel behavior over time. The sample size and survey instrument of the NPTS's varied by survey. In the 1990 NPTS, 22,000 households were interviewed and a computer-aided telephone interview was used. A response rate of 85% was attained in the 1990 NPTS.
2. **1988 Ontario Driver Survey**, sponsored by the Ontario Ministry of Transportation, collected detailed information on driving patterns in the province of Ontario, Canada. A total of 10,164 questionnaires were sent to Ontario licensed drivers, and 3,686 replies were received -- a response rate of 36%.
3. **Ontario's Accident Data System** is a data base that maintains detailed data on traffic crashes in Ontario. The data base contains information on the highway geometry, driver, vehicle, and environment in which the crash took place. This file is similar to the U.S. Highway Safety Information System (HSIS). The HSIS contains similar information on traffic crashes in five states in the United States. The HSIS is funded by the U.S. Department of Transportation and is maintained by the University of North Carolina.

None of the data sources has information on severity of medical conditions of interest. Our preliminary assessment of the currently available data sources suggests that perhaps three of them are suitable as a foundation to begin the work of identifying an appropriate statistical framework and of developing a preliminary model to establish the relationship between age-related physical and mental limitation and increased highway risk. They are the Quebec data base, the EPESE at Iowa and at New Haven and the Pennsylvania medical and vision re-examination data. However, as mentioned before, these assessments are preliminary and are without the benefit of actually obtaining and analyzing the data. The feasibility of using these data bases to establish statistical link(s) can not be assessed until possible selection bias issues and other shortcomings of these three data bases are thoroughly examined.

Data sources other than the three mentioned above also have varying levels of potential usefulness. Some of these data sources may be completely adequate after a significant amount of resource investment (time, staff effort and funds). None of the data sources (except the EPESE, Quebec and Pennsylvania data bases) provides a complete picture at the present time. However, with additional funding from NHTSA, responsible organizations are likely to complete the picture to meet their own as well as NHTSA's specific goals.

5. SUMMARY

The U.S. Bureau of Census has projected that by the end of this century the percentage of individuals 65 years or older in the United States will be more than five times that at the beginning of the century. Recent travel surveys confirm that an increasing number of older individuals are licensed to drive and that they drive more than their same age cohort a decade ago. Although older individuals continue to drive, studies show that they take more trips than their age cohort a decade ago. They continue to take shorter trips than younger drivers and they avoid driving during congested hours. This recent demographic transformation in our society, the graying of America, and the increased mobility of the older population impose a serious highway safety issue that cannot be overlooked. To address older drivers' safety issues, one of the major concerns is the establishment of licensing guidelines and procedures that are based on conclusive scientific evidence and the identification of "high-risk" older drivers. This report assesses the scientific basis of the 1980 AAMVA and NHTSA licensing guidelines; reviews ongoing research on the effects of medical impairment in older drivers; identifies areas for further research; and assesses the usefulness of currently available data sources as a basis for statistical evaluation of age-related impairment and traffic safety.

The first part of the report assessed whether licensing guidelines which appeared in the 1980 AAMVA and NHTSA licensing guidelines and other physicians' guidebooks were based on scientific considerations. Based on the assessment and a literature review, medical conditions for which more research is needed were identified. An inventory of medical and epidemiological data bases was included and each data base was briefly evaluated in terms of its feasibility for being used to develop conclusive statistical relationships between specific medical conditions and increased highway crashes. The possibility of "merging" different data sources to supplement each other's shortcomings is not discussed until a more comprehensive statistical framework is developed in the next task.

The assessment of various licensing guidelines suggested that medical conditions included in these guidelines can be grouped into two major categories - those for which a relatively significant amount of research has been completed and those where basically no research was done. For medical conditions (such as epilepsy, diabetes, impaired vision) which have been well studied, conclusive evidence is still limited. More research will be needed to overcome the problems of small sample sizes, discrepancies among methodologies, and selection bias. Of course, more research is also needed on medical conditions (such as impaired hearing, mental disorders, drug and medication-related conditions, and dementia) which were hardly studied for the 1980 AAMVA and NHTSA guidelines. Much of the existing guidelines were based on consensus and professional judgement, rather than on scientific evidence.

To this date, most research on medical impairment in older drivers and on their driving has been limited. Waller (1992) summarized obstacles to establishing statistical links between older drivers and highway crashes. He identified several methodological and administrative issues that contribute to the inconclusiveness in research involving older and medically impaired drivers. They include: diagnostic inaccuracy, small sample size, selection bias, inconsistent definition of criteria for excessive crash risk, the lack of research on the effect of mixes of medical conditions, and the subtle nature of the interaction between driver and environment.

In addition to the ongoing research, three areas were identified where more research will be needed to address older drivers' safety issues. The first is the effect of increased usage of prescribed and over-the-counter medication by older drivers on highway crashes. Second, although some studies were done in recent years on demented older drivers, methodological problems, small sample sizes and differences in the observations across these studies have prevented any confident conclusions regarding dementia and highway crashes. More empirical research with larger sample sizes in this area will be needed. The last, but perhaps the most important, area in which research is lacking are the synergistic effects of comorbid conditions on highway crashes. This area is especially relevant in trying to clearly identify older drivers who are frequently involved in highway crashes, since the aging process contributes to both physical and mental deterioration. Special attention should be given to the synergistic effects of alcohol and medication abuse and to other age-related physical and mental conditions.

Our preliminary assessment of the currently available data sources suggested that the majority of these data sources are significantly limited for the purposes of our study by their small sample sizes and incomplete information. Perhaps only three of them are suitable as a foundation to begin the work of identifying an appropriate statistical framework and of developing a preliminary model to establish relationships between age-related physical and mental limitations and increased highway risk. They are the Quebec data base, the Pennsylvania driver re-examination data, and the EPESE at Iowa and at New Haven, Connecticut. However, they are not without limitations. As mentioned before, our assessments are preliminary and were without the benefit of actually obtaining and analyzing the data. The feasibility of using these data bases to establish statistical link(s) can not be assessed until possible selection bias issues and other possible shortcomings of these three data bases are thoroughly examined. The selection bias in the Quebec data base needs to be ascertained. The sample size of EPESE might be too small to be medical condition specific. In addition, selection bias in New Haven's sample also needs to be ascertained. Although the Pennsylvania Driver Re-examination Program has relatively comprehensive data in regards to drivers' medical conditions, it lacks data on crash exposure. Information that none of these three data sources can provide is the severity of the medical conditions.

It should be re-emphasized that all the data sources in our inventory are collected by different institutes to meet their specific goals. It is, therefore, not surprising to learn that none of these data sources are "perfect" in terms of meeting the goals of *this* study. Data sources other than the three mentioned above also have varying levels of potential usefulness. Some of these data sources may be adequate after a significant amount of resources (time, staff effort and funds) is invested in them. Given the constraints on available resources, the question then becomes to what extent these data sources can be combined or made complementary. This question will be addressed in Task 3.

Table 17. Summary of Available Data Sources

Data Source	Overall Sample Size (n)	Subject Selection Procedure	Possible Selection Biases	Number of Older Drivers in Sample	Medical Condition Inform'n	Functional Capability Information	Crash Exposure	Crash & Violation	Preliminary Assessment
California Special Drive Test	9,500	Those with specific P&M[1] conditions, or who failed the regular drive test	Yes. Only those with their P&M condition known to the DMV[2]	Most of 9,500 were senior with P&M	General	Vision acuity	No	Yes	Great effort needed to prepare the data
Vision Test Study by CA DMV	4,200	Stratified sample of field office renewal applicants.		2,000 cases aged 52+		3 vision test batteries, inc. UFOV	Yes	Yes	Sample size might be small for a national study
Florida Geriatric Research Program	2,000	Volunteers	Yes. Volunteers in Dunedin, FL might represent a special group	1,229	General	Mental status	No	Yes	Provides limited picture of older drivers with P&M
British Columbia Crash & Insurance Claim Data	2.5 million	Those insured by Insurance Corp. of BC	No	Not available	Not available	No	Yes	Yes	Infor. on medical condition is not releasable
Saskatchewan Crash & Insurance Claim Data	Unknown	Those insured by Sask. Govern. Insurance	No	Not available	Yes. Those known to Insurance Corp.	No	Yes	Yes	No link between crash data and insurance data yet
Epi. Study on Vision in Elderly Drivers in Quebec	20,000	Permit holders of Classes 1 through 5 in Quebec	Renewal permit holders or those P&M known to licensing agencies.	7,500 aged 70 to 85	Yes. Those known to licensing agencies	No	Yes	Yes	Comprehensive data base to use

1 Physical and mental condition.
2 Department of Motor Vehicles

Table 17. Summary of Available Data Sources (Continued)

Data Source	Overall Sample Size (*n*)	Subject Selection Procedure	Possible Selection Biases	Number of Older Drivers in Sample	Medical Condition Inform'n	Functional Capability Information	Crash Exposure	Crash & Violation	Preliminary Assessment
Health & Functioning in Marin County, California	2,019	Stratified sample of residents in Marin County aged 55 or over	Marin County by itself is unique.	2,019	General	For daily activities	No	Is being linked to the main database	Has potential usefulness, once selection bias & crash data are addressed
EPESE at Iowa and at Yale	1,300 in Iowa 500 in New Haven	Census in Iowa rural counties. Stratified cluster sample of non-institutionalized older individuals aged 65+ in New Haven	Yes in New Haven. Older individuals in restricted housing units are over-sampled	n=1,300 in Iowa; n=500 in New Haven	General	Yes	Yes	Yes	Comprehensive; sample size might be small for further subdividing
Visual/Cognitive Study of Older Drivers	294	Stratified sample of licensed drivers aged 55+ in Jefferson County, AL	Potential bias between participants & those recruited but refused.	294	General eye health	Vision & cognitive	Yes	Yes	Comprehensive; selection bias might exist; small sample size
North Carolina Older Drivers	5,000	Sample of licensed drivers aged 65+	Potential bias between participants & non-participants	5,000	No	Cognitive & Vision/ attention	?	Yes	No data until 1994; has potential
Marshfield Diabetic & Epileptic Older Drivers	484 diabetes, 241 epilepsy	Patients at the Marshfield Clinic and/or St. Joseph's Hospital who still hold a valid license and still driving	Participants might be in a lower risk category than non-participants	200 diabetes and 50 epilepsy	Diabetes or Epilepsy	No	No	Yes	Selection bias exists; small sample size

Table 17. Summary of Available Data Sources (Continued)

Data Source	Overall Sample Size (*n*)	Subject Selection Procedure	Possible Selection Biases	Number of Older Drivers in Sample	Medical Condition Inform'n	Functional Capability Information	Crash Exposure	Crash & Violation	Preliminary Assessment
Pennsylvania DOT Visual Screen Data	12,400	Sample of in-person license renewal	Probably no.	3,000	General eye health	Vision	Yes	Yes	Comprehensive visual data base.
Pennsylvania DOT Medical Re-examination Data	1,600/ month	A statistical sample of drivers 45 and older	No	By mid 80's most of 150,000 participants were over 65	Yes	No	No	Yes	Need to add crash exposure data
Wisconsin Epidemiological Study of Diabetics	3,000	Sample of diabetic patients receiving care in 11 southern Wisconsin counties	Possible bias between participants and non-participants	800	Diabetics	Vision, Driving status	No	No	No data on crash exposure, crash and moving violation

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GLOSSARY

Acute myocardial infarction
A gross coagulation of dead cells in the middle and thickest layer of the heart wall, as a result of interruption of the blood supply to the area.

Aging
The gradual changes in the structure of any organism that occur with the passage of time, that do not result from disease or other gross accidents.

Alzheimer's disease
A progressive degenerative disease of the brain. The first signs of the disease are slight memory disturbance or subtle changes in personality. There is progressive deterioration resulting in profound dementia over a course of 5 to 10 years.

Angina pectoris
A recurring chest pain, with a feeling of suffocation and impending death.

Arteriosclerotic heat disease
A group of diseases characterized by thickening and loss of elasticity of arterial walls.

Cardiac arrhythmias
Any variation from the normal rhythm of the heart beat.

Cardiovascular diseases
Diseases pertaining to the heart and blood vessels.

Cerebral palsy
A group of conditions caused by non-progressive damage to the brain. The brain damage impairs movement reflexes and motor control in some parts of the body.

Comorbid conditions
Conditions affected with multiple diseases and/or functional impairments.

Dementia
An organic mental disorder characterized by a general loss of intellectual abilities involving impairment of memory, judgment, and abstract thinking as well as changes in personality. The most common cause is Alzheimer's disease.

Diabetes
A group of medical conditions that affect the human body's ability to produce appropriate levels of insulin. The disease is associated with retinal damage and the thickening of the arterial, which in turn leads to loss of consciousness.

Diabetic retinopathy
Inflammation of the retina associated with diabetes.

Dynamic visual acuity
The capability to see moving objectives.

Epilepsy
A neurological disorder due to recurring disturbance of the electrical activity of the brain. Epilepsy may be manifested as loss of consciousness, abnormal motor phenomena, and psychic and sensory disturbances.

Hearing
The capability to perceive sound.

Huntington's chorea
A relatively common autosomal disease characterized by chronic progressive chorea (involuntarily rapid and jerky movements) and mental deterioration.

Joseph's disease
A progressive degenerative disease of the central nervous system occurring in families of Portuguese-Azorean descent.

Mental disorders
Any clinically significant behavioral or psychological syndrome characterized by the presence of distressing symptoms or significant impairment of functioning.

Mesopic acuity
The capability to see at intermediate levels of illumination.

Metabolic conditions
Conditions that affect the nature of metabolism due to disturbances in the functioning of the endocrine glands.

Modes of transportation
A mode used for going from one place (origin) to another (destination). In the 1990 NPTS, private and public modes, as well as walking are included.

Private vehicle: Includes automobile, van, pickup truck, other truck, RV or motor home and motorcycle.

Public transportation: Includes bus, commuter train, Amtrak, streetcar or trolley, subway, and elevated rail.

Other modes: Include airplane, taxi, bicycling, walking, school bus, moped and other.

Multiple sclerosis
A disease in which there are patches of destructed myelin sheath throughout the white matter of the central nervous system. The symptoms include weakness, incoordination, paresthesia, speech disturbances, and visual complaints.

Muscular dystrophy
A group of genetic degenerative muscle diseases characterized by weakness and atrophy of muscle without involvement of the nervous system.

Musculoskeletal conditions
Conditions pertaining to or comprising the skeleton and the muscles.

Myasthenia gravis
A disorder of neuro-muscular function characterized by fatigue and exhaustion of the muscular system.

Narcolepsy
A recurrent, uncontrollable, brief episode of sleep.

Ocular motility
The ability of the eyes to move spontaneously.

Parkinson's disease
A progressive neurological condition characterized by a synthmic tremor, a slowing of voluntary movements, and weakness of the muscles.

Peripheral vision
The capability to see objects falling on areas of the retina distant from the macula.

Photopic acuity
The capability to see in daylight.

Respiratory function
Functions pertaining to the exchange of oxygen and carbon dioxide between the atmosphere and the cells of the body.

Retinitis pigmentosa
A group of diseases, frequently hereditary, marked by progressive loss of retinal response, attenuation of the retinal vessels, and clumping of the pigment, with contraction of the field of vision.

Static visual acuity
The capability to see stationary objectives.

Stroke
A condition with sudden onset caused by acute vascular lesions of the brain, such as hemorrhage. It is often followed by permanent neurologic damage.

Trip purpose
The main purpose that motivates the trip. The eleven trip purposes in the 1990 NPTS are categorized into the following five major trip purpose groups.

Earning a living: Includes travel to and from work, and work-related travel.

Family and Personal Business: Includes shopping, visits to doctor or dentist, travel to purchase services such as dry cleaning, haircut, car repair.

Civic, educational and religious: Includes trips to school and college for class(es), to church services, or to participate in other religious activities.

Social and recreational: Includes vacationing trips, trips to visit friends and relatives, and pleasure driving.

Other: Trips that can not be categorized into the above four groups.

Vehicle miles of travel (VMT)
A unit to measure vehicle travel made by a private vehicle. Each mile travelled is counted as one vehicle mile regardless of the number of persons in the vehicle.

Vehicle trip
A trip by a single vehicle regardless of the number of persons in the vehicle.

Vision
The act of seeing.

Visuocognitive skill
The ability to process visual information.

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