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IMPACT OF AGING DRIVER POPULATION AND IMPAIRED DRIVERS ON GEOMETRIC DESIGN

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OPERATION AND MAINTENANCE OF TRANSPORTATION FACILITIES

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INTRODUCTION

Committee A3A08, Operational Effects of Geometrics, has engaged in an activity which its membership believes is one of its several major charges, that of synthesizing the state of major knowledge in the fields of committee responsibility and communicating it to the research community. In recent years, the Committee has sponsored a symposium, in Denver, Colorado, on geometric design for large trucks, and several sessions on operational aspects of geometric design at TRB annual meetings in Washington, D.C.

In August 1985, the Committee held its mid-year meeting in Denver, Colorado. One of the primary objectives of the meeting was to define future committee organization and activities. In response to this goal, it was agreed that the organization would be a combination of subcommittees working in several related areas.

One of the problem areas for which a subcommittee was formed was the impact of aging driver population and impaired drivers on geometric design. Members of this subcommittee were as follows: Ron W. Eck, Chairman, West Virginia University; Jerome Hall, University of New Mexico; Timothy R. Neuman, Jack E. Leisch & Associates; James J. Schuster, Villanova University; R. Kenneth Shearin, Roy Jorgensen & Associates; Clinton A. Venable, Indiana Department of Highways; Robert C. Winans, Federal Highway Administration; and Walter E. Witt, Nebraska Department of Roads.

The subcommittee's primary charge was to recommend research needed to determine whether geometric design and traffic control policies meet the needs of aging and impaired drivers. Specific activities for the subcommittee include: (1) identify and review sources of information on the relationships between aging and impaired drivers and design and operational practices, (2) identify geometric and traffic control elements most closely related to accidents involving aging or impaired drivers, (3) develop recommendations for research projects to determine the need for changes in design and operational policies for specific roadway elements, and (4) make the research recommendations known to the highway community through publication of research problem statements. This Circular, which contains the results of activities (1) and (2) above, is the first of two planned publications. The subcommittee anticipates that the research problem statements will be published at a later date.

Readers of this Circular may be aware of a related study, undertaken by the TRB with support from a number of sources. The objective of the two-year study is to determine how the nation can better serve the transportation needs of older persons. At the time of preparation of this Circular, that study was also preparing a literature summary of broader scope (though not covering the topic of impaired drivers). It is anticipated that the study will also contain recommendations on highway geometric-related issues upon its publication in late 1987 or 1988.

THE PROBLEM

Geometric design and traffic operational policies of highway agencies have traditionally and practically been based on a set of median or 85th percentile driver characteristics, which may be thought to constitute a composite "design driver". However, there has been little formal attention paid to the portion of the driver population that exceeds one or more of the driver characteristics assumed in design. There is a need to identify what groups of drivers are not adequately considered in existing design policies, what the special needs of these drivers are, and what geometric and traffic control elements are critical for their safety.

Two particular groups of drivers whose needs may not be met by existing design and operational policies have been identified: aging drivers and drivers impaired by alcohol or drug usage. The driver population on American highways is aging, with a larger proportion of drivers over age 65 expected each year. Alcohol and drug usage among drivers is also a substantial problem that is associated with approximately 50 percent of highway fatalities. In addition, there are other drivers impaired by fatigue, poor vision, other physical defects, or emotional stress. These groups may have decreased visual acuity, decreased alertness, increased perception-reaction time, less coordinated motor skills, and other limitations in comparison to the "design driver." The special needs of these drivers should be explored as a means of increasing safety and decreasing the exposure of highway agencies to liability claims involving aging and impaired drivers.

APPROACH TO THE PROBLEM

An extensive literature search was made to acquire information on geometric design and traffic control elements related to aging and impaired drivers. Due to the breadth of the topic, the literature search covered the following areas: (1) highway/traffic safety engineering, (2) medicine, (3) law, (4) human factors, and (5) gerontology. The more important studies and publications were summarized and included in the annotated bibliography which comprises this Circular. While it was sometime difficult to distinguish between the two main categories, publications dealing with the aging driver are presented first, followed by those dealing with the impaired driver.

From these summaries, two principal products have been synthesized: (1) a preliminary list, for highway and traffic engineers, of what is currently reported about accident countermeasures (applicable to aging and impaired drivers) that may be useful but that need further evaluation, and (2) a summary of problem areas where research is needed relative to geometric and traffic control elements related to accidents involving aging or impaired drivers. This latter summary will be used by the subcommittee in developing more detailed research problem statements to fill in critical information needs. Such a targeted program of research can generate the information needed to address critical unanswered questions.

LIST OF POTENTIAL COUNTERMEASURES FOR FURTHER STUDY

Aging Drivers

Below is a list of countermeasures that have been proposed in past studies. Although they are not necessarily endorsed by the Committee and more research may be needed to evaluate them, they may be useful in addressing some of the safety-critical physical and behavioral problems associated with aging.

1. Modify highway design and operational practices dealing with safe sight distances.

2. Remove obstructions to provide adequate sight distance at intersections and other highway sections.

3. Complicated intersections requiring a high number of driver assessments should be reviewed and simplified whenever possible.

4. Advance warning and informational signs should be used more extensively to minimize the number of visual and other perceptual clues that elderly drivers must seek out.

5. Include the information presentation principles of <u>redundancy</u> (giving the same kind of information in more than one way on more than one carrier) and <u>repetition</u> (presenting the same information in the same form several times on the same type of carrier) in implementing driver information systems.

6. Improve the timing and phasing of traffic and pedestrian signals.

7. Traffic signs and signals should be made as large, graphic, simple and clear as possible.

8. Use traffic control devices that are uniform in appearance, brightness, placement, and meaning across the country.

9. Establish minimum levels of brightness and reflectivity for traffic control devices.

10. Reinforce information through the combined use of pavement markings and delineation systems with signs.

Impaired Drivers

A second list of potential countermeasures for further study was also developed from the review of past studies and publications. Again, these are not necessarily endorsed by the Committee and more research may be needed to evaluate them. As might be expected, many of the items on the list appeared on the previous list; in general, the higher design standards recommended will improve safety for all road users. However, the list below contains certain items which relate to specific behavioral or physical characteristics associated with impaired drivers.

1. Maintain high design standards.

2. Use higher type design, signing and lighting near taverns.

3. Use designs that increase driver's ability to see and understand overall intersection configurations.

4. Remove or mitigate roadside obstacles.

5. Clear obstructions from sight distance triangles.

6. Build wide shoulders and shoulders with contrasting color and texture at critical locations.

7. Consider the reduced ability of impaired drivers to track successfully in lanes of reduced width.

8. Take into account the intoxicated driver's increased variability when designing intersections, signal timing, lane delineation and signing.

9. Increase the clearance phase on signals, especially at night.

10. Consider possible confusion that flashing signals may cause for impaired drivers.

11. Use positive guidance techniques wherever possible.

12. Maintain high level of visibility and reflectivity with traffic control devices. Alcohol-impaired drivers require significantly brighter signs.

13. Maintain bright roadway edgelines to improve tracking behavior in both approach and negotiation of curves.

14. Use post delineators to supplement edgelines on curves.

15. Keep all traffic control devices well-maintained.

RESEARCH NEEDS

Aging Drivers

The review of the literature indicated that the highest priority relative to aging drivers should be the area of traffic control devices. Research is needed regarding sign design, size, composition, color, use of symbols and placement of signs. The MUTCD should be reviewed by human factors or medical experts to make needed changes, e.g., lettering sizes on certain signs, to take into account the diminished ability of elderly drivers. A subset of the traffic control elements area that should receive special attention involves nighttime road conditions and traffic control devices.

The design and operation of intersections, driveways, weaving areas, freeway entrance and exit ramps and other complex areas involving numerous and/or successive quick decisions by motorists is another high priority area.

What is an appropriate response time to use in design? Studies relating degradation in vision, hearing, and memory to the driving task are needed. Related questions deal with the elderly involvement in accidents. For example, has raising accident cost reporting thresholds caused engineers to overlook certain types of accidents which are more likely to involve the elderly?

Impaired Drivers

The highest priority relative to impaired drivers appears to be in the area of design, especially horizontal curves and at-grade intersections. These two areas have been repeatedly identified as causing problems for intoxicated drivers. On-road observational studies are needed to determine driver response to spot treatments for curves and intersections. A data base should be developed for establishing design standards which consider the impaired driver. For example, highway designs might incorporate vehicle simulation studies which consider vehicle operations by impaired drivers.

Another high priority area is traffic control devices, especially their nighttime operation. The effectiveness of increasing the traffic signal clearance interval at night should be determined. The impacts that flashing signals may have on impaired drivers need to be assessed. The effectiveness of devices, such as rumbling shoulder treatments, for arousing impaired drivers should be investigated. And finally, the effect of positive guidance techniques on drinking drivers warrants further study.

Much of the work done to date relative to countermeasures for impaired drivers has involved impairment due to alcohol. There is a need for large-scale field studies designed to identify specific drugs most prevalent in accident-involved drivers. Use of actual driving situations to test effects of licit and illicit drugs, alone or in combination with alcohol, on decision-making and perceptual-motor skills is needed. There is a lack of consensus on what skills contribute to driving performance and what change in these skills amounts to impairment.

Concluding Remarks

This discussion has summarized some of the voids and conflicts existing in information pertaining to aging and impaired drivers and geometric design. Although general in nature, the summaries set the direction for the next subcommittee task, that is, preparing detailed research problem statements in a form suitable for publication in a subsequent Circular. The subcommittee welcomes input from the highway, human factors, and medical communities on needed research related to aging and impaired drivers.

Material should be sent to the subcommittee chair, Ronald W. Eck, in care of the Department of Civil Engineering, West Virginia University, PO Box 6101, Morgantown, WV 26506-6101.

ANNOTATED BIBLIOGRAPHY

Aging Drivers

Cristarella, M., "Visual Functions of the Elderly," American Journal of Occupational Therapy, 31, 1977, pp. 432-440.

Limitations in visual function that result from normal age-related physiological changes are described. Environmental modifications are suggested to assist the elderly in accomplishing daily living tasks.

Decline in accommodation for near vision begins as early as 10 years of age, while visual acuity begins to diminish at 18 years of age. These and other limitations (light sensitivity, field, color discrimination, perception of ambiguous figures and illusions, figural after-effects serial learning, critical flicker fusion, figure-ground organization, closure, spatial abilities and memory) are the result of normal age-related physiological changes in the mechanisms underlying visual function.

In order to compensate for the visual limitations of the elderly, environmental modifications are recommended. An elderly person's ability to safely drive a car needs to be assessed for visual accommodation, depth perception, visual field, dark adaptation and recovery from glare. It will take an older person longer to accomplish a visual focus from the mileage gauge to the road and vice versa. An individual should be allowed more time when switching from light to dark surfaces and vice versa since the difference in the amount of reflected light will require visual adaptation. Efforts should be made to reduce glare to ensure that task materials receive principal illumination. Glare can be minimized by removing shiny objects. All unnecessary materials along the highway should be removed to aid figure-ground perception. Reading is more difficult when the words are not in sharp contrast to the boards they are printed on. Increasing illumination and size on the reading material will aid contrast somewhat.

"Does It Have To Be This Way? -- Research In Gerontology," Research News, Division of Research Development and Administration, University of Michigan, Vol. XXVI, Nos. 5/6, November/December 1975, pp. 3-9.

Research into the way older people with sensory deficits perceive their environment yielded several conclusions that are relevant to highway/vehicle design and operations. Glare from natural light and from unbalanced artifical light sources is the single most constant difficulty. In addition, colors all tend to fade (cool colors, such as green and blue, fade the most while reds fade the least). Older people often have trouble perceiving the boundary between two contrasting surfaces (e.g., two intense colors). Depth perception is affected with age; the recovery of vision when moving from light to dark and vice versa is very slow. The ability to see fine detail is seriously impaired. Fine muscle control used for such things as adjusting dials, turning pages, and gripping objects is greatly decreased.

There are numerous problems and hazards confronting the older driver. Some of them can be eliminated through environmental modifications: left-turn only signals, removal of roadside impediments, and larger more distinctive signs. Other problems are more difficult to solve. As drivers grow older, nighttime visual acuity declines steadily. Glare tolerance and light-to-dark adaptation also decrease, making night driving especially difficult. Driving ability may also be impaired by problems with physical movement, loss of sharp vision, or hearing defects. Elderly drivers often have trouble processing an overload of information from signs and traffic signals.

Freedman, M., <u>Traffic Signal Brightness: An Examination of Nighttime Dimming</u>, FHWA-TS-85-213, Federal Highway Administration, Washington, DC, 1985.

The study included laboratory and controlled field experiments to measure how quickly and accurately drivers, including older drivers and those with weak color vision, responded to various levels of signal dimming. Observational field studies at six in-service intersections indicated safe and efficient traffic operation when signals were dimmed to 30 percent of ITE's recommended daytime luminance levels.

Reducing brightness levels was found to improve signal recognition at night for certain drivers. Drivers who have the most common form of color vision deficiencies were better able to correctly identify signal colors when signal intensity was reduced to the 30 percent level in typical night roadway environment. Additionally, there was reduced discomfort and disability glare for all drivers within the 10-30 percent reduction in signal brightness.

Gordon, D.A., McGee, H.W. and Hooper, K.G., "Driver Characteristics Impacting Highway Design and Operations," <u>Public Roads</u>, Vol. 48, No. 1, June 1984, pp. 12-16.

The findings and recommendations of a FHWA study to analyze the driver components of highway design standards were discussed. Sensitivity analyses identified those standards significantly influenced by a driver or pedestrian characteristic specification.

<u>Stopping Sight Distance</u> -- The presently accepted AASHTO value of perception-braking time is 2.5 seconds. A time of 3.2 seconds is suggested as being more appropriate. The sum of latency, eye movement, fixation, recognition, decision, and the motor action of applying the brake equals a reaction time of approximately 3.2 seconds for the 85th percentile driver.

<u>Intersection Sight Distance</u> -- The formulation for Case I sight distance provides 2.6 seconds for the driver to perceive and recognize an approaching vehicle, to decide what evasive action is necessary, to move the foot to the accelerator or the brake, and to take the evasive action. Analyses of perception-reaction times, based on summing the times for latency, eye movement, fixation, recognition, decision and brake action suggest the 85th percentile driver would require 3.4 seconds or longer to react. The current sight distance response time of 2.6 seconds does not allow sufficient time.

In Case II, it is assumed that the vehicle operator on either highway must be able to see the intersection and the intersecting highway in sufficient time to stop the vehicle, if necessary, before reaching the intersection. Calculated perception-reaction times for the 85th percentile driver, include latency, eye movement, fixation, recognition, decision and braking in 3.4 seconds. Again, the standard of 2.5 seconds does not appear to allow the driver adequate time.

Rail-Highway Grade Crossing Sight Distance -- At passive grade crossings where there are no gates, the driver must scan the tracks and decide whether to stop or proceed. A perception-reaction time of 3.5 seconds, representing the 85th percentile driver, appears more appropriate than the 2.5 second interval now used.

Vehicle Clearance Interval -- Current practice in timing the yellow signal assumes a perception-reaction time of 1 second. A more valid estimate of perception-reaction time based on the 85th percentile population decision and brake action time is 1.77 seconds.

Sign Letter Height -- The rule of 50 ft (distance from driver's eye) to 1 inch of letter height allows drivers with 20/24 visual acuity 10 seconds of maneuvering time. Drivers with visual acuity poorer than 20/24 would need larger letters to complete the maneuver in 10 seconds. Current sign letter height specifications included in the MUTCD do not adequately consider the needs of the elderly, whose average letter legibility is 26 ft per 1 inch of letter height. As much as 25 percent of the driving population may be unable to read highway guide signs in sufficient time to react comfortably or safely. Thus, the letter size on highway signs needs to be increased.

Koltnow, P.G., "Improving Safety and Mobility for Older People," TR News, No. 120, September-October 1985, pp. 20-23.

Older people are fastest growing segment of U.S. population. However, the crash rate of older drivers is the highest of any age group over 24 years of age. Although the number of U.S. traffic fatalities dropped 14 percent from 1980 to 1982, there was no decrease for drivers over 65; women over 65 experienced a 14 percent increase in the number of deaths.

Older drivers have distinctive crash and traffic-violation patterns. They are involved in multi-vehicle crashes more often than other drivers--and are more often at fault. They are more commonly cited for failure to yield or stop for other motorists and are over-represented in crashes at low speeds.

Some of the physical and behavioral changes associated with aging are directly related to an individual's ability to cope successfully with modern traffic. Physical performance is less important than nerve or sensory operation in carrying out driving tasks. With aging there is a loss in intuitive power and basic sensitivity functions. Many older drivers compensate for reduced driving ability by cutting back on driving under certain conditions. However, there is often a misperception of the driving risk and a changed ability to recognize important features in a complex situation. Although older people generally have adequate knowledge of driving rules, they may exhibit inappropriate behavior in traffic.

The interrelated vehicle-highway-driver system has not yet dealt fully with the expanding mobility of the elderly. Traffic signal visibility and timing are designed for a population with a younger average age. Technical standards for safe sight distances at intersections and on curves reflect the reaction times of persons younger than those driving today. Lighting levels, legibility of traffic signs, and location of traffic control devices commonly are inadequate for the needs of elderly drivers.

Additional evaluation and organization of information relative to the safety-critical physical and behavioral aspects of aging is necessary to put it to use by those who create and operate the highway transportation environment. Potentially promising actions include:

- Upgrading the visibility of highway signs, markings, and signals;
- Improving the timing and phasing of traffic and pedestrian signals; and
- Modifying highway design and operational practices dealing with safe sight distances.

Malfetti, James L., Editor, "Drivers 55+," <u>Needs and Problems of Older Drivers: Survey Results and Recommendations -- Proceedings of the Older Driver Colloquium, Orlando, Florida</u>, AAA Foundation for Traffic Safety, Falls Church, Virginia, February 4-7, 1985, 132 pages.

These proceedings contain twelve papers, and panel recommendations based on those papers, relative to the aging (55 and over) driver. Several of the papers contain data or recommendations relevant to the areas of highway design and operations.

Above age 50, visual deterioration begins to be significant and is probably a factor in older-driver accidents. This can take the form of decline in visual acuity, glare resistance, color perception and intensity, focusing ability and peripheral vision. Reduced performance from poor vision shows up as a slowed response to signals, signs and the traffic events that might lead to an accident. To help compensate, designers should consider a longer response time than the 2.5 seconds recommended by AASHTO, or they need to provide improved vehicle, highway and signal systems that compensate for the degrading factors. In addition to problems of focus, losses in visual performance of the elderly are due to losses of light intensity in the eye. Combined losses of available light in the eyes of older people can easily be equivalent to reducing street and automobile lighting to 10 percent or less of their normal design levels. Older drivers are more susceptible to the illusory clues provided when headlights and tail lights are malpositioned.

Accommodation is the ability of the lens of the eye to change shape and thereby see things up close as well as far away. With aging, this ability declines and more time is needed to shift focus from near to distant. For example, this means increased time for the eyes to adjust from reading the speedometer on the dashboard to reading guide signs and route numbers along a road.

Another characteristic of the aging eye is loss of peripheral vision. A recent study showed the incidence of visual field loss was 3.0 to 3.5 percent for persons 16 to 60 years old compared to 13 percent for those over 65 years. Drivers with visual field loss in both eyes had twice the accident and conviction rate as those with normal field vision.

With aging, the ability to discriminate among colors declines. As the lens of the eye yellows with age, it filters shorter wavelength colors (blue, violet and green) and they are less discernible. Longer wavelength colors (yellow, orange, and red) remain more vivid, clear and easily seen. Some signs and signals (such as light green signal and lights) are especially difficult for older drivers to see and interpret. Poor color discrimination by older people emphasizes the need to use clear, bright colors for signs and signals.

One study found that symbol-signs were superior in legibility to equivalent word and number signs. While older drivers appeared to have less current symbol-sign knowledge, they did not have problems learning and retaining such knowledge when they had a chance to study it. They did require more time in processing symbol-sign information, but this was found to be influenced by the composition of the sign. Bold, simple, unique symbolic graphics were seen more easily from a distance and led to few errors in recognition. In testing colors, white symbols on blue background were superior to black and red symbols on white background; however, the type of message conveyed may have an influence on this finding. Research was recommended relative to design, size, composition, color, use of symbols and placement of signs.

Older drivers have a problem both in ignoring meaningless information and in correctly identifying meaningful clues. Inattention to the driving task and lack of concentration are the primary reasons for these problems. Older drivers need more time to perceive a situation, organize the information gathered and react.

Cognitive changes are also an accompaniment to aging. A decline in short-term memory causes problems, especially in organizing information coming from a variety of sources. Decision-making in traffic is less acute. There is some decline in the ability to estimate the passage of time and to judge the speed of other motor vehicles. The traffic environment may produce too many cues at one time, thus causing confusion or erratic driving behavior.

Physiologic changes occur in the musculo-skeletal system and in part account for the accident and injury-severity rates for drivers 55+. Reaction time is necessarily increased by arthritic joints and tight musculature. Aging brings about changes in the components and structure of the articular cartilage, underlying bone, ligaments and musculature which impair the capability of the muscular-skeletal system to perform the driving act. Muscle strength also diminishes with age. Although automobile power steering, power brakes and power seats compensate for these losses, there is nevertheless a degradation of performance. Finally, discomfort and pain while one is passively seated or active in vehicle-control motions further impair the driving act. Passive discomfort leads to early and excessive fatigue and distraction. Discomfort during motions of joints necessary for vehicle control slows such responses and at times may even prevent appropriate responses, particularly in emergency situations.

Main problems experienced by older drivers involve interaction with the overall traffic flow and their performance in changing lanes, passing, turning and backing. In traffic situations requiring rapid reacting and decision-making, stimulus overload coupled with perceptual motor problems make older drivers especially vulnerable. Four-, six- or eight-lane uncontrolled access highways are especially difficult for older drivers. Intersections are also leading trouble spots. Senior drivers have particular difficulty with intersections in which there is high density. The problem seems to be perceptual overload on the part of the driver.

The most commonly cited performance errors of older drivers are failure to yield right-of-way; failure to obey signs, signals and markings; careless crossings at intersections and improper turns (especially left turns). In spite of compensating behaviors by older drivers, accident rates that involve failing to yield right-of-way, improper turning, and ignoring stop signs are higher for older drivers than for middle age drivers. Certain types of violations appear to increase with advancing age. Drivers of 70 and over are more often convicted of sign and right-of-way and turning violations, and less often convicted of speeding, equipment and major violations.

Older drivers are generally shorter than younger ones and therefore sit lower in a vehicle. Lower eye-height affects the ability of older drivers to see traffic.

It was recommended that various laws, regulations and standards be reviewed to make needed changes in view of the diminished abilities of drivers over age 55. For example, the MUTCD contains provisions which do not adequately meet needs of elderly drivers. Lettering sizes on various important signs, including street name signs, are inadequate, especially at night and in other low-light conditions. Width and effectiveness of pavement-edge markings, especially at night leave something to be desired. Other examples include signs which do not give elderly drivers sufficient advance warning to react properly and traffic signal effectiveness under some conditions. A major question is for which drivers should standards prove adequate? For average drivers? For 70 percent of all drivers? This question has not been suitably dealt with.

Several recommendations were made regarding the highway environment for older drivers.

- traffic signs and signals should be made as large, graphic, simple, and clear as possible.

- with regard to traffic controls, it must be recognized that older people have difficulty with certain colors and that contrasts in colors are important.

- advance warning and informational signing should be used more extensively to minimize the number of visual and other perceptual clues that old drivers must seek out in making safe driving decisions.

- complicated intersections requiring a high number of driver assessments should be reviewed and simplified whenever possible. Unnecessary highway "furniture", signs, or plantings which interfere with clear view of the intersection should be eliminated.

- wider and brighter pavement striping for edge, center and lane delineation has been shown to improve driver performance.

Marsh, B.W., "Aging and Driving," Traffic Engineering, Vol. 31, No. 2, November 1960, pp. 3-29.

Author argues that "functional age" rather than chronological age should receive attention. However, no suitable criteria exist for determining functional age. Limited data through the date of the publication indicated that accidents per 100,000 miles driven increased sharply for both men and women after about age 60; rates for women above age 55 were substantially higher. Older drivers were adjudged to be at fault considerably more frequently than those in middle years among drivers involved in accidents. More study was recommended, especially that taking into account the proportion of driving in daytime, proportion of driving in rural areas and proportion of driving in bad weather.

Relative to perception and response, older individuals are generally less able to discriminate or recognize ambiguous stimuli and concealed or masked figures. Slowness or difficulty in perceiving the stimulus is assumed to constitute a large portion of the increased response time that is observed with aging. Applied to traffic, this seems to indicate that, for the aged, it is doubly important that stimuli (signs, markings, and signals) be simple and very clear. Complex situations and conditions which emphasize speed are more likely to reveal deficiences in an older person's performance. Clearly, the avoidance of complex or complicated traffic situations or traffic control devices will have added significance as the numbers of older drivers increase. Even greater attention should be devoted to avoiding surprise situations and situations calling for quick decision, and especially quick decisions in rapid sequence - as might, for example, be the case where urban interchanges are too close together. Older drivers more frequently disregard traffic signals. Inattentiveness or absent-mindedness was probably a major factor since older drivers tend to be more cautious and safety-minded than younger drivers.

Tasks which require a change in procedure or a substitution of new rules are particularly difficult at later ages. Older drivers need to be brought up to date on traffic regulations, yield signs, lane signals, reversible traffic lanes, freeway driving, etc.

McFarland, R. A., Tune, G. S. and Welford, A. T., "On the Driving of Automobiles by Older People," Journal of Gerontology, 19(2), 1964, pp. 190-197.

In this paper, the authors discuss sensory functions, speed of reaction, accuracy, "load shedding," age changes of capacities and intellectual capacities of the elderly. A brief review of some of the evidence pertaining to the problem of aging drivers led to the following conclusions.

The type of involvement of older drivers tends to be different from other age groups. Older drivers are more frequently involved in accidents resulting from improper starting and turning and failure to give right-of-way, among other factors. Attempts made at isolating sensory changes with age and identifying these as the causal agents of accidents have given equivocal results. More important are the age changes in perception, decision making and judgments involving the use of short-term memory in a dynamic situation. These deteriorate with age, as do intellectual capacities. There is evidence to suggest that these aspects of the aging process are more frequently the causes of accidents among old than young drivers.

McKnight, A.J. and Simone, G.A., Elderly Driver Retraining, National Public Services Research Institute, September 1982.

Traffic safety problems associated with drivers aged 55 years or older were investigated. A main objective was to determine what factors are most strongly related to the aging process and the accident experience of older drivers. Data were collected relative to subject's personal characteristics, vehicle use patterns, driving problems, and crash conviction histories.

Relevant findings included the following data:

Proportion of Travel by Type of Road

Type of Road	Proportion of Travel: Most	Some	Little
Expressway	22.0%	57.3%	20.7%
Residential	43.1	50.7	6.2
Business	34.5	57.4	8.2
Rural	9.5	37.3	53.2

Accidents by Highway Configuration

Configuration	Percent
Controlled Intersection	26.1%
Straight Road	14.4
Railroad Crossing	13.3
Parking Lot	12.2
Uncontrolled Intersection	9.2
Driveway	5.0
Curve	3.1
Other	16.7

Seventy-four percent of all accidents involved another car. The factor primarily responsible for accident involvement among older drivers appears to be exposure. Those who do the most driving and drive under the conditions that are most conducive to accidents have the highest accident involvement. Among older drivers, the variable most responsible for accident exposure is employment.

Mourant, R.R., "Driving Performance of the Elderly," Accident Analysis and Prevention, Vol. 11, No. 4, 1979, pp. 247-253.

While driving on a freeway, visual search patterns, vehicle velocity and voluntary visual occlusion times were recorded for a group of aged and a group of young drivers. The 13 aged drivers were between 60 and 70 years of age; the ten young drivers were between 21 and 29. In the laboratory, all subjects were given a visual search test, an embedded figures test and a motor test. Differences in aged and young performance were found in both freeway driving and the laboratory tests; differences were most apparent in stressful situations.

Aged drivers required more time to acquire the minimum information needed for vehicle control. The longer eye open times for aged drivers may be due to their requiring more time to look for particular clues, more time to extract information from the cues and/or having to look at more cues. Aged drivers drove slower on all night driving tasks except the night car-following during the occlusion testing. The reported significant differences between the aged and young in terms of eye travel distances and duration of eye looks occurred even though the aged were compensating by driving slower. If aged and young had driven at the same velocities, perhaps differences in search and scan patterns would have been larger.

It was noted that the effect of highway environment improvements on the aged driver is one area of research that has been completely ignored. If stop, yield and route guidance signs were larger would this result in aged drivers increasing their vehicle velocities so that they would keep up with other traffic?

Overend, R.B., "The Growing Plight of the Elderly: Balancing Safety with the Need for Mobility," Traffic Safety, Vol. 86, No. 2, March/April 1986, pp. 18-20, 30-34.

Crashes involving older people are most likely to be multi-vehicle accidents (83 percent) on non-Interstate arterial roads (62 percent) in urban areas (81 percent). Among older drivers, the highest rate of fatalities per 100 million vehicle-miles of travel occur on rural non-Interstate arterial roads (7.15) and rural collector roads (5.80), 87 percent of which are two-lane.

Driver license tests usually concentrate on visual acuity; visual acuity varies with contrast and illumination. Thus, a driver candidate may pass a day test, but still be unable to drive at night. Driver candidates should be asked about glaucoma and eye drops and be given a night test if indicated. Similarly, the candidate should be asked about diabetes since it can cause hourly changes in refractive error, a handicap in night driving. Poor vision can slow the driver's response to signals, signs and traffic events. To compensate, highway systems should provide a response time longer than the presently designed 2.5 seconds.

Driver orientation through peripheral vision is important. Peripheral vision provides early detection of hazardous objects and signs, since it constantly and rapidly monitors most of the forward 180 degrees of the environment. Peripheral vision also provides the most powerful information about spatial orientation that we have. After dark, drivers lose significant environmental orientation clues. By making roadway edges and lane lines more visible, driver feelings of security and orientation can be restored.

The main physical problems among the elderly that affect driving are problems with night vision and glare, reduced range of motion that makes it difficult to turn in tight situations, slower reactions and information processing, and tendency toward fatigue, causing inattention and affecting maintenance of proper speed.

Planek, T.W. and Fowler, R.C., "Traffic Accident Problems and Exposure Characteristics of the Aging Driver," Journal of Gerontology, 26(2), 1971, pp. 224-230.

Efforts at educating the aging driver should be based at least in part, on both his/her perception of problems and the accident-related violation problems that are particularly acute for that age group. Elderly drivers perceive themselves on one hand as driving too slowly, but feel that they follow other vehicles too closely. It can be hypothesized from this inconsistency that they would like to drive even slower, but obviously cannot. As a matter of fact, many of the elderly's accident problems involve interaction with traffic in situations where adaptive reactions must speed up to the rate of the rest of the driver population. For example, right-of-way, lane changing, or turning situations produce problems for the elderly.

The aging driver fails to perceive the problems of inattention as being of major importance, although accident-related violations involving running red lights or stop signs are part of the problem. As the aging driver tries to keep pace with traffic, he/she runs into difficulties in reception and processing of information, particularly in situations that demand, what are for the elderly, rapid reactions (for example, at intersections).

Problems of judgment or maladaptive response do not trouble the aged driver when he/she is moving at his own pace in the traffic stream. Such items as judging distance, keeping the car in its lane, and following too closely do not seem to be a major accident-violation problem for the elderly. Stress should be placed on reducing, wherever possible, the necessity to cope with increased traffic volumes, unfamiliar routes and high speed driving.

Planek, T.W. and Overend, R.B., "How Aging Affects the Driver," Traffic Safety, Vol. 73, No. 2, February 1973, pp. 12-14, 36-39.

Studies of the behavioral deficits of aging concentrate on three physical functions: (1) sensory reception, (2) neural processing and transmission, and (3) motor response. It is speculated that deficits in the visual field may be a significant factor in sideswipes, in collisions involving cutting in or in merging. The aged driver's increased need for illumination, heightened sensitivity to glare, and the extended time span needed to adapt to the dark appear to be relevant in a variety of nighttime collisions, particularly on two-lane rural roads.

An important part of driving involves searching for and identifying clues. A number of different task studies have shown that elderly people are rather inefficient at this kind of activity. While conducting a visual search, they seem unable to ignore irrelevant information. Foresignals "conveying partial advance information" are more likely to distract the older person rather than help. The aged are less able to learn repetitive sequences and to abstract economical rules of classification to reduce the range of information they must remember.

Once the relevant clues are identified, a driver must make certain decisions about the current traffic situation, how it will change and how he should react to it. An important factor in this decision process is short-term memory, which also declines with age. Studies have shown that the elderly have greater difficulty remembering what they see than what they hear, but they remember best when they have both visual and auditory cues. Studies have shown that the thinking of aged persons is characterized by a high degree of redundancy and increased difficulty in dealing with new concepts as problems become more complicated. However, discriminations and choices that have become habitual over the years are more likely to be made accurately than those required only infrequently.

Simulator findings confirmed that when controlling his own pace, the older driver could safely cope with impending crash situations. An additional finding was that older drivers tended to drive significantly more toward the outside of the lane (i.e. to the right of center) while the younger group tended to drive toward the inside of the lane.

A 1955 study in Great Britain found that not only does the accident involvement rate change as drivers get older but so does the characteristic pattern of accidents and violations. Increases were found in errors such as pulling out from the side of the road, and changing lanes without due care, careless backing, inaccurate turning and heedless crossing of road junctions. Another study of accident-related violations showed that aging drivers have difficulty with yielding right of way, turning, and changing lanes. Aging drivers are prone to making inattentive responses involving errors of omission such as the failure to read traffic signs and running red lights and stop signs. Failures that could be attributed to bad judgment occur at comparatively low rates among older drivers.

Planek, T.W. and Overend, R.B., "Profile of the Aging Driver," Traffic Safety, January 1973, pp. 9-10, 37-39.

Information on the type of driving done by drivers over 55 years old was summarized. The decrease in mileage found among older drivers was mainly in the "more-difficult" miles, i.e. rush hour, night and winter driving. The pattern for change with age does not appear when it comes to the type of road driven.

Studies were cited showing that aging drivers are not as frequently involved in serious accidents as drivers in other age groups. Another study found that drivers over 65 are much more likely to be traveling at below average speeds at the time of an accident. Among drivers judged as responsible for crashes, those aged 60 and over were found to have, on the average, significantly lower alcohol readings than drivers in other age groups.

If it is true that aging drivers do have less severe accidents on the average, then they are less likely than other age groups to come to the attention of motor vehicle departments because of poor driving records, particularly in those states that have raised their minimum property damage reporting levels.

Robinson, C.C., "Highway Mobility and the Safety of Older Drivers and Pedestrians," ITE Journal, December 1985, pp. 34-36.

Driving impairment is defined as the reduced ability to receive necessary information, to process the information and make proper judgments, to make timely and appropriate response to the decisions, or all three. As a result of a combination of factors, the physical environment of the roadway is often inadequate for the needs of the older driver. Conditions are frequently such that visual cues and decision-making time allowances are less than adequate for all but the most skilled drivers.

The most dangerous time for people aged 65 and over to drive is at night. Their chances of being involved in a fatal accident are 58 percent greater at night. This is so mainly because road conditions, sign design, and lighting do not adequately take into account the needs of the elderly.

A number of countermeasures, particularly important for older drivers but valid for all drivers, were suggested:

- install brighter signs, signals, and road markings.
- make more widespread and better use of pavement markings and delineation systems, including reflectorized guardrail, etc.
- use traffic control devices that are uniform in appearances, brightness, placement, and meaning across the country.

- establish minimum levels of brightness and reflectivity for traffic control devices, both for new installations and for those that are in service, so highway maintenance personnel will know when replacement or rehabilitation is required.
- increase sensitivity to sign clutter and information overload, and reduce introduction of unnecessary complexities in signs.
- promote sign redundancy.
- improve motorist information systems, including all forms of traffic control devices, especially in terms of reaction time and visual capabilities.

Rockwell, T.H. and Balasubramanian, K.N., "Carbon Monoxide Effects on Highway Driving Performance: An Investigation of the Effects of 12 percent COHb on the Nighttime Performance of Young and Aged Drivers.

Recent research on the effects of carbon monoxide on driving performance was summarized. An excellent review of the performance of aged drivers was included. Although older people appear to be able to maintain adequate control of their vehicle, they have difficulty interacting with other traffic and signing. There has been little controlled experimentation with aged drivers; however, there are many studies into the age-related changes in older people in numerous laboratory tests. Among the more significant of these changes are: (1) visual capabilities decline, particularly in acuity, accommodation, lateral visual field, pupil diameter, resistance to glare, adaptation, low contrast discrimination, and under hypoxia, the visual field shrinks; (2) perceptual capabilities decline; (3) reaction time increases; (4) less capability to centrally control movement; (5) reduced ability to translate stimuli to response when the S-R relation is complex; (6) short-term memory decreases when intervening activity is involved; (7) visual search efficiency drops; (8) greater use of vision to control motor action; (9) conditions of pacing greatly affect aged performance; and (10) dividing attention between tasks is difficult if one of the tasks involves short term memory. It is possible that task performance may not show decline if the aged person in some way compensates for his deficiencies. Some evidence of such compensation exists in the self-restrictions elderly drivers impose on themselves, (e.g., less night and freeway driving), reducing the amount of driving, and often reducing the speed of driving.

The major question of the study was to determine the effects of carboxyhemoglobin levels on nighttime driving performance of young drivers and in comparison with the performance of aged drivers. A highway driving test battery consisted of freeway driving, reading highway signs, car following, driving with voluntary occlusion, curve negotiation and estimation of time and velocity while driving. Five young healthy nonsmokers and five healthy aged (60 to 65) nonsmokers participated. Each subject was treated with 0 and 12 percent nominal COHb levels.

Results from the research indicated that the 12 percent COHb level significantly affected the nighttime visual search behavior of both the young and aged subjects but in a significantly different manner. The trend towards decreased visual activity that was observed during daytime driving performance was confirmed for nighttime performance for young subjects. Under the influence of 12 percent COHb level, the aged subjects demonstrated less peripheral sensitivity. In general, CO effects on the road were much less than those found in the laboratory. Results indicate that CO effects are first manifested in the visual system before driver control or vehicle performance measures are affected.

One of the by-product results from the research was experimental findings about the differences between the young and the aged in their night driving performance. The following results were statistically significant:

- The young underestimate time and the aged overestimate time in the range of 6-14 seconds.
- In velocity estimations, the aged underestimate more than the young.
- While negotiating curves, the young allow a higher peak lateral "g" than the aged.
- The aged drive slower than the young on freeways and on rural roads.
- Velocity variability is higher for the aged than for the young.
- Perceptual uncertainty is much higher for the aged compared to the young.
- In visual search behavior, the aged generally tend to (a) look longer at the central driving scene, (b) have higher variability in look durations, (c) spend higher percentage of total time in the central area, and (d) have shorter look durations away from the central region.

<u>Traffic Safety of Elderly Road Users</u>, Organization for Economic Co-Operation and Development, Paris, 1985.

One chapter attempts to identify the particular traffic trip patterns of the elderly, comparing them with those of other road user groups and highlighting the specific road safety needs of the elderly. Psychological and psycho-physical changes due to age and how they affect, directly or indirectly, the performance of the elderly are discussed. Perhaps the most important of these is vision. All the different parameters of vision tend, at their own pace, towards a "visual crisis" at around age 45. Impairment may take the form of a lower threshold of visual acuity, reduced eye watering, a fall in the capacity of accommodation and in the accommodation convergency ratio. Other significant changes include loss of dynamic visual acuity, poor visual acuity in twilight and increased sensitivity to dazzle. Deterioration is also observed in dynamic perception of distance, in the dynamic field and in the sense of contrasts.

A number of pathological aspects associated with aging were discussed. Although with advancing age, the effects of any given condition may be quite minor, the cumulative handicap, which is really what counts, can be quite significant. Though not specific to the elderly, over-prescription and over-consumption of drugs is a common phenomenon and constitutes a real risk because of harmful interaction and various psychotropic effects.

There are a number of psychological aspects of aging. When confronted with a choice, elderly subjects hesitate between speed and accuracy and tend to opt for the latter. Performance tends to be worse if the subject is faced with a severe time constraint. Overall, the elderly opt for lower speeds, a fact that can be explained by changes occurring in the central nervous system and more especially, the process of information under pressure of time.

The elderly resort to a pattern of driving that tends to reduce the frequency and difficulty of awkward and uncomfortable situations. Experimental studies have demonstrated that the elderly perform less well in certain tasks (driving in lanes, switching lanes, changing direction, and joining a stream of traffic). There are marked changes in the process of visual exploration, probably as a result of modifications to peripheral vision. It would appear that the elderly subject is less capable of using peripheral vision to acquire useful information. Other facts related to elderly drivers:

- elderly drivers are involved relatively less in accidents in which a single vehicle is concerned.
- elderly drivers are relatively more involved in collisions, especially at junctions, changes in direction or joining a traffic stream.
- intersections with stop signs pose particular problems in view of the greater difficulty in processing information and making a quick decision.

Since their sensory and motor capacities are falling behind the requirements of the increasingly complicated traffic situation, the elderly are more likely to be involved in accidents because of failure to give right of way, turning at inappropriate times, and ignoring advisory and mandatory road signs.

Research on the environment of the elderly has so far been confined to conditions of mobility and has paid scant attention to their safety. Little information is available on the impact of countermeasures especially designed to protect this category of user. The road situation should be analyzed in relation to the task demanded of users:

- legibility, comprehensibility: Is what is expected of users clearly expressed and sufficiently perceptible (quality of information supplied, transmission of the latter, and possible ambiguities)?
- the complexity of the decision-making demanded by the situation: is it excessive (number of alternatives offered to the user, possibility of untoward occurrences, need to modify initial decisions)?
- time available for reaction once the user has taken in the information and for performing the action required: is it sufficient to allow the situation to be negotiated adequately?

A number of specific recommendations were made relative to research needs. Most countries do not have any records of actual traffic participation of the elderly, although such data are necessary for monitoring the traffic risk levels under changing conditions of the amounts and composition of traffic. They should therefore be collected regularly and in sufficient detail and quantity to be broken down by mode of transport as well as age group. Research is also needed to determine in what ways and to what extent elderly drivers do in fact adapt to the age deterioration of their driving skills, particularly in conditions of bad weather, poor lighting, or dense and fast traffic. Research is needed to determine in what ways and to what extent the ergonomics of the tasks which must be performed by drivers to maintain the safety of certain accident-prone maneuvers, especially in junctions, exceed the normal capabilities of elderly drivers. Such knowledge may have practical applications for existing junctions and form the basis for revisions of junction design standards. Evaluations of the effectiveness of road safety measures based on modifications of the road or road environment should be conducted routinely so as to make it possible to determine the specific effectiveness of the measure with respect to the accidents of elderly road users.

Winter, D.J., "Needs and Problems of Older Drivers and Pedestrians: An Exploratory Study With Teaching/Learning Implications," Educational Gerontology, 10, 1984, pp. 135-146.

The percentage of older drivers is increasing steadily in the United States. In 1984, 25 percent of the licensed drivers were 55 and over. By the year 2000, the projection is 28 percent and will be 39 percent by 2050.

Statistics have shown that older drivers (65+) have the lowest median accident involvement index of any age group, but are more likely to have a fatal accident than any driver from age 36 to 64. However, this study did not consider number of miles driven, where, at what time, and so forth. When exposure is considered, drivers over 55 years are second to the worst group - the 15 to 24 year olds.

Driving and accident records reveal that older drivers are more often involved in specific types of accidents and more often cited for certain violations. These include failure to yield the right-of-way, improper turns, failure to read road signs, and inattention to traffic signals and stop signs. They also appear to have problems mixing with traffic; risk is especially high at intersections. They tend to use lanes improperly, drive left of center, drive the wrong way on one-way streets and fail to signal when changing lanes. They tend to join traffic without due care and sometimes seem to be unaware of traffic around them.

When older drivers are involved in fatal accidents, these are most often collisions with other vehicles as opposed to single vehicle accidents. Analysis has shown that the errors possibly arise from a necessity to select and process information at too fast a pace; other errors reflect the older driver's inability to react quickly to the "speeded-up" rate of the other drivers.

Older people do not see, hear, or otherwise perceive as acutely as younger people. These characteristics influence the medium used for instruction, i.e., print size, color, contrast, detail and audio fidelity. They also appear to process information more slowly as compared to younger people. This has relevance for stimulus complexity, memory association, pacing of material, and multi-media reinforcement. Most older people do not like critical or competitive situations, testing or non-relevant subjects. They appear to perform better in nonthreatening, small group, self-paced learning situations.

The author suggests the need for well-marked highways, large lettered signs spaced for ease in reading, definitive road markings, use of bright contrasting colors, removal of blinking lights or reflectors that cause confusion, removal of competitive unnecessary signs, and nation-wide standardization of signs on both secondary roads and limited access highway.

Yanik, A.J., "What Accident Data Reveal About Elderly Drivers," SAE Technical Paper 851688, Warrendale, Pennsylvania, September 1985, 6 pages.

A North Carolina study found that left turns were involved in about 25 percent of crashes of drivers over the age of 65, almost twice the rate of the average driver. The elderly also tended to be overly involved in accidents resulting from changing lanes, merging, or leaving from a parked position, thus suggesting that the elderly get into difficulty in more complex driving situations.

The elderly are involved in accidents well out of proportion to the time they spend on the road compared to the driving exposure of other drivers. Waller speculated that part of the reason for high crash rates based on exposure is the fact that they drive low mileage. Their study indicates that low mileage drivers of any age are worse drivers per mile than high mileage drivers.

While the elderly are overly represented in specific accident situations, very little scientific data exist delving into the root causes for these driving failures as a function of the driving task. This is not to ignore the numerous studies that have been made on vision, hearing, and memory degradation that occur with aging. However, studies that directly relate such degradation to the driving task itself are limited and sorely needed.

Impaired Drivers

Allen, R.W. and Schwartz, S.H., "Alcohol Effects on Driver Risk Taking," Proceedings of the Human Factors Society - 22nd Annual Meeting, 1978, pp. 579-582.

Selected results from past driving simulator studies are reviewed. Driving tasks included steering regulation against wind/road disturbances, speed control on curves, and decision-making in a traffic signal situation. A common alcohol impairment mechanism was found in each of these situations, namely increased driver variability. The driver's risk exposure also increases with alcohol impairment and is extremely sensitive to performance variability changes.

Drivers seem unaware of the rather substantial change in risk exposure under alcohol impairment. One reason may be that the basic variables which must be perceived, such as lane position, speed and signal timing, may not be perceived very accurately by the driver in the course of normal driving.

It was recommended that highway and traffic engineers should take into account the intoxicated driver's increased variability. This might include intersection design, signal timing, lane delineation, and signing--particularly for curve advisory speeds. Other countermeasures might include public information and driver education and training. Drivers should be appraised of the inexorable but subtle effects of alcohol impairment on driver variability (inconsistency) of performance and perception, and the dramatic effects these factors have on risk exposure.

Bauer, R.L., "Traffic Accidents and Minor Tranquilizers: A Review," Public Health Reports, 99(6), Nov.-Dec., 1984, pp. 572-574.

Because of widespread use and certain similarities to alcohol, minor tranquilizers, including benzodiazepines, have been studied as a risk factor for traffic accidents. In the United States, it has been found that about 8 percent of men and 20 percent of women had taken benzodiazepines or other minor tranquilizers within previous years. Minor tranquilizers, including the benzodiazepines, have been found to impair driving skills such as hand-eye coordination and reaction time. Several studies have also demonstrated an association between minor tranquilizer use and traffic accidents; however, the association may be due entirely to more frequent alcohol use or to the underlying anxiety found in the users of minor tranquilizers. Whatever the case, patients taking minor tranquilizers do have higher accident rates.

The author suggests that using seatbelts, driving at speeds appropriate for road conditions, and avoiding alcohol before driving are well-defined risk factors that can be altered. Driving while under the influence of minor tranquilizers should be avoided.

Blanke, R.V. and Granger, R.H., Prosecuting the Drug Impaired Driver: A Technical Study, Virginia Highway and Transportation Research Council, Charlottesville, Virginia (undated).

The findings of a six month study to determine the technical aspects of prosecuting the drug-impaired driver are presented. While much of the work relates to fluid sampling and analytical methodology, a thorough literature review on drugs and driving is presented. Scientific literature support for driving impairment, resulting from drugs or the direct correlation of drug concentrations with driving impairment, is uncertain at best. Reasons for this include:

- Defining driving impairment and measuring this endpoint have yet to be standardized; real-life driving tasks are difficult if not impossible to reproduce in a controlled manner.
- The vast number of drugs or classes of drugs which could potentially impair driving, seriously dilute efforts at definitive research.

- Tolerance to the effects of a drug which may impair driving will also present complications in interpreting drug concentration and driving impairment (like alcohol, chronic use of many drugs will result in gradual tolerance to the pharmacological effects).

- The underlying weakness of all such epidemiological studies is failure to distinguish and control for the population of drivers who are taking drugs and are not involved in traffic accidents.

It should be noted that in promoting and supporting the healing processes of the body, drugs often ameliorate many conditions of poor health that would otherwise adversely affect driving ability. Many examples of persons suffering from hypertension, epilepsy, diabetes, stress, pain, psychosis, visual defects and cardiovascular disturbances can be cited in which driving performance may be improved by drugs. Thus, the state of health of the subject must be considered when interpreting drug concentrations.

One appendix of the report contains a rather complete literature review on the issue of drugs and driving. Numerous studies indicate that the use of benzodiazepine compounds (e.g. Valium) have a negligible effect on driving skill or, in fact, appear to improve performance. However, the largest percentage of studies would indicate an impairment of driving ability.

Case, H.W. and Hulbert, S.F., <u>Wrong Way Deterrents</u>, Final Report, California Department of Transportation, Sacramento, California, August 1975.

Most wrong-way fatal accidents occur at night and involve drivers with blood alcohol levels exceeding 0.20 percent. Drivers under the influence of alcohol are not proficient in divided attention tasks. The effectiveness of seven devices in getting the attention of drunk drivers was to be tested on a driving simulator. Devices to be tested were: (1) Standard wrong-way sign package with secondary wrong-way signs; (2) Activated illuminated signs; (3) Activated non-blinding pavement lights; (4) Activated water jets from edge of ramp; (5) Activated pop-up posts; (6) Passive ramp derailer of pavement markers; (7) Blinding lights. The driving simulator tests of these devices required nighttime filming of the devices in operation. Several types of color film and developing processes were tried, but none were capable of producing a film with the required resolution and color density. This study was terminated without testing the wrong-way deterrent devices.

Compton, R.P. and Anderson, T.E., <u>The Incidence of Driving Under the Influence of Drugs 1985: An Update of the State of Knowledge</u>, DOT HS 806 900, NHTSA Staff Technical Report, National Highway Traffic Safety Administration, Washington, D.C., December 1985.

No empirical evidence yet exists to document the nature and magnitude of the highway safety problem that might be due to drugs. Even if a drug has the potential for producing severe impairment, it would not be considered a problem unless there was strong evidence that a significant number of drivers who are driving under the influence are consuming a sufficient quantity of the drug prior to driving. In order to determine whether any drugs are significant highway safety problems, field research is required that will determine (1) their frequency of occurrence in accident-involved drivers and (2) the extent to which they contribute the accidents. The work reported on in this document reviews recently published studies to determine whether they contain sufficient data to allow more definitive conclusions regarding which drugs are likely to be highway safety hazards.

The studies of drug use by impaired drivers detained by police are particularly difficult to interpret. The drivers dealt with in these studies are a special subsample of the general driving population. Because study samples are not drawn in a random or unbiased fashion, they are not representative of the driving public, nor necessarily of drivers who use drugs, or drivers who the police detail for suspicion of drug use. The data indicated that drugs are detected in 10 to 22 percent of the accident-involved drivers. The majority of the drug using drivers (53 to 77 percent) were found to have high levels of alcohol in combination with the drugs. In these cases, the alcohol may have been primarily responsible for the driver impairment leading to the accident. From the studies reviewed, it was not possible to factor out the alcohol effects from the drug effects, or to determine whether there were any combined alcohol and drug effects. Those drugs (or drug classes) most frequently detected were (in order of decreasing incidence): marijuana, diazepam, cocaine, barbiturates, methaqualone, and PCP.

The critical piece of information necessary for establishing that certain drugs pose significant safety risks, i.e., the extent to which nonaccident-involved drivers use these drugs is still not available. Without this information, it is not possible to meaningfully interpret incidence rates by accident-involved drivers.

Cottrell, B.H., "The Effects of Wide Edgelines on Lateral Placement and Speed on Two-Lane Rural Roads," Paper presented at Annual Meeting of Transportation Research Board, Washington, D.C., January 1986.

Results of an evaluation of 4-inch and 8-inch wide edgelines on lateral placement and speeds of vehicles on two-lane rural roads were presented. Data were collected at twelve locations on sections of roadway covering 55.2 miles. It was concluded from analysis of variance of lateral placement, lateral placement variance, encroachment by cars and trucks, mean speed and speed variance that, overall, there were no statistically significant differences between the 4-inch and 8-inch wide edgelines. The mean lateral placement was significantly lower for the 8-inch line. However, changes in lateral placement and speed were not significant from a practical viewpoint.

"Engineering the Way Through the Alcohol Haze," <u>ITE Journal</u>, Vol. 50, No. 11, November 1980, pp. 12-15.

Medical research has shown a number of effects on visual perception by alcohol ingestion. Visual contrast sensitivity is reduced. The ability to recognize objects, particularly at night, depends in large part on contrast perception. The peripheral vision of the eye is rendered less effective. The field of visual concentration is narrowed until the driver simulates viewing from inside a tunnel. Researchers have observed a shorter visibility distance experienced by impaired drivers in which they concentrate on a field of vision directly in front of them rather than looking further down the road. Studies of the eye search patterns of drivers under the influence of alcohol have shown that the search is limited and that fewer objects or parts thereof are seen and understood in any given period of time. There is also a reduced dynamic visual acuity which makes it more difficult for drivers to perceive objects which are being passed, such as signs or various warning or signalling devices.

If the ability of a driver to negotiate a road is the ultimate determinant of whether or not an accident will occur, and if that ability depends on communications from the roadway, then there is a possible engineering approach, which is to increase the nature and strength of the communications to penetrate the blockage which alcohol causes. This improvement in communications may also have to do with road design and high hazard treatment, but it may principally concern the development and installation of warning devices, signs and highway markings.

A Potters Industry study directly analyzed the effect of normal four inch and wider edgelines as an alcohol countermeasure on rural roads. Driver performance was measured by vehicle position in the driving lane, positional variability, vehicle-to-vehicle grouping, average vehicle speed and range of vehicle position on the road. Data obtained on curved roadways confirmed the hypothesis that a wider edgeline should provide an incremental improvement over that found with standard width edgelines. With the wide edgelines, impaired drivers exhibited less weaving and greater certainty of position in the driving lane. They also performed more like one another as demonstrated by their tighter grouping performance, thereby indicating that there were fewer differences in their perception of the road. On rural roads, 63 percent of all fatal accidents are either single vehicle accidents or opposite direction collisions. If drivers can be influenced to drive more centrally in their lane on a two-lane road, then the probability of these types of accidents can be reduced. No significant effects on vehicle speed were found.

Federal Highway Administration, RFP DTFH61-86-R-00044, "Traffic Control Design Elements for Accommodating Drivers with Diminished Capability," Washington, D.C., 1986, 37 pages.

A contract to have this study performed was being negotiated as the annotated bibliography was being prepared. The overall objective of the study is to determine the extent to which drivers with diminished capability are being adequately accommodated by the current generation of traffic control devices and whether special needs of these motorists are being met by traffic control design criteria.

The scope of work of the study includes a number of items relevant to impaired drivers and geometric design. The study will specify the driving styles and travel patterns of the population of drivers with diminished capability and quantify their visual and processing decrements with respect to the driving task and the reception and use of highway signs, signals and markings. Included will be the range of drivers and driver attributes affected by diminished physiological capacity including but not limited to, visual acuity, contrast sensitivity, dark adaptation, glare sensitivity, color vision, and reaction time. The compatibility of diminished driver characteristics with design standards for traffic control devices will be the major focus.

Hall, J.W., "Engineering Factors in Alcohol-Involved Traffic Accidents," ITE Journal, Vol. 56, No. 1, January 1986, pp. 25-28.

The study examined five years of fatal accident data for New Mexico to determine if selected highway characteristics differed among crashes involving sober and impaired drivers and pedestrians. Initially, crashes were subdivided into three classes (single vehicle, pedestrian, and multiple vehicle) and crash characteristics were examined versus intoxication level using contingency table analyses.

In certain cases, the variables of light condition, roadway curvature, driver residence, pavement condition, and urban versus rural area were found to differ significantly for sober and impaired persons. There is a strong indication that roadway curvature poses a special hazard for intoxicated drivers. The absence of significant differences for other highway parameters suggests that, in general, the hazard of a location is independent of the sobriety of persons involved in accidents at these locations. Although the data tended to support the contention that edgelines provide benefit for intoxicated drivers, they failed to support a statistically significant conclusion on this issue.

Two principal highway-related factors that may contribute to crashes on curves were mentioned: the driver is unaware that the road curves, or he is unaware of the safe speed on the curve. Proper application of warning signs and delineation devices can help to solve these problems for drivers, especially at isolated curves and locations with sharp curvature. It is possible that current standard signs and markings have design or placement features that cause them to be overlooked by impaired drivers.

Hicks, J.A., An Evaluation of the Effect of Sign Brightness on the Reading Behavior of Alcohol Impaired Drivers, TTC Research Report No. 6, Traffic and Transportation Center, University of South Carolina, Columbia, May 1974.

Primary purpose of this investigation was to study and evaluate the relationship between highway sign brightness and alcohol impairment under night driving conditions. Sign brightness was controlled by varying the reflectivity of the signs and by employing both low and high headlight beam conditions. Data were collected under controlled conditions at night with the subjects actually driving the vehicle up and down the test track, which was approximately one and a half miles long and had signs mounted at 700-foot intervals. All of the signs were mounted on the right shoulder. The dependent measure was the correct reading distance. Three blood alcohol concentrations (BAC's) were investigated: sober, 0.08 percent, and 0.15 percent. Fourteen subjects completed the study and each subject participated on three separate nights. Each night was under a different BAC. Some of the subjects experienced difficulty in achieving and/or maintaining th 0.15 percent BAC. The actual observed overall mean BAC for the 0.15 percent BAC condition was 0.13 percent. The results confirmed the experimental hypotheses that high reflectance signs significantly increase sign reading distance under night driving conditions and that alcohol impaired drivers require significantly brighter signs. Increases in both sign reflectance and headlight brightness yielded significant improvements in sign reading performance under all three BAC conditions. A significant interaction between the reflectance and headlight main effects indicated that the higher reflectance signs yield a greater relative improvement in sign reading performance under low headlight conditions than under high headlight conditions. This is particularly important in light of the fact that previous research has indicated that approximately seventy percent of the nighttime drivers drive with low headlight beams. A significant fatigue effect was noted under both the 0.08 percent and 0.15 percent BAC conditions. A significant interaction revealed the synergistic nature of the relationship between the effects of alcohol and fatigue on performance.

Hollister, L.E., "Psychotherapeutic Drugs and Driving," Annals of Internal Medicine, 50(3), 1974, p. 413.

Although many individuals drive automobiles while taking drugs that might impair their judgment or performance, experimental approaches to determine the degree of impairment have been of limited value. Volunteer subjects are usually not troubled individuals; however, drivers who are given psychotherapeutic drugs should be. Effects of single doses of drugs may differ vastly from those of chronic doses.

A typical laboratory study of the effects of drugs on driving used four drugs-amobarbital sodium, chlordi azepoxide, haloperidol and trifluoperazine - in doses suitable for use as antianxiety agents over a 36-hour period. They were tested alone and in interaction with ethanol. Driving was tested in real vehicles. All drugs with the exception of haloperidol adversely affected some functions of driving, but interactions with alcohol could not be proved. Perhaps the most important observation was that the experimental subjects were unaware of the possibility that their driving ability was being impaired.

Howat, P.A. and Mortimer, R.G., "Review of Effects of Alcohol and Other Licit Drugs on Driving-Related Performance," Proceedings of the Human Factors Society - 22nd Annual Meeting, 1978, pp. 564-572.

A review of the effects of alcohol and other licit drugs on performance related to driving was presented. About 20 percent of persons of driving age use some licit drug, while a much greater percentage drink alcohol. Alcohol is used in combination with another licit drug by about 10 percent of persons of driving age.

Of all the drugs, alcohol has received most attention in tests of its effects on driving-related performance. While there have been a number of tests in laboratory settings, there have been relatively few on-the-road driving tests. Drivers under the influence of alcohol show more tracking errors and reduced number of high frequency steering responses. Alcohol has only a minor effect on simple reaction times; however, alcohol is significant in increasing complex or choice reaction times. Alcohol affects the ability to process appreciable quantities of information when these arrive from more than one source simultaneously, as is typical of requirements for driving.

Effects of alcohol on driving-related skills are relatively well-documented, but tests on the effects of other licit drugs present variable findings. Some research indicates additive or synergistic effects when alcohol is combined with other drugs. Research to date on the effects of licit drugs alone, and in combination with alcohol, has many limitations. There have been comparatively few studies to test decision-making and perceptual-motor skills, such as used in driving or those involving actual driving tasks. A need exists for further research involving more complex driving-related tests and actual driving situations.

Hurst, P.M., "Amphetamines and Driver Behavior," Accident Analysis and Prevention, Vol. 8, No. 11, 1976, pp. 9-13.

In this review, it was found that amphetamines mitigated alcohol impairment of some but not all the functions tested. Direct evidence concerning the role of amphetamines in highway accidents is scant. Most of the basic skills involved in driving are not adversely affected by amphetamine dosages within the normal clinical range, and may in fact be slightly enhanced. Such enhancement is generally greater in sleep-deprived subjects, but is not limited to states of sleep deprivation. Enhancement has also been reported in subjects whose skills have been degraded by alcohol, although results have not been consistent across performance measures.

Although there is some evidence that amphetamines induce overconfidence or increase risk acceptance, the effects have been neither so strong nor so consistent as to justify much of the apparent concern. Excessive or prolonged use is widely recognized to result in abnormal psychological states that are incompatible with safe driving performance, and known amphetamine abusers have been found to be involved in disproportionate numbers of highway accidents. From the available epidemiological statistics, it was not possible to establish how often such excessive consumption is associated with driving, or in any other way to quantify the total contribution of amphetamine abuse to traffic accidents.

Joscelyn, K.B. and Donelson, A.C., "Drugs and Highway Safety: Research Issues and Information Needs," HSRI Research Review, Vol. 9, No. 2, September-October 1978, pp. 2-17.

A study was conducted to assess present knowlege of how and to what extent drugs other than alcohol contribute to traffic accidents. An extensive review of the research literature showed that the problem had not been adequately defined. The review also indicated that much past research in this area has been less than fully reliable because of limited research designs and methodological weaknesses. Specific problems include:

- drug use by drivers may interact significantly with other accident factors, e.g., by increasing driver susceptibility to error.
- legal, ethical, and political constraints hamper efforts to obtain representative samples.
- types and amounts of drugs in drivers are still unknown.
- the driving task is complex and resists complete analysis; the relative significance of component skills and how they inter-relate are not known. Personal, vehicular, and environmental factors also play roles in driving performance.
- reliance on parallels between alcohol and other drugs may be unfounded.

Methodological requirements and research priorities are discussed. Research programs recommended as having the highest priority are large-scale field studies designed to identify specific drugs most prevalent in accident-involved drivers. Only when such information is obtained and assessed can effective countermeasures be developed.

Joscelyn, K.B., Jones, K.B., Maickel, R.P., and Donelson, A.C., <u>Drugs and Driving: Information Needs and Research Requirements</u>, DOT HS-804 774, National Highway Traffic Safety Administration, Washington, D.C., April 1979.

The report presents the results of a comprehensive review and analysis of the relationship between drugs and highway safety. Research to define the problem of drugs and driving is identified. Epidemiological and experimental studies are examined. A number of more specific findings pertinent to this synthesis are presented below.

No ready reference exists for the interpretation of drug levels in terms of driver impairment. The presence of two or more drugs in driver body fluids presents an added degree of uncertainty. It is possible that several accident factors are interactive. Drugs may act to increase the susceptibility of drivers to other causal factors. Until these limits to field research are addressed and removed, studies involving the measurement of drugs in drivers will remain exploratory and indicative only of the existence of a problem. Definitive research must involve the comprehensive analysis of accidents involving drugs.

The lack of progress in three problem areas: (1) analysis of driving tasks, (2) reproduction of actual driving performance in the laboratory, and (3) validation of experimental findings, hampers attempts to assess the potential of drugs to increase the likelihood of traffic crashes. To enhance the value of experimental results, component behaviors associated with driving and their interrelationships should be determined. The absence of this information has had two major consequences: (1) the significance of laboratory results has remained uncertain and (2) the literature of drug effects on driving-related skills has become a patchwork of suggestive but insubstantial findings. Literature on the effects of drugs also reflects the absence of a systematic, coordinated effort to characterize the nature and extent of the potential driver impairment resulting from drug use. Systematic evaluation of drug-risk potential depends on the resolution of fundamental methodological issues, e.g. reliability and validity. It is essential to (1) analyze behavior tests for performance factors that are valid indicators of driving performance; (2) analyze performance tests for factors that are differentially affected by drugs, thus characterizing drug effects potentially dangerous to driving ability; and (3) study the effects of drugs on validated, well-defined performance measures and to determine the influence of interacting variables, such as dose, time of measurement, subject characteristics, etc.

A systematic research program in drugs and highway safety was outlined. The four program areas were: (1) state of knowledge assessment, concerning informational and methodological requirements of other program areas, (2) epidemiologic research concerning exploratory and definitive research related to drug accident risk, (3) experimental research concerning the determination of drug potential risk and driver impairment, and (4) drug analytical methodology concerning the development of screening systems with detection and quantitation capabilities.

Kibrick, E. and Smart, R.G., "Psychotropic Drug Use and Driving Risk: A Review and Analysis," Journal of Safety Research, 2(2), 1970, pp. 73-85.

This review deals with studies of the incidence of psychotropic drugs in general populations, in samples of non-fatal accident drivers and in samples of fatal accident drivers. Investigations have varied in terms of drugs studied, reliability of data collection procedures and criteria for choosing sample populations. This variability plus lack of reproducible investigations have made the generation of conclusions tentative.

The studies showed that as high as 35 to 50 percent of the general population risk driving after drug use at least once per year and suggest that 11 to 15 percent of fatal accident drivers have taken a psychotropic drug prior to their accident. Psychotropic drug use is most likely to be found among certain drinking driver groups, especially the fatally injured.

It was found that psychotropic drug usage is a potential hazard to drivers and the following tentative conclusions were arrived at:

- There is a substantial problem of psychotropic drug use among drinking drivers. At least 7 percent of drinking drivers have a psychotropic drug in their system (this estimate is almost certainly very low).

- At least some psychomotor impairment in drivers with low or non-existent blood alcohol levels is due to their use of psychotropic drugs.

- Barbiturates are the psychotropic drugs commonly found among accident and non-accident drivers. However, it should be noted that the only stimulant drug screened for has been caffeine.

The authors indicate that the veracity of drivers' statements about drug use is very low and drug use estimates derived from questioning are probably very conservative. Further research is recommended in associating the use of psychotropic drugs with driving errors or with responsibility for accidents.

Linnoila, M., "Tranquilizers and Driving," <u>Accident Analysis and Prevention</u>, 8(1), 1976, pp. 15-19.

Consumption of tranquilizers has increased tremendously in recent years. Epidemiological studies have demonstrated an increased traffic accident risk to be associated with the use of tranquilizers. Combined use of tranquilizers and alcohol, which is common among patients, increases one's accident risk from that due to either agent alone.

Laboratory studies concerning the effects of tranquilizers on skills related to driving have demonstrated impaired information processing capacity and eye-hand coordination due to these agents. Neuroleptics impair information processing especially at the onset of the treatment whereas the hazards of benzodiazepines become evident during long term treatment. Most of the tranquilizers increase the deleterious effects of alcohol on skills related to driving. Particularly strong is the interaction between diazepam and alcohol.

Mason, A.P. and McBay, A.J., "Ethanol, Marijuana, and Other Drug Use in 600 Drivers Killed in Single Vehicle Crashes in North Carolina, 1978-1981," <u>Journal of Forensic Sciences</u>, October 1984.

Objective of the study was to determine the incidence of ethanol, THC, barbiturates, cocaine and other drugs in single-vehicle fatal accidents in North Carolina. Blood samples were tested from drivers involved in 600 single-vehicle fatal accidents in North Carolina between 1978 and 1981.

Ethanol was detected in 79% of the samples, THC in 8%, methaqualone in 6%, and barbiturates in 3%. Other drugs were detected rarely or not at all. Eighty-six percent of drivers whose blood contained ethanol and 68% of all drivers had BEC's ≥ 0.10%. Drug concentrations were usually within or were below accepted therapeutic or active ranges. Only a small number of drivers could have been impaired by drugs, and most of them had high BEC's. Ethanol was the only drug tested for that appears to have a significantly adverse effect on driving safety.

Moskowitz, H., "Marijuana and Driving," <u>Accident Analysis and Prevention</u>, Vol. 8, No. 11, 1976, pp. 21-26.

Survey studies have found that marijuana use is increasing and that users frequently drive under its influence. There is little direct epidemiological evidence to indicate if the presence of marijuana in drivers increases accident probability. However, the experimental evidence suggests strongly that marijuana use while driving produces a performance impairment.

Perceptual functions of importance for driving are clearly and greatly impaired and would be expected to interfere with the ability of drivers to monitor the environment for important signals and potential dangers. To some degree, tracking aspects of driving would also be affected by the impairment of the perceptual functions necessary for their control. The motor aspect of tracking is less likely to be affected as motor performance seems to be less affected by marijuana. No evidence was found that emotional or attitudinal changes under marijuana would be likely to lead to increased risk-taking in the driving situation. The decrease in driving performance skills leads to some increase in accident probability.

Moskowitz, H., Hulbert, S., and McGlothin, W. H., "Marijuana: Effects on Simulated Driving Performance," <u>Accident Analysis and Prevention</u>, Vol. 8, 1976, pp. 45-50.

Experiments were carried out on 23 male subjects to find out their performance under smoked marijuana treatments on 4 occasions in a complex driving simulator. There was little evidence for a significant effect of marijuana upon car control and tracking. None of the 25 car control-tracking scores was significantly changed in either mean or variance by the treatments. However, there was a clear, statistically significant decrement in performance of the search-and-recognition task. It appeared highly probable that cannabis-induced deficits are primarily related to attention or perception and not to an impairment of motor responsiveness. Several laboratory studies have found that cannabis has little or no effect on the speed of simple motor behavior. The relatively long reaction times obtained from the experiments are indicative of perceptual rather than motor impairment. A laboratory experiment found marijuana markedly reduced the probability of perceiving briefly presented peripheral visual stimuli, but did not alter the reaction time for those stimuli which were perceived.

The available evidence from this study and other studies reveal that any marijuana-related impairment of driving ability is more likely to be associated with perception and attention deficits than with the motor skills involved in car handling.

National Highway Traffic Safety Administration, "Marijuana and Other Drugs and Their Relation to Highway Safety," U.S. Department of Transportation, Washington, D.C., February 1980, 36 pages.

The extent to which drugs contribute to problems in highway safety is unknown. However, the available evidence indicates that some drugs at certain dosages can impair driving skills, that certain drugs may increase the likelihood of traffic crashes, and therefore further inquiry is warranted. The conclusions that can be drawn from past epidemiological research studies have been limited by methodological problems and other important constraints. Despite many reports, information relating drug effects and performance on laboratory tests of driving behavior to traffic crashes is quite limited. Reasons for this include the large number of drugs to be studied, the wide range of methods used to measure behavior, low levels of funding, and the comparatively few research groups available to conduct needed studies.

A study under actual road conditions showed the effects of marijuana adversely affected driving performance, though some subjects performed better. Studies with driving simulators showed that marijuana degraded performance on some, but not all variables measured. One study found no significant effect of marijuana on 25 performance measures related to car control, such as steering wheel reversals, brake and accelerator pad usage, as well as tracking; however, dose-related increases in subjects' reaction times were observed in subsidiary visual search and recognition tasks. Other laboratory studies, using specific mental, psychomotor, and sensory tests, e.g. time sense, reaction time, perceptual-motor coordination, and auditory signal detection, have also shown impairment by marijuana, depending on the dose and type of task. Combined effects of alcohol and marijuana result in greater impairment than with either drug alone in some laboratory tests. Certain dose levels of marijuana can impair tracking and perceptual functions involved in driving. Perception and other complex mental functions appear more affected than simple motor or sensory tasks that demand little processing of information. The few studies involving actual car handling on closed courses support the implications of laboratory tests that marijuana use by drivers especially in high doses, can increase the likelihood of traffic crashes. However, whether the differences found in a laboratory are large enough to have impact in an actual driving situation is unknown.

Effects of barbiturates and other sedative-hypnotics are similar to alcohol, e.g. impaired thinking, lack of emotional control, aggressive behavior, loss of motor coordination, drowsiness and decreased eye movement. Less obvious impairment of psychomotor skills is produced by antianxiety agents. On tests of vigilance, choice reaction time and motor coordination, some indications of impaired performance were reported. The combined effects of the drugs and alcohol may be of greater concern, since antianxiety drugs can further decrease performance by alcohol.

Nedas, N.D., Balcar, G.P. and Macy, P.R., "Road Markings as an Alcohol Countermeasure for Highway Safety: Field Study of Standard and Wide Edgelines," Transportation Research Record 847, 1982, pp. 43-46.

Even small quantities of alcohol tend to block the visual linkage between the driver and the roadway. The problems of low sensitivity to contrast, reduced peripheral vision and shortened visibility distance have been described in other literature. These problems are compounded because alcohol reduces the ability to process information. Also, the impaired driver has a relatively inflexible search strategy when viewing objects in the roadway. He or she concentrates his or her visual search strategy or a few items for relatively long periods of time; in an unimpaired searching strategy, information is acquired from many objects, each viewed for relatively short time periods. Alcohol impaired drivers also suffer some loss of dynamic visual acuity, so that objects in the periphery that are in motion relative to the vehicle, such as signs and signals, appear blurred. Finally, the alcohol-impaired driver is relatively indifferent to deviations in the driving path. Weaving on the part of an impaired driver is much more pronounced, as a result of taking corrective action rather late, and such corrections tend to be over-corrections.

The study evaluated four edgeline conditions -- no edgelines and edgelines 4, 6, and 8 inches in width. Three dosage levels of alcohol were applied -- a placebo level of 0.00 BAC and 0.05 and 0.08 BAC. Sixteen test subjects were selected from among male students aged 21-25. The test was conducted between midnight and 3:00 am on a section of road that was closed to traffic. Effect of increasing edgeline width was to move drivers away from the edgeline toward the centerline. The range was compressed against the centerline so that more driving was in lane and centrality of positioning was greater. A 4-inch wide edgeline reduces positional variability for both unimpaired and alcohol impaired drivers. The presence of a wider edgeline serves to decrease variability even further.

Alcohol impairment may well relate to other forms of impairment, such as fatigue, the use of drugs, and the reduced visual ability common among older drivers. Hence, the beneficial effects of wider edgelines found for the alcohol-impaired driver may well extend to drivers who have other types of impairment, since the improved driver performance of test subjects in the presence of wide edgelines indicates that strengthening the visual signal at the road edge may compensate to some degree for impairment and, therefore, reduce the risk of accidents.

Paltell, E. and Booz, M.L., Combatting the Drug-Impaired Driver: A Prescription for Safer Highways, Virginia Highway & Transportation Research Council, Charlottesville, Virginia, November 1985, 97 page + Appendices.

Law enforcement officials face major obstacles in their efforts to detect and prosecute persons who drive under the influence of drugs (DUID). Greatest impediment to DUID enforcement is the lack of certain crucial statutory provisions. These are reviewed in this paper and certain recommendations made. The first chapter of the report provides background information on the magnitude and effects of the drug-impaired driving problem.

The sporadic nature of DUID enforcement and the fact that until recently few states had authorized chemical testing for drug content have made it difficult to accurately assess the incidence of DUID offense on the basis of police and court records. Virginia police officers report that an average of 17 percent of all drivers stopped for unsafe driving are suspected of being under the influence of drugs other than or in addition to alcohol. Because of the wide variety of drugs there is less scientific documentation on any one substance's dosage/effect relationship than there is for alcohol. Also, because of the individualized nature of a person's reaction to a particular drug, it is difficult to draw a conclusion as to impairment solely on the basis of the drug content of a person's bodily fluids. Similarly, different drugs are metabolized at varying rates; the by-products of some substances remain in a person's system for up to 30 days.

Describing the effects of drugs on driving ability suffers from a lack of consensus on what skills contribute to driving performance and what change in those skills amounts to impairment. The sheer number of drugs available and the variety of effects they can have also dilute the amount of documentation and research available on any one substance. Below is a brief summary of the impact of several drugs on sensory and psychomotor skills.

<u>Benzodiazepines (Valium and Librium)</u> -- Produce effects very similar to those of alcohol; impairment increases as the dosage taken increases. Coordination and the ability to react to emergency situations are definitely impaired, which leads to accidents in driving simulator tests. One of the most significant effects of these drugs is that the user is unable to assess his own impairment and thus is unlikely to refrain from driving. Studies have shown Valium to be present in up to 20 percent of drivers injured in accidents, about half of the time in combination with some other drug or alcohol.

<u>Amphetamines</u> -- Abuse of amphetamines results of mental exhaustion and impaired concentration. Though data are meager, amphetamine users have been found to have a higher accident rate than nonusers.

<u>Marijuana</u> -- The effect of marijuana use on driving is controversial, possibly because a common effect of marijuana use is passivity and tendency to avoid risks, both of which are inconsistent with dangerous driving behavior. There is some evidence suggesting that reaction time is increased and the ability to react to multiple stimuli is impaired.

Pendleton, O.J. and Hatfield, N.J., <u>Alcohol Involvement in Texas Driver Fatalities</u>, Texas Transportation Institute, Texas A & M University System, College Station, Texas, June 1986.

The first phase of this research compared estimates of the proportion of driver fatalities, in which the driver was legally intoxicated, from two data sources: accident reports and toxicological reports of blood alcohol concentration. Over half of the drivers examined in this study were legally intoxicated (BAC $\geq$ 0.10%). Sixty-four percent of the total sample had at least some measurable alcohol in their systems.

A second phase of the study involved a description of driver and accident characteristics associated with fatally injured DWI drivers. An analysis of single versus multiple vehicle accidents revealed that the proportion of the fatally injured drivers who were DWI was significantly greater among those involved in single vehicle accidents (66%) than those in accidents involving two or more vehicles (36%).

Results of the study suggest that the extent of alcohol involvement in driver fatalities is not adequately represented by the reporting of alcohol as a contributing factor on accident reports. The study emphasized the need for more complete information on alcohol involvement than is accessible at this time. The only way to measure the full extent of drunk driving and the effect of various countermeasures designed to reduce alcohol-related accidents is to record a BAC for every driver involved in a traffic accident.

Ranney, T.A. and Gawron, V.J., Identification and Testing of Countermeasures for Specific Alcohol Accident Types and Problems, Volume I: Executive Summary, DOT-HS-806-649, National Highway Traffic Safety Administration, December 1984.

Alcohol impairment is associated with more severe accidents, as shown by alcohol involvement ranging from approximately 16 percent of drivers in property-damage crashes to 60 percent of drivers fatally injured. Single vehicle accidents generally involve higher proportions of drinking drivers than multi-vehicle accidents. Alcohol-related accidents are overrepresented at night, on two-lane roads, and on curves. Major collision types associated with alcohol impairment are: single vehicle crashes, head-on collisions, and rear-end, striking vehicle collisions.

Based on accident and observational studies, four basic alcohol impairment effects were identified: (1) lowered arousal/alertness -- the sedative and fear-reducing effects of alcohol enable drivers to relax and become inattentive to the driving task; (2) time-sharing/information-processing rate -- alcohol slows the rate of information-processing, especially in situations where performance of two or more tasks is required; (3) speeding/recklessness -- erratic accelerations and inappropriate speed were among a set of observable cues associated with alcohol impairment; (4) lane maintenance/tracking impairment -- drifting, swerving, weaving, and other problems of lane-maintenance were prominent in one study of observable cues associated with alcohol impairment.

Based upon the identified alcohol accident types and the underlying impairment effects, four general approaches to alcohol countermeasures were identified. Approaches were selected to be consistent with the stated objective of reducing the "behavioral errors" involved in accident causation. They include: (1) arousing the impaired (inattentive) driver, (2) alerting the impaired driver to the existence of specific hazards, (3) providing enhanced information to the impaired driver to help simplify the driving task, and (4) providing additional skills to help compensate for alcohol-impaired driving.

Several specific modifications were considered in the roadway modifications category. Roadway devices applicable to study objectives included improvements in signs and delineation treatments which provide enhanced information to the driver concerning existing hazards or roadway alignment and roadway alerting devices such as rumble strips or raised pavement markers which upon contact with a vehicle's wheels, cause the vehicle to vibrate and thus alert the driver to a particular stimulus. Specific sign improvements considered include improved sign messages, improved conspicuity of signs, improved placement to maximize detection likelihood, multiple signs of same message, adding flashing beacons to existing signs and inclusion of hazard rating information on signs. Delineation treatments considered included standard and wide edgelines as well as innovative road markings such as a pattern of transverse stripes spaced to give an illusion of increasing vehicle speed.

Overall evidence supporting the effect of the rumbling treatments was positive although not strong. Only two measures, speed and speed variability, exhibited significant reductions in the presence of the countermeasures. It should be noted that more lane deviations occurred in the presence of the rumbling treatments when subjects were sober.

Edgeline presence was found to improve tracking behavior in both the approach and negotiation of curves. Wide edgelines were associated with incremental performance benefits of between 1 and 11 percent, although they were not statistically significant. Edgeline presence was also associated with increases in curve entry speed and lateral acceleration in curve negotiation, which were interpreted as evidence of increased driver certainty.

The herringbone pattern of pavement markings exhibited consistent, but primarily detrimental effects. The flashing beacons were associated with a beneficial effect at one curve only, but exhibited stronger detrimental effects. The chevron alignment signs improved the tracking performance of drivers when sober, but increased speeds at two curves. Post delineators were associated with beneficial effects including reductions in speed and lateral acceleration in the absence of edgelines and a tracking improvement for drivers in the sober condition.

Specific recommendations of the study included:

- Additional research is needed relative to the rumbling shoulder treatment.

- On-road observational studies are needed to determine drivers' responses to spot treatments for curves.

Scifres, P.M. and Loutzenheiser, R.C., Wrong-Way Movements on Divided Highways, Technical Paper, Joint Highway Research Project, Purdue University and Indiana State Highway Commission, July 1975.

The objectives of the study were to make: (1) a quantitative assessment of the frequency of wrong-way movements on divided highway in Indiana with and without fully controlled access; (2) an evaluation of the influence existing geometric design practices, including channelization and median design, have on the frequency of wrong-way movements on divided highways; (3) and evaluation of the effects existing driver information practices have on the frequency of wrong-way movements on divided highways; (4) proposals for alternative geometric design practices to reduce the frequency of wrong-way movements on divided highways; and (5) proposals for alternative driver information practices to reduce the frequency of wrong-way movements on divided highways.

Ninety-six such accidents were found utilizing accident records of divided highways in Indiana for the years 1970-72. Based on the data collected, causes of wrong-way movements were identified and preventive measures responsive to these causes were developed. The following are some of the major findings of this study: (1) Wrong-way accidents are more severe but occur less frequently on highways with fully-controlled access than on those without; (2) Wrong-way accidents occurs most frequently on Fridays, Saturdays, and Sundays and also between 6:00 p.m. and 4:00 a.m.; (3) Wrong-way drivers tend to be drunk (42 of 77 observations), tend to be older, or tend to be driving late at night when they are likely to be fatigued; (4) Only 31 percent of the 96 wrong-way drivers were not adversely influenced by advanced age, fatigue, and/or alcohol consumption; (5) Wrong-way movements tended to originate from areas with low land-use density; (6) Wrong-way movements tended to take place where and when traffic volumes were low; (7) Wrong-way movements tended to take place at times of low visibility; (8) Signing at most wrong-way movement sites was good, with the exception of little or no signing at driveway access points.

The types of design elements that had potential to reduce the frequency of wrong-way movements were found to be (a) any design that increases the driver's ability to see and understand the overall intersection configurations and (b) the use of channelizing islands and curbs to impede potential wrong-way movements; and (c) geometric design modifications to reduce wrong-way movements at certain locations were developed, including channelization at diamond and parclo interchanges and raising the crossroad elevation at divided highway intersections and directional driveways.

Stone, J.R. and Tidwell, J.E., "Driving While Impaired: An ITE Workshop," ITE Journal, Vol. 54, No. 8, August 1984, pp. 40-44.

A two-day workshop involving educators, law enforcement officials, engineers and other interested citizens was held to discuss the drunk driving problem and to identify approaches that can help mitigate the problem. Several of the speakers addressed the area of highway design.

Humphries pointed out that roadway and traffic control device design standards are based on the assumption that the driver is alert and able to control the vehicle. The fatigued, elderly, or alcohol-impaired driver who is within the legal BAC limit is not considered in design standards; yet they are legally operating vehicles on our roadway system. He called for additional consideration of the impaired driver in design standards.

Several ideas relative to highway design were put forth, including:

- maintain high design standards
- build wide shoulders and shoulders with contrasting color and texture at critical locations

- remove or mitigate roadside obstacles
- judiciously use rumble strips to warn impaired drivers if they leave the road
- use higher type design, lighting and signing near taverns
- consider the reduced ability of impaired drivers to track successfully in lanes with reduced width as a result of TSM improvements.

Traffic control device recommendations include:

- maintain a high level of visibility and reflectivity
- increase the clearance phase on signals, especially at night
- wider edge lines and centerlines
- increase use of strobe lights for the red phase.
- mark horizontal and vertical curves
- use high reflectivity pavement markings
- consider possible confusion that flashing signals may cause for impaired drivers

Maintenance recommendations included:

- keep all traffic control devices well maintained
- maintain pavement edges and shoulders
- clear sight distance triangles of obstructions

Research recommendations included:

- develop a data base for establishing design standards which consider the impaired driver

- use vehicle simulation studies in highway design which consider vehicle operations by the impaired driver

Terhune, K.W., <u>The Role of Alcohol, Marijuana, and Other Drugs in the Accidents of Injured Drivers: Volume 1--Findings</u>, National Highway Traffic Safety Administration, Washington, D.C., January 1982.

Blood samples from almost 500 injured drivers at a Rochester, New York hospital were used to determine incidence rates of alcohol, THC and other drugs. Accident data were also collected; analyses were made to determine driver culpability rates, collision types, and crash circumstances involving alcohol and certain drugs. Main substances found were alcohol (25%), THC (10%) and tranquilizers (8%). Thirty-eight percent of the drivers had alcohol or some other drug in their system. Culpability rates were: 75% for intoxicated drivers, 53% for THC-only drivers, 34% for drug-free drivers, and 22% for tranquilizer-only drivers.

Alcohol-involved crashes were predominantly single-vehicle accidents, followed by striking vehicles in head-on and rear-end impacts. Circumstances overrepresented in alcohol crashes were curves, unlighted streets, and non-intersection locations. No unique THC or tranquilizer collision types were found.